Received: 9 June 2023 | Revised: 21 August 2023 | Accepted: 1 September 2023

DOI: 10.1002/bdr2.2249

REVIEW ARTICLE

Birth Defects Research | Society for Birth Defects Research & Prevention | WILEY

# A narrative review of exercise dose during pregnancy

**Alex Claiborne**[1,2,3] | **Filip Jevtovic**[1,2,3] | **Linda E. May**[1,2,3,4]

[1]Department of Kinesiology, East Carolina University, Greenville, North Carolina, USA

[2]Human Performance Laboratory, East Carolina University, Greenville, North Carolina, USA

[3]East Carolina Diabetes and Obesity Institute, East Carolina University, Greenville, North Carolina, USA

[4]Department of Obstetrics and Gynecology, East Carolina University, Greenville, North Carolina, USA

**Correspondence**
Linda E. May, Department of Kinesiology, East Carolina University, Greenville, NC 27858, USA.
Email: mayl@ecu.edu

**Abstract**

The current recommendations for prenatal exercise dose align with those from the American College of Sports Medicine; 150 min of moderate intensity every week of pregnancy. However, recent works suggest there may be a dose-dependent beneficial effect for mother and offspring; maternal and offspring health outcomes respond differently to low, medium, and high doses of prenatal exercise. It is, therefore, our aim to summarize the published evidence (years 1950–2023) for five metrics of prenatal exercise training commonly reported, that is, "FITT-V": Frequency (number of sessions), Intensity (metabolic equivalents "METs"), Time (duration of sessions), Type (exercise mode), Volume (exercise MET*mins). The target audience includes clinicians and health care professionals, as well as exercise professionals and physiologists. Data suggest that moderate exercise frequency (3–4 times weekly) appears safe and efficacious for mother and offspring, while there is contradictory evidence for the safety and further benefit of increased frequency beyond 5 sessions per week. Moderate (3–6 METs) and vigorous (>6 METs) intensity prenatal exercise have been shown to promote maternal and offspring health, while little research has been performed on low-intensity (<3 METs) exercise. Exercise sessions lasting less than 1 hr are safe for mother and fetus, while longer-duration exercise should be carefully considered and monitored. Taken together, aerobic, resistance, or a combination of exercise types is well tolerated at medium-to-high volumes and offers a variety of type-specific benefits. Still, research is needed to define (1) the "minimum" effective dose of exercise for mother and offspring health, as well as (2) the maximum tolerable dose from which more benefits may be seen. Additionally, there is a lack of randomized controlled trials addressing exercise doses during the three trimesters of pregnancy. Further, the protocols adopted in research studies should be more standardized and tested for efficacy in different populations of gravid women.

**KEYWORDS**

birth outcomes, exercise, FITT, gestational diabetes mellitus, gestational weight gain, infant health, pregnancy

# 1 | BACKGROUND

Early clinical recommendations encouraged the *continuation* of regular exercise for newly pregnant women in their initial obstetrics visits (Benensohn, 1953). Despite initial concerns about exercise during pregnancy (Hon & Wohlgemuth, 1961), studies have shown pregnant women undergo different but healthy (Newton & May, 2017) respiratory (Bedell & Adams, 1962; Pernoll et al., 1975) and cardiovascular (Clapp et al., 1993; MacPhail, 2000; Purdy et al., 2019; Sady et al., 1989) responses to acute exercise with low injury rates (Pivarnik et al., 2016). Furthermore, observational studies show that women can tolerate more demanding exercises, such as running and high-impact aerobics (American College of Obstetricians & Gynecologists, 2013; Mottola, 2002; Tenforde et al., 2015) without adverse fetal responses (Davenport, Meah, et al., 2018; Juhl et al., 2010; McDonald et al., 2018; Skow et al., 2019) or pregnancy outcomes (Dressendorfer, 1978; Kuhrt et al., 2018). However, it is important for a challenging, but safe prenatal exercise prescription that frequency, intensity, time, type, and volume (FITT-V) be assessed in an individualistic manner.

Exercise interventions typically are structured around three core elements: fitness testing, exercise prescription, and supervised exercise sessions. Fitness testing provides a "baseline" fitness level from which to compare fitness after completing the intervention. Often based on baseline fitness, exercise prescriptions provide targets for FITT-V; the frequencies, intensities, time, and type of exercise, which are commonly combined a reported as weekly or total exercise volume. To ensure the prescribed parameters are met, exercise sessions are commonly supervised by exercise professionals.

Supervised prenatal exercise programs provide an effective strategy to promote an active lifestyle throughout pregnancy (Bisson et al., 2015). Among a continually growing body of evidence, various prenatal exercise interventions are associated with improved pregnancy outcomes such as normalized birth weight, labor duration (Bell & Palma, 2000; Clapp, 1996a; Davenport, Kathol, et al., 2019; Juhl et al., 2008; Kramer, 2002; Penttinen & Erkkola, 2007; Schlüssel et al., 2008; Schramm et al., 1996; Sternfeld, 1997) and normal childhood growth and development (Bell & Palma, 2000; Clapp, 1996b; Clapp, Simonian, et al., 1999; McMillan et al., 2019); similarly, exercise during pregnancy is associated with improvements in maternal health markers such as weight gain during (Dempsey et al., 2005; Gascoigne et al., 2023) and after pregnancy (Clapp, 2008). Prenatal exercise also reduces labor duration (Beckmann & Beckmann, 1990; Botkin & Driscoll, 1991; Salvesen & Mørkved, 2004; Veisy et al., 2021), pain, the acute stress in delivery (Varrassi et al., 1989) and is associated with improved pregnancy outcomes (Clapp & Dickstein, 1984; Gascoigne et al., 2023; Jarrett & Spellacy, 1983; Latka et al., 1999; Lokey et al., 1991; Schlüssel et al., 2008; Wolfe, Brenner, & Mottola, 1994). Prenatal exercisers also tend to undergo fewer delayed or operative deliveries (Bungum et al., 2000; Clapp, 1990; Davenport, Ruchat, et al., 2019; McDonald et al., 2022; Salvesen & Mørkved, 2004; Veisy et al., 2021). Related to maternal health and well-being, large observational studies and reviews show that women who continue or begin to exercise during pregnancy maintain a healthy weight and normal pregnancy outcomes (Clapp & Dickstein, 1984; Kramer, 2002; Kulpa et al., 1987; Latka et al., 1999; Lynch et al., 2007; Sibley et al., 1981; Sternfeld, 1997). Specifically, prenatal exercise enables women to maintain exercise capacity (Charlesworth et al., 2006; Clapp & Dickstein, 1984; South-Paul et al., 1988; Wolfe, Walker, et al., 1994), appropriate gestational weight gain (Goodwin et al., 2000; McDonald et al., 2016), reduces low back pain (Garshasbi & Faghih, 2005), prevents gestational diabetes mellitus (GDM; Artal, 1990, 2003; Boden, 1996; Lochan Yadav et al., 2017; Oken et al., 2006), and enhances psychological well-being (Wolfe, Hall, et al., 1989). For infant outcomes, Clapp, et al. show exercise during pregnancy is associated with normal child developmental and behavioral outcomes in the first 1-year follow-up (Clapp et al., 1998; Clapp, Lopez, & Harcar-Sevcik, 1999; Clapp, Simonian, et al., 1999), with other, morphological benefits extending to 5 years of age (Clapp, 1996b; Clapp et al., 1998). Ongoing works from our and other groups have confirmed that prenatal exercise positively influences infant morphometrics (Bisson et al., 2017; Davenport, Meah, et al., 2018; McDonald, Isler, et al., 2021; Strom et al., 2022), while also contributing to the understanding of prenatal exercise effect on infant metabolic (Jevtovic & May, 2022) and cardiovascular (Dietz et al., 2016; May et al., 2012; May et al., 2020; May, Drake, Suminski, & Terry, 2014; May, Scholtz, Suminski, & Gustafson, 2014; May & Suminski, 2014; May, Suminski, & Langaker, 2014) health.

This growing evidence (Artal, 2003; Clapp, 1996b; Kulpa et al., 1987; Leet & Flick, 2003; Sibley et al., 1981; Sternfeld, 1997), including international efforts from groups in Canada (Davies et al., 2003; Wolfe et al., 2003; Wolfe & Weissgerber, 2003), Australia (Bell et al., 1995), and the United States (Clapp, 2006; Clapp, 2008; Dempsey et al., 2005; May, 2011; May et al., 2012; McMurray et al., 1988; McMurray & Katz, 1990), has continually driven updates to the American College of Obstetricians and Gynecologist (ACOG) guidelines and other national policy recommendations for exercise during pregnancy (American College of Obstetricians and Gynecologists, 2003; American College of Obstetricians and Gynecologists, 2020; Birsner & Gyamfi-Bannerman, 2015; American College of Obstetricians and Gynecologist, 2020; Newton & May, 2017). However, the ACOG guidelines limit discussion of initial fitness testing and suggest more research is needed to elucidate effects of exercise FITT-V during pregnancy (American College of Obstetricians and Gynecologists, 2020). Recent works suggest there may be a dose-dependent effect of prenatal exercise on maternal and offspring health (Allman et al., 2022; Chaves et al., 2022; Davenport et al., 2022; Jevtovic et al., 2023; McDonald et al., 2022; McDonald, May, et al., 2021; Murphy et al., 2022), necessitating further investigation into the five metrics of exercise training, "FITT-V": Frequency (number of sessions), Intensity (metabolic equivalents "METs"), Time (duration of sessions), Type (exercise mode), Volume (exercise MET*-mins). Although there continues to be a lack of randomized controlled trials addressing exercise dose during pregnancy (Beetham et al., 2019; Bell & Palma, 2000; Stevenson, 1997a), and the lack of standardized protocols limits the power of meta-analyses (Skow et al., 2019), there are many studies from which we can inform us of the influence of exercise dose on health outcomes for mother and child. It is therefore the aim of this narrative review to summarize the evidence for dose-dependent benefits for mother and child.

## 2 | METHODS

In Spring 2023, the authors performed a web search of PubMed-indexed original research and review articles published in the English language. We used the following keywords to ascertain peer-reviewed articles: "prenatal exercise" AND "exercise during pregnancy." Articles were obtained in chronological order, beginning in the year 1950, and lasting until June 2023, then examined for relevance. In addition, reference lists of all articles were scanned to ensure a comprehensive collection of literature. There were no restrictions placed on country, pre-pregnancy body mass index (BMI), or gestational age at study entry.

## 3 | PRENATAL EXERCISE FREQUENCY, INTENSITY, TIME, TYPE, AND VOLUME

Complete (100%) adherence to the ACOG, and similar, guidelines have been shown to augment the beneficial effects of exercise during pregnancy (Tables 1 and 2; McDonald et al., 2016). Furthermore, recent evidence shows that pregnant women can safely exercise beyond the currently recommended dose (Davenport, Ruchat, et al., 2019). For instance, increased amounts of vigorous-intensity exercise, and total physical activity energy expenditure can further alleviate gestational health risks (Zavorsky & Longo, 2011). Still, caution is advised as some studies have suggested there may be an upper limit to "safe" exercise dose, an issue especially pertinent to pregnant athletes (Pivarnik et al., 2016; Wieloch et al., 2022). Accordingly, an assessment of maternal fitness level, and health clearance, should be undertaken before completing any prenatal exercise program, to ensure a safe but challenging exercise prescription (Kardel, 2005; Mottola et al., 2006). Given the variety of fitness and health goals of pregnant women, prenatal exercise programs must utilize an individualistic approach, in which pre-pregnancy fitness and desire for certain types of exercise are considered (Mottola, 2002; Revelli et al., 1992). The Get Active Questionnaire for Pregnancy was released in 2021 to enable women to self-screen for contraindications to exercise and pregnancy (Davenport et al., 2022). Use of this or other instruments is aligned with guidelines and recommendations (Bullard, 1981; Davies et al., 2003; Fishbein & Phillips, 1990; Jarski & Trippett, 1990; Romero-Gallardo et al., 2020); however, due to a lack of information regarding the exercise recommendations in preclinical and clinical gestational disease states, the use of such questionnaires should be in consultation with an obstetric provider (Davenport et al., 2022; Stevenson, 1997b).

The guidelines from the World Health Organization, the International Olympic Committee, and Canadian and American councils, all recommend a similar exercise dose (American College of Obstetricians and Gynecologists, 2020; Bø et al., 2018; Evenson et al., 2019; Rudin et al., 2021; Wolfe, Hall, et al., 1989) which has been justified as safe by past research groups. Yet, there is evidence of a dose–response relationship to gestational health outcomes (Davenport, Sobierajski, et al., 2018; Ehrlich et al., 2016; Ruchat et al., 2018; Wang et al., 2017), suggesting that exceeding the recommended dose may be beneficial. The current recommendations from the ACOG align with those from the American College of Sports Medicine, which are 150 min of moderate intensity every week of pregnancy (American College of Obstetricians and Gynecologists, 2020; Birsner & Gyamfi-Bannerman, 2015). This cautionary recommendation is probably due to the lack of agreement on the "upper" limit for safe exercise in pregnancy (Rudin et al., 2021; Wieloch et al., 2022), despite numerous studies showing no adverse effects of high(er) intensity exercise on

**TABLE 1** Prenatal exercise FIT-V affects maternal and offspring outcomes.

| **Prenatal exercise frequency (per week)** | | |
|---|---|---|
| **<3 times** | **3–4 times** | **5–7 times** |
| | ↓ GWG (Ruchat et al., 2018) | |
| | ↓ GDM risk (Wang et al., 2017; Zeanah & Schlosser, 1993) | |
| | ↓ Pelvic pain (Andersen et al., 2015) | |
| | ↓ Birth weight (OWOB; Wang et al., 2017) | |
| | ↓ Abnormal FPG (GDM; Zhang et al., 2023) | |
| **Prenatal exercise intensity** | | |
| **Low** | **Moderate** | **Vigorous** |
| | ↓ FPG (Davenport, Sobierajski, et al., 2018) | ↓ GWG (Beetham et al., 2019; Bisson et al., 2017; Ehrlich et al., 2016; Hamann et al., 2022; Zavorsky & Longo, 2011) |
| | ↓ Pre-eclampsia risk (Sorensen et al., 2003) | ↓ FPG (Davenport, Sobierajski, et al., 2018) |
| | ↑ Infant lean mass (Bisson et al., 2017) | ↓↓ Pre-Eclampsia Risk (Sorensen et al., 2003) |
| | | ↑ CRF (Bisson et al., 2015) |
| | | ↑ Fetal Heart (Bisson et al., 2017; May et al., 2012) |
| | | ↓ Infant Fat Mass (Bisson et al., 2017) |
| **Prenatal exercise time (per session)** | | |
| **<35 min** | **35–60 min** | **>120 min** |
| | ↓ GWG (Hamann et al., 2022; Ruchat et al., 2018; Zeanah & Schlosser, 1993) | |
| | ↓ FPG (GDM; Zhang et al., 2023) | |
| | ↑ Glycemic response (Davenport, Sobierajski, et al., 2018) | |
| | ↑ Fetal heart (May et al., 2012) | |
| | ↓ LGA (Juhl et al., 2010) | |
| **Prenatal exercise volume (per week)** | | |
| **~500 MET*mins** | **500–750 MET*mins** | **~750 MET*mins+** |
| ↑ Preterm birth (Takami et al., 2018) | ↓ FPG (McDonald, Strom, et al., 2021) | ↓↓ FPG (McDonald, Strom, et al., 2021) |
| | ↓ GWG (Ruchat et al., 2018) | ↑ Placental volume (Clapp et al., 2002) |
| | ↑ Placental volume (Clapp et al., 2002) | ↓ Birth weight (OWOB; McDonald et al., 2022) |
| | | ↓ Infant fat mass (Bisson et al., 2017) |
| | | ↓↓ GWG (Ruchat et al., 2018) |

*Note*: ↑ or ↑↑ (larger) significant positive association $p < .05$; ↓ or ↓↓ (larger) significant negative association $p < .05$.
Abbreviations: CRF, cardiorespiratory fitness; FPG, fasting plasma glucose; GDM, gestational diabetes mellitus; GWG, gestational weight gain; LGA, large for gestational age; OWOB, overweight/obese.

pregnancy or birth complications (Juhl et al., 2008; Juhl et al., 2010; Kardel, 2005; Kardel & Kase, 1998; Lokey et al., 1991; Penttinen & Erkkola, 2007; Zeanah & Schlosser, 1993). In the words of Raul Artal, "Pregnancy should not be a state of confinement and cardiovascular and muscular fitness can be reasonably maintained. Restriction of physical activity should be dictated by obstetric and medical indications only (Artal, 1992)."

**TABLE 2** Prenatal exercise type affects maternal and offspring outcomes.

| Prenatal exercise type | | |
|---|---|---|
| **Aerobic** | **Resistance** | **Combination** |
| Mother | Mother | Mother |
| ↓ Lipids (McDonald et al., 2022; Strom et al., 2022) | ↓ BP (Murphy et al., 2022) | ↓ GDM risk (Gascoigne et al., 2023) |
| ↓ GWG (Hamann et al., 2022; Ruchat et al., 2018; Zeanah & Schlosser, 1993) | ↓ FPG (McDonald, May, et al., 2021; Yaping et al., 2020) | ↓ BP (Gascoigne et al., 2023) |
| ↑ Fitness (Bisson et al., 2015) | Offspring | Offspring |
| ↓ FPG (McDonald, May, et al., 2021) | ↓ Macrosomia (GDM; Yaping et al., 2020) | ↓ Preterm birth (Juhl et al., 2008) |
| Offspring | ↑ Metabolism (Jevtovic & May, 2022; Jevtovic et al., 2023) | |
| ↓ Body fat (McDonald, Isler, et al., 2021) | | |
| ↑ Cardiovascular (May et al., 2010; May, Suminski, Berry, et al., 2014) | | |
| ↑ Metabolism (Jevtovic & May, 2022; Chaves et al., 2022; Jevtovic et al., 2023) | | |

Abbreviations: BP, blood pressure; FPG, fasting plasma glucose; GDM, gestational diabetes mellitus; GWG, gestational weight gain.

While cautionary health practices are essential during gestation, evidence-based conclusions drawn from the past 50 years refute any threatening circulatory adjustments to the mother or fetus during high-dose exercise training (Bonds & Delivoria-Papadopoulos, 1985; Clapp, 1996b; Jones et al., 1985; Kolata, 1983; Lotgering et al., 1985; van Doorn et al., 1992), and necessitate further investigation to determine the upper limit of safe and effective doses of prenatal exercise FITT-V (Kehler & Heinrich, 2015; McDonald et al., 2016).

## 3.1 | Frequency

Prenatal exercise recommendations from ACOG and other professional organizations (Rudin et al., 2021) suggest a training frequency of *at* least 3–4 times per week, with a maximum of 7 days per week (American College of Obstetricians and Gynecologists, 2020). Studies have implemented frequencies within the guidelines, and there is a lack of evidence concerning lower-frequency prenatal exercise (Table 1). Zavorsky and Longo provide an explanation of how exercise frequency can be manipulated to alter prenatal exercise dose (Zavorsky & Longo, 2011). It has been shown in healthy and overweight women that gestational exercise frequency (>2 times per week) is associated with reduced gestational weight gain (Zeanah & Schlosser, 1993). It has been shown in women with overweight or obesity that exercise at least three times per week shows a decrease in risk for gestational diabetes mellitus (GDM; Wang et al., 2017). Additionally, exercise training three times per week reduces birth weight in overweight/obese pregnancies to a "healthy" weight (Wang et al., 2017). Bell et al. showed in healthy-weight women that vigorous prenatal exercise 3–4 times each week led to no differences in birth weights between exercisers and nonexercisers (Bell et al., 1995). After controlling for maternal weight status, it has been shown that an increase in exercise beyond five times per week, in women of both healthy- and overweight BMI, is associated with reduced (−200 to −500 g) birth weights below the 15th percentile (Bell et al., 1995; Campbell & Mottola, 2001). Yet more recent replication of Bell's study in 102 healthy-weight pregnant women, no influence of exercise frequency is seen on birth weight (Duncombe et al., 2006). Other data suggest that an exercise frequency of 4–5 times weekly provides a critical reduction in excessive gestational weight gain (Ruchat et al., 2018), with no adverse pregnancy outcomes (Hale & Milne, 1996). Together, evidence to date suggests minimal risk with moderate frequency gestational exercise, while implementation of higher exercise frequency remains debated and should be monitored.

## 3.2 | Intensity

Current prenatal exercise recommendations suggest exercise intensity below 60%–80% of the age-predicted maximum heart rate (American College of Obstetricians and Gynecologists, 2020). Researchers have implemented intensities within or above this recommended range; however, the lack of evidence concerning the effects of low-intensity prenatal exercise remains (Table 1). Evidence shows that prenatal exercise up to 85% maximum HR has no adverse effects on pregnancy outcomes (Bonnin et al., 1997; Clapp, 1989; Durak et al., 1990; Klebanoff et al., 1990; Wolfe, Hall, et al., 1989; Wolfe, Ohtake, et al., 1989). Additionally, limitations in the studies cautioning against vigorous exercise have been elucidated (Carpenter, 1988; Jovanovic et al., 1985; MacPhail, 2000; Steegers et al., 1988; Wolfe & Mottola, 2002). For example, it has been shown that circulatory compensations, such as increased stroke volume, cardiac output, and $VO_2$, during prenatal exercise allow women to perform acute vigorous exercise with no adverse responses (Artal, Rutherford, et al., 1986; Artal, Wiswell, et al., 1986; Bell et al., 1995; Bonds & Delivoria-Papadopoulos, 1985; Clapp, 1994; Duncombe et al., 2006; Kardel & Kase, 1998; Kulpa et al., 1987; MacPhail, 2000; Penney, 2008; Penttinen & Erkkola, 2007; Stevenson, 1997b; Zeanah & Schlosser, 1993), even in late pregnancy (Beetham et al., 2019; Edwards et al., 1981; Ueland et al., 1973) and during maximal exercise (Watson et al., 1991). After adjusting for maternal weight status, large observational studies have shown no increased risk for poor birth outcomes, including low birth weight, small for gestational age (SGA), and prematurity in women who exercise vigorously (Duncombe et al., 2006; Hatch et al., 1998). Fetal adaptations, such as resting heart rate are negatively correlated with maternal intensity of exercise (May et al., 2012) in a cohort of mostly healthy-weight women. Moderate-intensity prenatal exercise (>60% maximum heart rate) is associated with reduced risk for GDM (Zavorsky & Longo, 2011). It has been shown that vigorous-intensity exercise reduces the risk for prematurity (Beetham et al., 2019). Further, regular participation in physical activity reduces the risk for pre-eclampsia by up to 26% and reduces a further 54% if the exercise intensity is vigorous, that is, >6 METs (Sorensen et al., 2003). Vigorous intensity exercise may be an important goal for women with overweight or obesity (Ehrlich et al., 2016; Zavorsky & Longo, 2011). Vigorous exercise provides benefits for maternal health such as reduced gestational weight gain (Beetham et al., 2019; Bisson et al., 2015; Chiu et al., 2017; Ehrlich et al., 2016; Hamann et al., 2022; Zavorsky & Longo, 2011), body fat accumulation (Chiu et al., 2017; Yu et al., 2022), circulating plasma glucose (Davenport, Sobierajski, et al., 2018), and improved cardiorespiratory fitness (Bisson et al., 2015). Additionally, it has been shown that the performance of vigorous exercise reduces neonatal fat mass independent of maternal weight status (Bisson et al., 2017). Though previously conditioned pregnant athletes often supersede six METs in their training bouts with no adverse pregnancy outcomes (Pivarnik et al., 2016), vigorous intensity prenatal exercise requires caution. The International Olympic Committee (IOC) guidelines report that vigorous-intensity exercise required for pregnant athletes has been associated with fetal bradycardia (Bø et al., 2016; Salvesen et al., 2012), and individual responses to intense prenatal exercise should be monitored closely. The glycemic response to intense prenatal exercise may be altered and care should be taken to ensure proper nutrition before and during exercise (Clapp & Capeless, 1991).

Obtaining a valid measure of intensity in prenatal exercise is critical. Fitness testing before the commencement of exercise training guides prescriptions for proper HR zones and gives achievable targets for energy expenditure and work rates. Still, exercise professionals must realize there are potential errors in assessing intensity in gravid women. It has been shown that expenditure per HR changes as pregnancy progresses (Evenson & Hesketh, 2023; Pivarnik et al., 2002). Further, it has been postulated that HR could underestimate exercise intensity at high levels, while overestimating intensity at lower levels (Wolfe & Weissgerber, 2003). Thus, utilization of multiple measures of intensity, such as HR, Rate of perceived exertion (RPE), and the talk test are recommended (Wolfe & Mottola, 2002; Zavorsky & Longo, 2011). Therefore, a sensible ramp-up protocol is essential to provide time for women to adapt to the exercise workloads (Lumbers, 2002). To date, no published, trimester-specific, compendium of metabolic equivalents (METs) has been compiled for gravid women, and future research is needed to validate this metric. As women advance into late gestation, intense exercise should be monitored as maximal ventilation may be reduced (Knuttgen & Emerson, 1974). Although further research is needed related to extreme intensities (Beetham et al., 2019), pregnant exercisers should feel comfortable exercising up to 90% maximum heart rate, RPE of 12–14 on a 6–20 Borg RPE chart, and to the point where talking becomes difficult (Rudin et al., 2021).

### 3.3 | Time

Prenatal exercise recommendations suggest an exercise duration per session of 30–60 min (American College of Obstetricians and Gynecologists, 2020; Rudin et al., 2021). Studies have generally focused on bouts lasting longer than 30 min, with a lack of evidence regarding low-duration prenatal exercise (Table 1). Obtaining sufficient exercise duration is important to achieve the health benefits of prenatal exercise (Avery, 1997). Still, duration should be controlled during prenatal exercise in order to avoid compromising available energy stores for mother or fetus (Soultanakis et al., 1996). It has been shown that exercising with a duration greater than 35–40 min per session leads to no adverse pregnancy outcomes, and actually improves gestational outcomes by reducing excessive weight gain (Hamann et al., 2022; Ruchat et al., 2018; Zeanah & Schlosser, 1993). As with exercise intensity, duration is an important target for women with overweight or obese. Furthermore, increased duration beyond 40 min has been shown to correlate with improved glycemic response to an acute exercise bout (Davenport, Sobierajski, et al., 2018) and if applied through chronic training, better maintains fasting plasma glucose in persons with GDM (Zhang et al., 2023). In healthy women, chronic prenatal exercise training bouts of up to 1-hr show no adverse effect on mother or fetus (Lokey et al., 1991). Endurance exercise has been associated with a 200-g reduction in birth weight without increasing the occurrence of SGA (Leet & Flick, 2003). Research shows that prenatal exercise duration can positively influence fetal heart function (i.e., heart rate) in a dose-dependent manner (May et al., 2012), further translating into favorable infant cardiac autonomic system development (May & Suminski, 2014). However, glucose metabolism increases as fetus develops (Treadway & Young, 1989) and could contribute to the risk of maternal exercise-induced hypoglycemia. As blood glucose has been shown to decrease more so during exercise in pregnancy (Soultanakis et al., 1996), this is an important consideration for long-duration prenatal exercise. Independent of maternal weight status, Bisson et al. showed that prolonged exercise beyond 112 min per day does not influence offspring birth weight (Bisson et al., 2017). At birth, individuals exercising greater than 5 hr per week give birth to normal weight and size neonates, with no increase in rates of SGA and a decreased incidence of large for gestational age infants (Juhl et al., 2010). As further, anecdotal evidence, pregnant athletes often endure exercise training bouts lasting longer than 2 hr per day (Pivarnik et al., 2016). Duration of prenatal exercise bouts should be tailored for the individual's prepartum exercise capacity, but generally, it seems that 1 hr per bout incurs many benefits for mother and fetus, while participation in longer bouts is safe but may require more monitoring.

## 3.4 | Type

Most organizations suggest a variety of prenatal exercises: walking, stationary cycling, aerobic exercises, dancing, and resistance exercises (Table 2; American College of Obstetricians and Gynecologists, 2020), which also include flexibility and yoga exercises (Rudin et al., 2021). Prenatal exercises should target large muscle groups when the aim is to improve metabolic health, energy balance, and control weight gain (Hartmann & Bung, 1999). Some classic case reports tell of women jogging and running in marathons, and cross-country skiing (Penttinen & Erkkola, 2007), through all three trimesters (Bailey et al., 1998; Cohen et al., 1989; Jarrett & Spellacy, 1983; Korcok, 1981) with healthy birth outcomes (Pivarnik et al., 2003; Zaharieva, 1972), even birthing healthy twins (Bailey et al., 1998). Swimming is a popular form of prenatal aerobic exercise, and incurs no adverse pregnancy outcomes (Juhl et al., 2010; Lynch et al., 2007). Although most studies have prescribed aerobic exercise (Jones et al., 1985; Kulpa et al., 1987; Strom et al., 2022; Veisy et al., 2021; Wallace & Engstrom, 1987), such as jogging (Clapp, 2006; Sady & Carpenter, 1989), dancing (McMurray et al., 1996; Sanders, 2008), cycling and other types of aerobic exercise (Clapp, 2000), it is recommended that pregnant women also participate in muscular strength exercise as well (American College of Obstetricians and Gynecologists, 2020; Birsner & Gyamfi-Bannerman, 2015). Yet historically, more researchers have studied aerobic prenatal exercise than resistance and flexibility exercises. The cardiac responses of mother and fetus to resistance, aerobic, and concurrent exercises have been reviewed previously (May et al., 2016). Overall, aerobic prenatal exercise shows cardiovascular and pregnancy benefits for mother and fetus, while resistance and concurrent training are safe for mother and fetus (May et al., 2016). Aerobic prenatal exercise improves maternal and infant markers of metabolic (Clark et al., 2019; McDonald et al., 2020; McDonald, Strom, et al., 2021; Strom et al., 2022a, 2022b) and cardiovascular health (May et al., 2010; May et al., 2012; May, Scholtz, Suminski, & Gustafson, 2014). Resistance exercise has been shown as safe (Hall & Kaufmann, 1987; *Journal of Science and Medicine in Sport*, 2002), and is equally effective for reducing fasting glucose and insulin requirement, especially in women with overweight or obesity (McDonald et al., 2022). Aerobic, Concurrent, and Resistance exercise improves maternal blood pressure compared to no exercise; however, resistance exercise offers more efficacy for maintaining healthy maternal blood pressure during pregnancy (Murphy et al., 2022). Additionally, current research suggests that offspring glucose metabolism could be altered by both aerobic, concurrent, and resistance training, with the greatest effect from resistance training (Chaves et al., 2022; Jevtovic et al., 2023). Resistance exercise also reduces fasting plasma glucose, insulin dependence, and macrosomia in women with GDM (Yaping et al., 2020), thus normalizing newborn body size and health (Zavorsky & Longo, 2011). Care should be taken in exercises demanding a quick change from sitting to standing, as a relatively large increase in HR is seen through this movement in pregnant women (Sandström, 1974). Finally, the concurrent exercise of resistance and aerobic exercise has been shown to have powerful benefits for maternal health and perinatal outcomes (Perales et al., 2016). These include a lower risk of preterm deliveries and abnormal birth weight (Silva-Jose, Sánchez-Polán, Barakat, Díaz-Blanco, Mottola, & Refoyo, 2022), gestational weight gain and GDM (Silva-Jose, Sánchez-Polán, Barakat, Díaz-Blanco, Carrero Martínez, et al., 2022; Silva-Jose, Sánchez-Polán, Barakat, Díaz-Blanco, Mottola, & Refoyo, 2022; Uria-Minguito et al., 2022), and hypertension (Gascoigne et al., 2023; Juhl et al., 2008), without compromising fetal well-being (Fernández-Buhigas et al., 2023). To date, data from observational and small intervention studies show that prenatal resistance exercise can incur many of the same benefits for mother and fetus as aerobic exercise, but more randomized controlled trials for resistance exercise are needed.

### 3.5 | Volume

Prenatal exercise volume is calculated from frequency, intensity, and time in the units of MET*minutes per unit of time (METmin/week); yet pregnancy and postpartum guidelines do not give recommendation for ranges of prenatal exercise volume (American College of Obstetricians and Gynecologists, 2020; Rudin et al., 2021). Based on the low and high ranges of recommended exercise dose of 150 min/week of moderate-intensity (3–6 METs) exercise, this prenatal exercise level converts to women engaging in 450–900 METmin/week. Studies typically prescribe a volume greater than 500 MET*minutes per week, and there is a lack of evidence for lower-volume prenatal exercise (Table 1). Large observational studies have shown no adverse effects of prenatal exercise volume on birth outcomes (Duncombe et al., 2006; Hatch et al., 1998; Takami et al., 2018). Clapp et al. have shown that exercise volume is positively associated with placental volume (Clapp et al., 2002); further, maintaining high-volume exercise into the third trimester can reduce birth weight, within the normal range, and infant adiposity (Clapp et al., 2002). Additionally, studies have shown that fetal heart outcomes such as heart rate and heart rate variability adapt in a dose–response manner (May et al., 2012; May & Suminski, 2014). It has been shown that if prenatal exercise dose is insufficient, the health benefits from exercise could be minimal (Avery, 1997). For example, a recent review stratified exercise volume into low (<360 METmin/week), medium (500 METmin/week), and high (750 METmin/week) and shows that maintaining medium volume throughout the entire pregnancy, or implementing high volume in the second trimester, improves maternal glucose metabolism (McDonald, May, et al., 2021), and a reduced risk for GDM (Zavorsky & Longo, 2011). In addition, another group has shown in healthy-weight women that if exercise volume falls below 500 METmin/week, risk for premature birth increases (Takami et al., 2018). To combat excessive gestational weight gain, at least 550 METmin/week of prenatal exercise have been shown necessary, especially in women with overweight or obesity (Ruchat et al., 2018). Clearly, the recommendations of ACOG and other entities could be updated to recommend moderate exercise volume (e.g., 500 MET*minutes per week), with a potentially higher recommendation to see more robust improvements in women with overweight or obesity. As for the timing of exercise, moderate-to-high volume of exercise is more beneficial for reducing birth weight when performed in the second and third trimesters (Clapp et al., 2002). Maintaining an exercise-related energy expenditure beyond 2000 kilocalories (roughly ~1600 MET*min) per week has been shown as safe for mother and fetus, with no reduction in birth weight (Hatch et al., 1993). In some cases, pregnant athletes are conditioned for 3600 METmin/week of exercise volume (Pivarnik et al., 2016). Researchers continually show that endurance athlete women can continue high-volume training regimens throughout the antepartum period (Kardel, 2005; Penttinen & Erkkola, 2007), and highly conditioned pregnant women can run 100 km per week with no adverse outcomes (Bergmann et al., 2004; Davies et al., 1999). However, for the general public, this relatively ambiguous range should be more stringently tested in future studies. Setting prenatal exercise volume recommendations, which could also be presented as "kilocalorie per week" targets might give women more freedom to manipulate their exercise intensity, frequency, mode, and duration, (e.g., shorter-duration and higher-intensity exercise) to fit their busy schedules, while achieving the same volume as longer-duration and lower intensity exercise, and still provide similar health outcomes (Zavorsky & Longo, 2011).

## 4 | TRIMESTER-SPECIFIC EXERCISE FITT-V

Prenatal exercise has been safely completed through all three trimesters of pregnancy (Bailey et al., 1998; Cohen et al., 1989; Jarrett & Spellacy, 1983; Korcok, 1981), with healthy birth outcomes (Pivarnik et al., 2003; Zaharieva, 1972). As for the timing of exercise prescriptions across the three trimesters of gestation, interesting work shows trimester-specific effects of exercise. Implementing a high-volume exercise regimen in the second trimester improves maternal glucose metabolism (McDonald, May, et al., 2021), and could reduce the risk for GDM (Zavorsky & Longo, 2011). Specifically, exercise session duration beyond 45 min in the third trimester specifically prevents abnormal fasting plasma glucose in women with GDM (Zhang et al., 2023). Developmental needs of the fetus increase through the third trimester, and so research within this period is critical as the existing guidelines do not provide trimester-specific recommendations. However, meta-analysis has shown that vigorous-intensity exercise (6–9 METs, 70%–90% $HR_{max}$, 60%–85% $VO_{2max}$) has been shown as safe for growth of the fetus, as offspring born to vigorous exercisers do not present SGA (Beetham et al., 2019). Additionally, Clapp et al. have shown that moderate-to-high volume of exercise is more beneficial for reducing birth weight and body fat when performed in the second and third trimesters (Clapp et al., 2002). This could be due to the accelerated growth of fetus during this period (Nesler et al., 1988). As growth progresses through the third trimester, supine exercise appears a safe modality for women wishing to perform specific resistance or stretching exercises (Nesler et al., 1988). Of note, it has been shown that self-paced exercise intensity of pregnant women has been shown to be reduced −20% to 30% (Clapp et al., 1987) as pregnancy progresses. In order to achieve increased exercise doses, pregnant women should receive external motivation, and social support, as their self-selected exercise intensity and volume may wane as gestation advances (van Raaij et al., 1990). As data continue to emerge, the recommendations of ACOG and other entities could be updated for trimester-specific exercise FITT-V.

### 4.1 | Recommendations for future research

Most of the research in prenatal exercise has been performed with healthy-weight women and future emphasis should be placed on serving women with overweight or obesity across races, ethnicities, health history, and socioeconomic status. Data is also scant related to twin and multifetal pregnancies, in vitro fertilization, or similar assisted reproductive technology, and in women taking medications through pregnancy.

## 5 | CONCLUSION

Recent works suggest there may be a dose-dependent beneficial effect of prenatal exercise for mother and offspring, with evidence that maternal and offspring health outcomes respond differently to low, medium, and high doses of prenatal exercise. Upon further review, research articles often report FITT-V in their protocols, allowing meta-analysis of these metrics. Still, relatively few randomized controlled trials have independently tested the different effects of prenatal exercise FITT-V on pregnancy outcomes. Limited evidence therefore exists on the dose-dependent effects of prenatal exercise on mother and offspring in a few select cardiovascular, morphometric, metabolic, and developmental measures. Additional investigations will also highlight the particular markers of cardiometabolic and developmental health in mother and offspring that respond well to prenatal exercise. More research is needed to define (1) the "minimum" efficacious prenatal exercise dose, and (2) the maximum tolerable dose throughout the three trimesters of pregnancy, both of which could vary among individuals of different health status and demographics. As impactful evidence for exercise FITT-V during pregnancy continues to emerge, committees such as ACOG should frequently reassess and amend the guidelines with specific fitness testing and exercise prescription insights.

### 5.1 | Implications for practice

Evidence shows that in women with gestational diabetes mellitus (GDM), higher frequency (>3 days per week; Wang et al., 2017; Zeanah & Schlosser, 1993), duration (>40 min per bout; Zhang et al., 2023), volume (>500 METmin/week; Zavorsky & Longo, 2011), of resistance or aerobic (Gascoigne et al., 2023; Yaping et al., 2020) exercise elicits a decrease in fasting plasma glucose and adverse birth outcomes. Clinicians should promote increased exercise FITT-V, above recommended guidelines, in women with, or at risk for GDM. Conversely, though an increased dose of prenatal exercise has been shown to be beneficial to mother and fetus, it is important for pregnant women to ensure moderation in their exercise programs. The exact upper limits for exercise volume during pregnancy have not yet been determined and likely vary among individuals. Excessive exercise and dietary habits aimed at losing weight or preventing healthy gestational weight gain can indirectly lead to malnutrition and poor psychological states for mother and fetus (Spieker, 1996) and should be avoided. As impactful evidence for exercise FITT-V during pregnancy continues to emerge, committees such as ACOG and WHO should frequently reassess and amend the guidelines with specific fitness testing and exercise prescription insights.

## ACKNOWLEDGMENT

The authors thank all who have contributed to the works discussed in this review.

## CONFLICT OF INTEREST STATEMENT

The authors have nothing to disclose.

## DATA AVAILABILITY STATEMENT

Data generated/analyzed during the current study is available upon request from the corresponding/senior author.

## ORCID

*Alex Claiborne* https://orcid.org/0000-0001-7427-3851
*Linda E. May* https://orcid.org/0000-0002-8231-2280

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**How to cite this article:** Claiborne, A., Jevtovic, F., & May, L. E. (2023). A narrative review of exercise dose during pregnancy. *Birth Defects Research*, 1–17. https://doi.org/10.1002/bdr2.2249