27 Exercise Guidelines During Pregnancy

Elvis Álvarez Carnero, Brianne L. Guilford, Danika A. Quesnel, Claudia Cardona-Gonzalez, Jacalyn J. Robert-McComb, and Maria Fernandez-del-Valle

Learning Objectives

After completing this chapter, you should have an understanding of:

- Acute and chronic adaptations to physical activity and/or exercise training during pregnancy
- Benefits of regular physical activity for pregnant women and fetus
- How to avoid risks for fetus and mother associated with exercise training
- Recommendations and guidelines to prescribe exercise during pregnancy and the postpartum period

E. Álvarez Carnero
AdventHealth Orlando, AdventHealth Translational Research Institute, Orlando, FL, USA
e-mail: elvis.alvarezcarnero@adventhealth.com

B. L. Guilford
Department of Applied Health, Southern Illinois University Edwardsville, Edwardsville, IL, USA
e-mail: bguilfo@siue.edu

D. A. Quesnel
Department of Psychological Clinical Science, University of Toronto, Toronto, ON, Canada
e-mail: Danika.quesnel@mail.utoronto.ca

C. Cardona-Gonzalez
Departmento de Ciencias de la Salud, Exercise Science, Universidad del Valle de Mexico, Merida, Yucatan, Mexico

J. J. Robert-McComb
Department of Kinesiology and Sport Management, Texas Tech University, Lubbock, TX, USA
e-mail: jacalyn.mccomb@ttu.edu

M. Fernandez-del-Valle (✉)
Department of Functional Biology, School of Medicine and Health Sciences, University of Oviedo, Oviedo, Asturias, Spain

Health Research Institute of the Principality of Asturias (ISPA), Oviedo, Asturias, Spain
e-mail: dr.maria@fdelvalle.net

27.1 Introduction

Despite previous controversy surrounding the benefits vs. consequences of exercise during pregnancy, there is an accumulating body of evidence that supports the benefits of exercise and provides recommendations for reducing risk to both the mother and fetus. Physical activity (PA) and exercise training provide several benefits for both the mother and the fetus: blood pressure control, blood glucose regulation, healthy birth weight, prevention of obesity, and maintenance of pre-gravid physical fitness. Nevertheless, there are potential risks (hyperthermia, hypoglycemia, chronic fatigue, abortion, etc.) associated with excessive and poorly planned exercise regimens. These conditions primarily occur when environmental conditions, volume and intensity thresholds, and contraindications are not respected. National associations of obstetricians and gynecologists from several countries have collected scientific knowledge to develop useful guidelines to design safe and effective PA and exercise training programs. However, due to the lack of research in the field of exercise prescription during pregnancy, these guidelines must not be considered specific, and some rules are adapted from recommendations for healthy people.

27.2 Research Findings

27.2.1 Physiology of Pregnancy

Pregnancy is a period of a female's vital cycle lasting 40 weeks to carry and gestate a new human person. Parturition is the formal term for birth, and labor is the sequence of events that occur leading up to birth. Classical pregnancy is divided into trimesters, and each is characterized by milestones. Weeks are also used to quantify gestational age at delivery, anatomical and physiological development of the fetus or assessment agenda (ultrasound or blood samples). In order to support the life growing inside her body, pregnant women undergo several organic morphologic and functional

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changes, affecting multiple organ systems, and may affect physical performance (Table 27.1) [1, 2].

27.2.1.1 Cardiovascular Function

The most striking changes operate at the level of cardiovascular system. Increased weight-bearing elicits increased heart load which promotes myocardial hypertrophy, either volumetric or wall thickness [49]. By the end of the first trimester, the diaphragm has raised resulting in a progressive increase in resting cardiac output that continues throughout pregnancy, peaking around the 20th week (40% more than in the non-pregnant state), and remaining steady during the final 3 months. Increased cardiac output induces several hemodynamic changes during the resting state

Table 27.1 Physiological changes during pregnancy

System	Function	Mechanism
Cardiovascular	(a) Higher peripheral oxygen demands (from 50 mL/min to 500 mL/min) [3, 4] (b) Cardiac output increases by 40%: heart rate (HR) increases at the beginning up to 10–15 bpm and systolic volume by 10–12% [4–6] (c) Peripheral resistance decreases from week 12 to week 24, becoming normal later [7–9]	(a) Oxygen uptake increases from 15 to 20% during the second half of pregnancy. This is caused by increased oxygen uptake from the uterus, placenta, and fetus [3, 4] (b) Resting HR increases due to increase in gonadotropin hormone, reduced parasympathetic system activity, and reduced concentration of blood catecholamines [4, 5] (c) Caused by vasodilatation produced by hormones (i.e., estrogen, relaxin, etc.) [7, 8, 10]
Blood	(a) Plasma volume increases gradually until 32 weeks (30–60%) [14, 15] (b) Red blood cells number and size increase [15, 16] (c) Veins increase capacity and peripheral vascular resistance decreases [14]	(a) Causes hemodilution of the blood causing physiological anemia of pregnancy [14, 15] (b) Produced by increased renal erythropoietin [15, 16] (c) Produced by effect of progesterone [14]
Respiratory	(a) Resting hyperventilation to compensate alkalosis (increased ventilation from 6 L/min to 9 L/min) (b) Decreased AV-O_2 difference (blood returning to the heart is more oxygenated) [9, 10] (c) Resting respiratory rate is reduced, while vital capacity is preserved [17–20]	(a) Due to increased tidal volume, which removes more CO_2 from blood, thus raising pH. In addition, enhanced chemoreceptor sensitivity to CO_2 prevents fetal ischemia and acidosis [18–21] (b) Minute volume increases more than oxygen uptake [7, 8, 10] (c) This is caused by a slight increase in inspiratory capacity [11–13]
Renal and urinary	(a) Dilated ureters and renal pelvis producing an increase of the dead space and delay [22] urine elimination [23, 24] (b) Increased kidney length [24] (c) Diastolic blood pressure decreases 5 to 10 mmHg [25, 26] (d) Increased renal plasma flow, in the first quarter (600 mL/min to 836 mL/min) [25, 26]	(a) Caused by increased aldosterone and estrogen release, which balance progesterone (b) Caused by increased kidney vascular and interstitial volume, compressive mechanical forces and may be due to increased progesterone concentrations [24] (c) Increased renin secretion and activation of the renin–angiotensin–aldosterone axis [25, 26] (d) Due to increased glomerular filtration, which later decreases [25, 26]
Gastro-intestinal	(a) Nausea, vomiting [27] (b) Predisposition to tooth decay and gum hyperemia [28] (c) Delay in time for gastric evacuation producing constipation [29] (d) Pyrosis [28]	(a) Associated with hormone secretion (gonadotropins and estrogens) [27, 30] (b) Related to hormone concentration in saliva [28] (c) Due to increased uterus size, displaced bowel and stomach and hormonal influence (d) Cardiac sphincter relaxation causes the hydrochloric acid in the stomach to reflux into the esophagus [28]
Metabolic	(a) Diabetogenic effect of pregnancy [31] (b) Change in blood lipid profile [32, 33] (c) Increased resting metabolic rate [32, 34]	(a) Due to hormones such as cortisol, estrogens and lactogen from placenta which can inhibit the effects of insulin (insulin resistance). Pancreas can naturally produce more insulin, leading to gestational diabetes (b) Lipids increase from 600 to 900 mg/mL. Produced by the influence of estrogens and cortisol [33] (c) Caused by increased absolute metabolic demand from gestational state [32, 34]
Water metabolism	Increased total body water [33, 35]	– Increased hydrostatic pressure in vessels – Increased lower limb blood flow return – Increased capillary permeability – Increased sodium retention

Table 27.1 (continued)

System	Function	Mechanism
Dermatological	(a) Increased pigmentation [36] (b) Striae gravidarum or stretch marks [36–38] (c) Increased sweat secretion [36, 38]	(a) Caused by increased estrogen and progesterone concentrations [36] (b) Caused by distension of tissues, increased adrenocortical and estrogenic activities, or excessive weight of babies and mothers [36] (c) Increased eccrine sweat gland activity due to elevated hormonal secretion (i.e., estrogen, progesterone) [36]
Skeletal system	(a) Ligaments become more relaxed (sacroiliacus, sacrococcygeal, and pubic joints) [39, 40] (b) Increased lumbar dorsal curvature (lordosis) [41, 42] (c) Pain in zones around peripheral innervation [41, 43] (d) Frequent muscle cramps in the third trimester, especially in legs [37, 44]	(a) Caused by relaxin [39, 40] (b) Produced by the displacement of the center of mass [41, 42] (c) Produced by liquid retention and relaxation of ligaments due to increased relaxin [41, 43] (d) Related to sodium depletion [37, 44]
Hormonal changes	(a) Increased human chorionic gonadotropin [44] (b) Increased estrogens [44, 45] (c) Increased progesterone [44, 45]	(a) Human chorionic gonadotropin develops the placenta (b) Estrogens increase the size of the uterus [44, 45] and prepare milk ducts for breastfeeding (c) Progesterone retains pregnancy and develops the lobules of the breast [44, 45]
Body weight	Increase between 9 and 12 kg [46–48]	Due to fetus growth; increased maternal fat mass, increased plasma volume, uterus blood volume, amniotic fluid, and placenta and breast tissue [46–48]

which begin at 5 weeks [4]. The changes may be a result of vasodilation occurring in the maternal systemic vasculature and renal system [26]. There is also a notable reduction in peripheral vascular resistance (35–40%) beginning in the first trimester and subsequent plateau during the remainder of pregnancy [14, 50].

Systolic blood pressure during pregnancy is completely stable, while the diastolic blood pressure falls from 5 to 10 mm Hg, consequentially due to the reduction in peripheral resistance and development of circulation in the uterus and placenta up to 22 weeks. Diastolic pressure tends to drop more than systolic pressure resulting in a widened pulse pressure [11, 50–52].

Blood volume increases up to 40%, peaking in weeks 32–34 of pregnancy. The increase in plasma volume begins at 6–8 weeks and continues through to 28–30 weeks and associated with activation of renin–angiotensin–aldosterone system [53]. Plasma volume increases more than increased production red blood cells, resulting in hemodilution, reduced blood viscosity, reduced circulation time, and physiological anemia [53].

Hemodynamic changes during pregnancy are accompanied by changes in oxygen uptake. Although, the oxygen content of arterial and mixed venous blood (a-V O_2 difference) decreases during the first few months, oxygen uptake (VO_2) increases between 15 and 20% at the second half of pregnancy, thus resulting in increased a-V O_2 difference. This increase is primarily due to increased oxygen consumption by the uterus, placenta, and growing fetus [51]. Subsequently, the a-V O_2 difference returns to previous levels (normal) in the third trimester. Partial pressure of carbon dioxide ($PaCO_2$) decreases to 32–34 mm Hg during pregnancy during first trimester as a consequence of the hyperventilation (see next section), which might enhance the CO_2 output from fetal tissues [51, 53].

27.2.1.2 Pulmonary Function

During pregnancy, ventilation (VE, L/min) is increased at rest and during incremental exercise compared to nonpregnant women [20, 54–56]. Residual respiratory capacity is reduced, while vital capacity is not altered, due to the slight increase in inspiratory capacity noted during pregnancy. Tidal volume increases, even though the respiratory rate is held constant, leading to an increased volume about 40% [20, 56]. Maternal hyperventilation leads to a compensated respiratory alkalosis, which decreases the concentration of carbon dioxide in the blood and increases pH slightly [12]. Adaptations in pulmonary volumes and capacities are necessary to meet the increased metabolic demands of the fetus, uterus, and maternal organs. VO_2, carbon dioxide production (VCO_2), and basal metabolic rate are increased by 20–30% at term [20, 56]. In addition, there is increased edema and hyperemia of upper airway mucosa which can cause nasal congestion and contribute to difficult endotracheal intubations in pregnant women.

27.2.1.3 Endocrine System

The endocrine system of a pregnant woman undergoes significant changes driven primarily by placental hormone production (prolactin and growth hormone, steroid hormones, and neuropeptides) [57]. For example, human chorionic gonadotropin (hCG), which is released by the placenta, is responsible for decreasing thyrotropin-stimulating hormone secretion in early pregnancy when the thyroid function is partially taken over by the placenta. hCG is also the main trigger to increase T4-binding globulin, the main factor contributing to an elevation of T4 concentration [1]. Thyroid function is relatively stable during pregnancy; although the concentrations of T3 and T4 in plasma are increased [58], their molar ratio is stable [58].

Regulation of glucose homeostasis is a main concern during pregnancy. The pancreatic beta cells increase in volume due to hypertrophy and hyperplasia of the islets of Langerhans [59]. This morphological adaptation increases insulin secretion and creates an imbalance between hormones from the endocrine pancreas (glucagon and insulin), which antagonizes diabetogenic hormones of placenta (human lactogen/estrogens/progesterone). Both placental release and excess insulin secretion would contribute to insulin insensitivity, commonly diagnosed during pregnancy. Peak concentrations of glucose and insulin become progressively higher, and up to a 50–60% reduction in insulin sensitivity occurs in both normal pregnancy and in pregnancies with gestational diabetes [59]. This significant reduction in insulin sensitivity indicates insulin resistance during the late phase of pregnancy. However, PA can promote positive acute and chronic effects on insulin resistance, making pregnant women an important population to consider for these benefits [60–62].

In addition to endocrine pancreatic secretions, lipid metabolism is also under strong hormonal control. Adrenal cortex hormones, such as cortisol and adrenaline, regulate lipid oxidation which is necessary to compensate excessive lipid influx. Under resting conditions, plasma adrenaline levels remain the same as before pregnancy [63]. Stimulation of the pituitary adrenal axis increases the production of adrenocorticotrophic hormone, which results in increased total and free cortisol [63]. Often, a threefold increase in the production of plasma triglycerides is considered normal. Relatedly, during late pregnancy, concentrations of free fatty acids typically increase by 2–4 times above normal [32]. Increased triglycerides occur due increased maternal storage of carbohydrate and increased fat oxidation in order to preserve placental, fetal, and uteral energy demands. The increase in cortisol and decreased insulin sensitivity help meet the glucose needs of the growing fetus [59, 63]. As a consequence, in the third trimester, increased plasma acetone and decreased fasting plasma glucose induce a metabolic state characterized by hypoglycemia, hypoinsulinemia, and hyperketonemia [59, 61].

27.2.1.4 Metabolism, Energy Expenditure, and Weight Control

Weight gain is inevitable during pregnancy and supports the growth of the fetus throughout pregnancy. An increase in body fat between 3.5 and 5 kg (mainly from 10th to 30th week) can be expected. Although weight gain can be expected for all pregnant women, the health normal range of weight gain varies based on the body mass index (BMI) of the female prior to pregnancy (Table 27.2). A proportional increase in energy intake from a balanced diet must be ensured to support the nutritional needs of the fetus. During pregnancy, an additional daily caloric intake of approximately 300 kcal is required to maintain metabolic homeostasis. All pregnant women should eat a diet well-balanced in macronutrients [64] and micronutrients [65] and should not restrict calories [64].

Basal metabolic rate is elevated during all trimesters of pregnancy (first trimester: ~30 kcal/day; second and third trimester ~390 kcal/day), which is associated with body weight gain, increased cardiac output and respiratory work, fetal activity, and metabolic rate of fetal tissues observed during pregnancy [66]. Furthermore, the growth of the placenta, uterus, and fetus during the second part of pregnancy [67] also contributes to increased total daily energy expenditure described in women during gestation [68]. However, the amount of energy expenditure adjusted per kg of fat free mass during the pregnancy is relatively constant [69]; therefore, the energy needs to maintain a healthy weight gain which is proportional to the gains in fat free mass (FFM).

27.2.1.5 Musculoskeletal System

Several adaptations during pregnancy and labor promote changes in musculoskeletal tissues. The action of the hormone relaxin (produced by placenta) progressively leads to a softening of the ligaments, particularly at the region of the pubic symphysis and sacroiliac joints. The process of ligament softening reaches its peak at the beginning of the third trimester. Together, the effects of relaxin and the increased uterus size induce a great pressure against the lumbar spine, which increases lordosis, joint angle changes, and joint

Table 27.2 Recommended weight gain during pregnancy, as related to the pregravid body mass index (BMI). Adapted with permission from Gunderson EP, Nutrition during pregnancy for the physically active woman, Clinical Obstetrics and Gynecology, Vol. 46/Issue 2, pgs. 390–402, https://journals.lww.com/clinicalobgyn/Citation/2003/06000/Nutrition_During_Pregnancy_for_the_Physically.18.aspx© 2003 [64]

Pregravid BMI groups	Recommended total weight gain (kg)	Recommended rate of weight gain (kg/month)[a]
Underweight (<19.8 kg/m^2)	12.5–18	2.3
Normal weight (19.8–26.0 kg/m^2)	11.5–16	1.8
Overweight (>26.0–29.0 kg/m^2)	7–11.5	1.2
Obese (>29.0 kg/m^2)	7.0 maximum	2.0–0.9

BMI body mass index

[a] Rate of gain applies to gain during the second and third trimesters

relaxation which often leads to lumbar pain [39]. In addition, the relaxed pubic symphysis can move a few millimeters which can cause pain when walking or standing [2]. All these adaptations are important concerns when selecting activity to prescribe exercise during pregnancy [70].

27.3 Contemporary Understanding of the Issues

27.3.1 Benefits of Exercise in Pregnant Women

Since engagement in PA and exercise has positive effects on the health of non-pregnant women, these outcomes could be expected during pregnancy (Table 27.2). However, a decrease in daily PA has been widely reported among pregnant women [71, 72], although PA participation has increased since 1999–2002 [71]. Misperceptions about exercise risks during pregnancy may be one of the most important reasons explaining this behavior [73, 74]. Available evidence shows that pregnant women spent more than 50% of their time being sedentary [71, 72].

Despite historical beliefs about the harmful consequences of exercise in pregnancy, there is mounting evidence indicating positive health outcomes of exercise for both mother and fetus [75, 76]. Furthermore, current understanding of the risks associated with exercise training during pregnancy are well-known and easily managed [75, 77]. Moreover, PA can be incorporated safely into the lives of pregnant women even if they were not previously active [78]. In this section, we will summarize benefits associated with regular PA or exercise training during gestation (Table 27.3).

The American College of Sports Medicine suggests that pregnant women should accumulate at least 150 min of moderate-intensity aerobic exercise every week [79, 80]. Available data from 2007 to 2014 underscore the lack of exercise engagement for pregnant females, with 23.4% of pregnant women in the USA meeting the minimum recommendation [78]. Despite the low rate of activity engagement, pregnant women who participated in regular activity had a lower probability of cesarean delivery [81, 82]. For pregnant women, regular activity has also been associated with a reduction in gestational diabetes mellitus (38%), pre-eclampsia (41%), gestational hypertension (39%), prenatal depression (67%), and macrosomia (39%), a term that describes a baby who is born much larger than average for their gestational age [83, 84].

27.3.1.1 Cardiorespiratory Health

The hormonal and physiological changes that occur during pregnancy impact the cardiorespiratory system during exercise [9, 50]. Cross-sectional data indicate a general reduction in VO_{2max} in women who are not regular exercisers during

Table 27.3 Possible benefits of exercise training during pregnancy

Cardiovascular effects	– Reduces HR [76, 126] – Improves circulation [76, 126] – Prevents varicosities [86] – Improves blood pressure regulation [86, 127]
Improvement of muscle fitness	– Increases muscle tone [70, 128] – Reduces muscle cramps [70, 128] – Improves posture [70, 129] – Reduces prevalence of back pain [95, 129]
Prevention of excessive weight gain	– Prevents excessive weight gain [130] – Reduces fluid retention [129]
Digestive system regulation	– Reduces digestive discomfort [131] – Reduces constipation [131]
Psychological well-being enhanced	– Reduces: fatigue [124], postpartum depression and insomnia [117, 122, 125] – Reduces anxiety [123, 132] – Reduces stress [123, 132] – Creates healthy lifestyle habits [75]
Prevention of gestational diabetes	– Regulates glucose and insulin [104, 133] – Prevents excessive weight gain [130]
Enhancement of postpartum recovery	– Reduces hospitalization time [81, 82] – Reduces the risks of pregnancy [70] and helps labor [84, 134] – Reduces cesarean section risk [81, 82, 135–137] – Helps restore physical appearance [70, 136, 138]

pregnancy. However, VO_{2max}, and thus overall aerobic fitness is maintained in women who are able to remain active throughout pregnancy [85]. Currently, the role of power output and aerobic and anaerobic threshold HR in maintaining VO_{2max} during pregnancy is unclear [86]. As a general rule, VO_{2max} will not be reduced during pregnancy if women maintain exercise training, at least when expressed in absolute units (L/min) [87, 88]. However, if VO_{2max} is normalized to body weight (ml/kg/min), a slight reduction of 9% is observed during the first weeks of postpartum. For female athletes, this reduction seems to recover around 4 months after delivery [88].

Although adjusted aerobic fitness (VO_{2max} by kg of body weight) does not improve in pregnant women, aerobic training may result in other positive effects, such as reduced insulin resistance [89, 90]. In addition, resting HR is lower in trained vs. sedentary pregnant women, as a result of greater cardiac reserve in trained women [87]. It is important to note that even moderate levels of PA can have a positive impact on overall health in pregnant women. Thus, engaging in exercise for at least 30 min per day even in the last trimester of pregnancy can benefit general health [82].

27.3.1.2 Decreased Lumbar Pain

At least 50% of pregnant women suffer from lumbar pain [91–93]. Although meta-analysis indicates that there is limited high-quality evidence that exercise itself completely prevents low back pain during pregnancy [94, 95], there are some studies showing exercise-associated pain reduction. Exercise used to enhance spine flexibility during the second half of pregnancy has been related to reduction in the intensity of back pain. In addition, muscle strengthening exercises have been found beneficial to overall prevention in pain that may occur during pregnancy and postpartum [93]. Fortunately, a significant decrease in the intensity of low back pain is commonly noted around 8 weeks after childbirth [70].

A second factor impacting lumbar pain is maternal weight gain and the related loss of pelvic girdle stability. The pelvic girdle can lose stability as a result of interplay between weight gain and hormonal changes, which concentrate the weight in the abdominal region. Specifically, lumbo-pelvic stabilization can be improved with posture training strategies and should be included within the exercise prescription. A study in 2005 reported reductions in the intensity of lumbar pain and improved mobility of the spine, in spite of no changes in lordosis (angle of inward curve of the lumbar spine) [92]. Thus, it appears that internal mechanisms more than lordosis angle are responsible for low back and pelvic pain [92, 94]. Overall, exercise treatment to address low back pain has important implications for health-related quality of life in pregnant women.

27.3.1.3 Weight Control

Excessive weight gain is associated with gestational diabetes, pre-eclampsia, and postpartum weight retention [37]. In 2020, the American College of Obstetricians and Gynecologists (ACOG) endorsed the Institute of Medicine's weight gain goals during pregnancy based on a woman's BMI at her first prenatal visit (Table 27.2). Exercise can help prevent excessive weight gain during pregnancy. For example, women who attended 24 supervised exercise sessions during a 12-week program stayed within the Institute of Medicine's weight gain guidelines compared with 62% of the control group [96]. In addition, preventing an increase in body weight >10% of pre-pregnancy mass has been shown to reduce the risk of diabetes or pre-eclampsia, and the probability to deliver a macrosomic baby [78]. Specific activities which have beneficially impacted maternal weight gain were aqua-aerobics 1–2 days per week; supervised walking/biking at 60% of VO_{2max}; walking 3–4 days per week at 30% of HR reserve; or resistance training with a personal coach [78]. Taken together, prenatal PA is associated with reduced risk for excessive gestational weight gain [96].

27.3.1.4 Prevention of Gestational Diabetes

Gestational diabetes is a result of the interaction between insulin and placental hormones. Together, these factors lead to insulin resistance and can result in macrosomia [57, 60]. In addition, a lack of PA and overweight or obesity can aggravate the risk of gestational diabetes [97].

Fortunately, both pre-pregnancy exercise [98] and prenatal exercise [99, 100] can reduce the risk of developing gestational diabetes. Notably, results from a large meta-analysis indicate that any pre-pregnancy PA or early pregnancy PA was associated with 31% and 24% reduced risk of gestational diabetes, respectively [100, 101]. In addition, prenatal exercise can help in mitigating the onset of gestational diabetes and can improve glucose control once diagnosed [61]. Most studies using exercise as an intervention to treat gestational diabetes were successful to control the negative consequences of the diabetes [102].

Physically active pregnant women have shown significantly lower glucose levels after an oral glucose tolerance test between the 24 and 28 weeks of pregnancy [102, 103]. For example, women involved in 30 min per day of moderate PA during pregnancy reduced the risk of gestational diabetes by 50–75% compared to women who remained sedentary [83, 103]. Among pregnant women who are overweight or obese with gestational diabetes, a simple exercise program (25 min 3–4 days per week and increments of 2 min per week until 40 min per sessions is reached) can improve glucose regulation and insulin action [83]. In addition, pregnant women had significantly decreased fasting insulin levels after exercise training [104].

The results of randomized control trials examining the effects of exercise training during pregnancy on measures of insulin sensitivity are variable. There are exercise interventions showing no improvement in insulin sensitivity [105], fasting glucose, or insulin levels [106], while other studies show reduced incidence of gestational diabetes, improved glucose tolerance, reduced insulin resistance [83], and/or decreased fasting glucose and insulin levels [104, 107] in pregnant women [61]. The contrasting outcomes of these studies are likely attributed to a number of variables, including exercise frequency, duration, type, intensity, level of exercise supervision, and study population (healthy vs. overweight, obese, or at risk for gestational diabetes). In addition, the benefits exercise training during pregnancy appear to carry over to the postpartum period, as exercised pregnant women exhibit lower insulin levels and markers of insulin resistance compared to those who did not exercise during pregnancy [107].

Furthermore, in women already diagnosed with gestational diabetes, exercise training is an effective method for maintaining normoglycemia and improving maternal and fetal outcomes [61, 62]. For example, a home cycling program (2 days/week, 25–30 min sessions, moderate intensity with high intensity intervals) was effective at reducing mean daily postprandial glucose levels compared to non-exercising women with gestational diabetes [108]. In addition, exercise training can reduce the need for insulin in women gestational diabetes. This is especially important, since insulin use during pregnancy is associated with an increase in hypertensive disorders [109]. As indicated by de Barros et al., females diagnosed with gestational diabetes at 24–34 weeks of pregnancy who performed resistance exercise were less likely to require insulin during the remainder of their pregnancy as compared with women with gestational diabetes in non-exercise control group [109].

Conclusively, studies suggest that exercise interventions improve several markers of insulin resistance and gestational diabetes; nevertheless, there is large individual variability in response to exercise treatment.

27.3.1.5 Hypertension and Preeclampsia

There are several disorders related to high blood pressure during gestation, the most prevalent are preeclampsia/eclampsia, gestational hypertension, and chronic hypertension [52]. Preeclampsia is a disorder related to hypertension, which occurs in 3–9% of pregnancies and is associated with glucose intolerance, hypertriglyceridemia, systemic chronic inflammation, and endothelial dysfunction [52, 78]. Furthermore, preeclampsia has been associated with perinatal complications and it is one of the main risk factors for maternal mortality during pregnancy [110]. The risk of preeclampsia appears to be reduced by about 30% in mothers who are physically active before and during gestation [111, 112]. However, there is no consensus on the effect of PA/exercise training on preeclampsia as some research studies have demonstrated benefit [112, 113], while others show no effect [78].

Pregnant women who experience anxiety or depression are at three times greater risk of preeclampsia. Given the benefits of activity on both mental health outcomes and preeclampsia, exercise benefits health via many avenues for these individuals [112, 114]. Several studies have shown the positive effect of PA on blood pressure regulation during pregnancy. However, research should be interpreted with caution as several confounding variables may account for some the exercise benefits. In fact, a review on the influence of PA on hypertensive disorders concluded that leisure time PA seems to protect against preeclampsia [111]. More randomized control trials in all forms of pregnancy hypertensive disorders are needed to confirm these findings. Despite these outcomes, the effect of exercise and diet on preeclampsia was reviewed and concluded that there is no difference in the development of preeclampsia when comparing women who exercised with those who did not [78]. The limitations of these studies highlight that exercise dose may be an important factor impacting the effects of exercise on preeclampsia. Data from large cohort studies suggest that >25 bouts of PA per month or 270–419 min per week of leisure PA can help expecting females to reduce the likelihood of suffering preeclampsia [78].

Although there is mixed-quality evidence about the relationship between exercise and a decreased risk of hypertensive disorders of pregnancy [78], epidemiological data seem to support that PA during pregnancy reduces the risk of hypertensive complications during pregnancy, such as preeclampsia [111]. In addition, gestational hypertensive complications may be less common in women who are physically active not only during but also before pregnancy [113].

27.3.1.6 Psychological Benefits

Pregnancy and childbirth are physically and psychologically stressful events. Not only do changes occur to one's physical health, but the mother's mental health can also be impacted, both positively and negatively, during this time. During pregnancy and the postpartum period, dramatic fluctuations in steroid hormones (progesterone, estrogen, and cortisol) are thought to contribute to antenatal and postpartum depression [115]. Importantly, estrogen has extensive interactions with the central serotonergic systems and low estrogen levels may decrease serotonergic activity and contribute to depressed mood during the postpartum period [115]. Furthermore, chronic sleep deprivation, while caring for a newborn can contribute to depressive symptoms [116]. Importantly, it is well-established that exercise increases serotonin levels [117] and is comparable to medication use for treating symptoms of anxiety and depression [118]. Untreated depression during pregnancy is associated negative birth outcomes and child development [119]. In addition, postpartum depression has negative effects on maternal–fetal bonding [120]. Furthermore, antidepressant medication use is associated with small, but increased risk of negative birth outcomes including miscarriage, cardiac malformations, preterm birth, and few antidepressant medications are safe for use during breastfeeding. Thus, the psychological benefits of exercise during pregnancy and the postpartum period are just important as the physiological benefits for both mother and the baby.

Indeed, pregnant women who engage in exercise exhibit improved body image [121], reduced depression symptoms [122], increased self-esteem [122] and reduced psychological stress [96, 123] during pregnancy. Furthermore, exercise during postpartum period has also been shown to reduce symptoms of depression [119], reduce fatigue [124] and is associated with lower odds of very poor sleep quality, short sleep duration, and better self-reported sleep quality [117, 125].

Regarding female athletes who are able to train during pregnancy, additional psychological benefits ensue as they are able to maintain their identity and return to competition sooner with more confidence and motivation [119]. On the other hand, improved performances observed after having children have been attributed either physiological or psychological reasons [122] (see Table 27.3).

27.3.1.7 Benefits for the Fetus

Improved Labor and Birth Outcomes

The seminal research conducted by Clapp et al. in 1984 showed that women who maintained at or near preconception levels of endurance training during pregnancy until the third trimester of the gestation period, gained less weight, gave birth faster and had lighter weight babies compared to women stopped exercising before 28 weeks of gestation [139]. Since then, this group and others have conducted studies [82, 134, 140–142] reporting numerous positive effects of exercise training on fetus weight/body composition and placental adaptations. However, this beneficial relationship has not always been confirmed by others [134]. Other studies concluded that exercise engagement can decrease the duration of the active stage of labor and diminish the incidence of obstetric difficulties during labor [138, 141]. Moreover, a meta-analysis found no difference between mothers who did exercise vs. control in duration of labor, birth weight, or APGAR score (standardized scoring system that rates infant color, HR, reflexes, muscle tone, and respiration) [77].

The human placenta is not excluded from the adaptations of exercise training. A study showed increased fetoplacental growth (greater functional volume, nonfunctional volume, villous volume, and terminal villi) and birth weight after a walking exercise program [140, 141]. In addition, newborns of exercising women are leaner and have lower body fat percentage compared to newborns of non-exercising women [141]. Nonetheless, it is difficult to isolate the effects of exercise on the characteristics of the fetus at birth, given the immense influence by many other factors, such as genetics, nutrition, socio-economic elements, or environmental factors [33].

More Active Children

Engagement in activity starting at a young age contributes to the healthy long-term development in children. This is not limited to exercise in childhood and can include the benefits of maternal exercise during fetal development [142]. For example, one study which assessed the impact of maternal exercise on motor and intellectual capacities of children (between 1 and 5 years) showed that at 1 year of age, children whose mothers exercised during pregnancy had improved motor skills, but mental abilities and morphological characteristics identical to non-active mothers. When 5-year-old children were assessed, children of exercising mothers have much better levels of intelligence than the latter, mainly in oral skills. The consequences of these data on future life remain to be elucidated [138]. A relationship of causality between PA during pregnancy and children's PA, psychomotor development, and morphology is appealing; however, there is not strong evidence supporting it.

27.3.2 Risks of Exercise in Pregnant Women

Despite the numerous benefits of activity on the pregnant body, there are some risks associated with exercise during pregnancy. There are many ways in which sport and PA during pregnancy may induce risk to the mother and fetus such as during strenuous PA when medical conditions appear throughout the pregnancy. The ACOG has classified relative and absolute risks and identified warning signs during exercise in order to guide pregnant women and PA professionals to prevent risks associated with exercise and PA practice (Fig. 27.1).

Although there is epidemiological evidence supporting a lack of association between PA practice and hospitalization [82], complications related to poorly planned exercise are still plausible and reported. For example, severe *hypoglycemia* can occur in pregnant women after intense exercise, which, if repeated chronically, can prompt malnutrition and low birth weight in the fetus [76]. *Chronic fatigue* is another common symptom associated with erroneous exercise prescriptions; this must be a main concern when planning PA for pregnant women, because physiological characteristics of pregnancy can induce early fatigue. Increased body size and weight during gestation induces fatigue, even at lower workloads. Likewise, increased hCG together with hemodynamic changes and lower parasympathetic activity results in higher maternal HR by approximately 15 beats per minute [5]. Consequentially, all strenuous activities performed during the third trimester of pregnancy can lead to chronic fatigue; thus, special care must be taken in prescribing weight-bearing activities.

Musculoskeletal injury is associated with the increased body mass (15–30%) during pregnancy. This increased risk is associated with biomechanical modifications occurring in the pelvic/abdominal region, leading to greater elasticity of the ligaments and changes in the musculature (abdominal diastasis) and thus inefficiency of movement [94, 95]. Further risks are associated with increased relaxin (promotes joint laxity and mobility), while the expanding uterus coupled with unfamiliar weight gain leads to axial shifts in forces that create additional pressures on the spine, pelvis, and joints [39, 43]. Together, these factors augment the risk of suffering from a musculoskeletal injury while performing basic movements, such as moderate intensity or long duration walking [42].

27.3.3 Risks of Exercise During Pregnancy for the Fetus

Similar to the mother, if caution is not taken when engaging in PA, risk could ensue for the unborn fetus. This section describes the most common events affecting the fetus as consequence of unhealthful maternal exercise.

27.3.3.1 Acute Hypoxia

It has been hypothesized that the fetus may experience acute hypoxia (rapid reduction in oxygen levels) during aerobic exercise due to the redistribution of blood flow to working muscle and away from the uterus [143]. However, although reduced oxygen delivery to the placenta may result in a slight reduction in fetal oxygen saturation, this effect stimulates a fetal sympathetic response that maintains fetal perfusion and fetal oxygen uptake [140]. In addition, evidence indicates that uterine blood flow is not changed during moderate (40–59% of HR reserve) or vigorous intensity exercise (60–84% of HR reserve) in regular exercisers and non-exercising pregnant women [144]. This is further supported by a meta-analysis of 91 studies showing no significant changes in umbilical or uterine blood flow during or after acute exercise sessions [145]. Furthermore, chronic exercise training results in increased maternal (and possibly fetal) plasma volume, intervillous space blood volume, cardiac output, and placental function. a-V O_2 difference also determines O_2 delivery, which is improved in the active mother [10]. These beneficial effects buffer acute reductions in oxygen and nutrient delivery during exercise [140].

HR responses in the fetus can reflect tissue oxygenation. The fetal HR, which reflects cardiac output, ranges between 120 and 160 beats per minute (bpm). Exercise engagement inducing fetal HR elevations above 160 bpm for ≥10 min is designated as tachycardia, and lower than 120 bpm is considered bradycardia. Parer et al. report that an increase of 10–30 bpm in the fetus during maternal exercise is not dangerous [146]. Furthermore, a review on fetal HR response to maternal exercise concludes that current ACOG guidelines for exercise in pregnancy are consistent with fetal HR response to exercise and submaximal exercise (not in the supine position) is well-tolerated by the fetus if the pregnancy is uncomplicated [147].

27.3.3.2 Acute Hyperthermia

Fetal temperature is approximately 0.5 °C higher than the mother and excessive elevation of maternal body temperature during the first weeks of pregnancy may increase risk for developmental defects and fetal death [21, 148]. However, the pregnant woman has thermoregulatory mechanisms that increase the circulation to the skin to lose heat, so the increase in temperature of the fetus is tightly regulated to prevent fetal hyperthermia. Regardless, it is not advised for women to perform exercise in high environmental temperatures (above 40 °C). Hydration and avoiding dehydration can reduce internal warming and thus close attention must be paid to ensure that enough water is consumed throughout training [33, 128].

27.3.3.3 Low Glucose Availability

The use of carbohydrates by skeletal muscle in pregnant women increases significantly during strenuous exercise [140]. This may limit the ability to extend vigorous exercise and predispose pregnant women to hypoglycemia [126]. This effect may be the result of the insulin resistance that develops in the latter half of pregnancy [59]. However, a drop in blood glucose levels, which can limit glucose consumption by the fetus, may be a consequence more probable of long-term nutritional short comings than exercise engagement [33]. Nonetheless, frequent hypoglycemia may lead to low birth weight or alterations in the growth of fetal organs and tissues [149], so carbohydrate intake after exercise training should be considered, primarily for those training longer than 60 min.

27.3.3.4 Spontaneous Abortion in the First Trimester

Beliefs about PA as a promoter of abortion have not been supported in the literature [73, 150]. The risk of spontaneous abortion was not found to be higher in athletes than in healthy controls [151]. Furthermore, there are no significant differences in early miscarriage rates between recreational runners, aerobic-training participants, and physically active-fit controls [152]. Nonetheless, very vigorous exercise in the first trimester can lead to early abortion, so avoiding strenuous PA is of the great importance to prevent other risk factors, such as hyperthermia [21].

27.3.3.5 Risk of Preterm Delivery

It has been purported that acute exercise may induce premature birth, because it increases the secretion of catecholamines, especially norepinephrine, which causes uterine contractions after exercise [73]. This hypothesis was refuted by a study that included more than 7000 women and showed that standing 8 h per day increased the risk of preterm delivery. However, exercising 4 h per day was not associated with preterm delivery. Similarly, there were no significant differences in the rates of premature births compared to women who did sedentary or physically active jobs [153]. Moreover, there were no significant differences in birth outcomes (preterm births and birth weight) in women exceeding ACOG recommendations, while participating in 3–9 vigorous continuous exercise sessions per week (ranging from 16 to 40 min) compared to those who exercised within the guidelines [82]. Indeed, guidelines point out that moderate-intensity activity in healthy women during pregnancy does not increase the risk of preterm labor.

27.3.3.6 Reduced Birth Weight

There appears to be a dose–response relationship between days per week/weekly energy expenditure of training and low birth weight of babies among pregnant athletes. As a suggestion, exercise energy expenditure, less than 2000 kcals per week or intense exercise 1 h a day performed 5–7 days per week, must be avoided in order to reduce the probability of delivering a low weight baby, mainly after 28th week of gestation [88]. Conversely, recreational exercisers or those who meet the ACOG guidelines (see next section) gave birth to babies within a healthy weight range, even while continuing to perform vigorous intensity activities [152, 154]. In addition, children of high-performance female athletes (and ex-participants in the Olympic Games) have been of normal weight [155].

However, it has been shown that exercising beyond preconception levels could limit fetal growth. Specifically, regular running and/or an aerobic exercise program at 50% or above the preconception levels in the last 5 months of pregnancy explained 40% of the variability in birth weight over an 1100 g birth weight range [142]. Since there seems to be lower (>120 min per week) and upper (see sentences above) thresholds of safe levels of exercise [77, 152], it seems rational that individual exercise programs and nutritional prescriptions should be followed to ensure that a baby with a healthy birth weight is born when exercising at high-performance level [76].

27.3.4 Recommendations for Exercise During Pregnancy

27.3.4.1 General Recommendations for Programming Exercise

As pointed out in the previous sections, PA and/or exercise has many positive effects in both pregnant women and fetus; however, risks can ensue. As a result, supervision during activity is encouraged, both to mitigate risk as well to facilitate benefits [77, 78]. Furthermore, gestational physiology and possible complications as a consequence of excessive workload highlight that the extra care required in designing exercise protocols for pregnant women. The core of a training program is determined by the appropriate interaction of its major components: intensity, duration, frequency, and type of exercise [86, 89, 156]. It is important to note that non-programmed, spontaneously undertaken PA in pregnancy, even though still safe for the mother and fetus, does not always result in an easier childbirth [150] and weight management during pregnancy [157].

Load (duration and intensity), mode (contraction pattern and metabolic pathway), type (activities), periodization, nutrition, and environment have been the variables most commonly studied in order to define specific guidelines by the representative professional/academic associations of pregnancy or exercise [21, 86, 89, 156, 158, 159]. These recommendations have been updated during the last decade and are summarized in Table 27.4. Further details can be found in the ACOG guidelines [159] and the PA readiness examination (PARmed-X for pregnancy) [160].

Before starting any exercise program, considerations should be made regarding the overall health status of the pregnant woman. It is therefore necessary to consider the contraindications to exercise that may arise in pregnancy. In addition, several physical signs outlined in Fig. 27.1 must be considered in order to stop the exercise and proceed with an emergency protocol if necessary (Fig. 27.1). Daily PA during pregnancy can be encouraged if no contraindications arise. As a general recommendation, pregnant women can accumulate at least 150 min of moderate intensity PA each week to achieve clinically meaningful health benefits and reductions in pregnancy complications (including previously inactive and/or overweight and obese women) [136]. However, it is important to note that these guidelines have not been experimentally designed for pregnant women and are an adaptation from healthy adult guidelines. Pregnant women can incorporate a variety of aerobic and resistance training activities while complimenting these activities with yoga and/or gentle stretching [75].

The intensity of exercise is considered by many to be one of the most important aspects of an exercise prescription. HR control is a classic parameter used to quantify the intensity of continuous aerobic activities. While HR may be a good indicator for exercise prescription in the general population, maximum HR decreases during pregnancy [77] as a result of an attenuated sympathetic response to exercise. Thus, in order to accurately recommend exercise intensity in pregnant women, fitness level, BMI prior to pregnancy and age must all be taken into consideration [161]. To safely prescribe exercise, one must first set an upper limit of HR. A meta-analysis examining HR and pregnancy found that engaging in training up to 80% of HR_{max} (144 beats in women around 26 years), 43 min per session, up to 3 days/week did not harm the mother or growing fetus [77]. As mentioned, HR is only one consideration for safe exercise prescription during pregnancy. Consideration of underlying fitness and previous sporting level intensities is important. Indeed, although pregnant athletes are able to train during pregnancy; their previous regime may not be well-suited to pregnancy and training at lower intensities is recommended [88, 156, 159, 162]. For that reason, the ACOG recommends the use of rate of perceived exertion (RPE) to monitor exercise intensity [86, 150, 159, 163, 164]. According to the ACOG [159], women who were regular exercisers before pregnancy and who have uncomplicated healthy pregnancies should be able to engage in high-intensity exercise programs (while avoiding maximal levels of exertion), such as jogging and aerobics, with no adverse effects [151]. Nonetheless, elite athletes who continue to train during pregnancy are advised to seek supervision from an obstetric care provider with knowledge of the impact of vigorous-intensity PA on maternal, fetal, and

Table 27.4 Recommendations for exercise prescription during pregnancy

Exercise prescription variables	Level of performance/practice			
	General	Sedentary	Recreational	Elite/athlete
Bout volume	At least 15 min	– 30 min – Strength: Low repetitions (8–10 repetitions ×1 set)	– 30–60 min – Strength: Low repetitions (12–15 repetitions x 2–3 sets)	– 60–90 min – Strength: high repetitions (2–3 sets)
Bout Intensity	– 140–160 bpm (safe for walking and cycling) – %HR_{max}: 70% (cycling and aerobics) – %VO_{2max}: 70% (swimming and water exercises), lower HR than biking – "Talk Test" * High intensity	– RPE: 12–13 (6–20 scale) moderately hard – %HR_{max}: 65–75% – Strength: Submaximal, moderate fatigue	– RPE: 14–17 (6–20 scale) moderately hard to hard – %HR_{max}: 65–80% – Strength: Submaximal, moderate fatigue	– RPE: hard – %HR_{max}: 75–80% – Strength: Light weights
Frequency	3 days/week	3 days/week Strength: 1 day/week	3–5 days/week Strength: 2 days/week	3–5 days/week Strength: 2–3 days/week
Mode	– Low impact * Extensive isometric contractions, anaerobic exercises – Strength training without Valsalva maneuver	– Low impact – Flexibility	– Low and moderate impact – Flexibility	– Low and moderate impact * Maximum and isometric strength exercises * Exercise in supine position first quarter – Flexibility
Type (Activities)	– Childbirth preparation (minimum) – Start with no weight-bearing exercises (cycling, swimming, etc.) – Walking and brisk walking – Aerobics – Water exercises are recommended to relieve back pain. They make easier the blood mobilization and reduction of edema – Pilates under individual supervision	– Walking, cycling, swimming and water aerobics – Resistances machines and body weight exercises – Flexibility exercises	– Low impact, and progress to moderate as jogging/running, tennis – Resistances machines, body weight exercises – Flexibility exercises	– Jogging/running, tennis and similar, progress to racing activities – Change races by elliptical device – Resistances machines, body weight exercise and free weights – Water exercises to prevent back pain – Flexibility exercises
Avoid (*) or Proceed with Care	* Participating in competitions, contact sports or risk of trauma * Exercises that could overload the lower back * Exercise at moderate altitude (2500 m over the sea) * Frequently shallow diving (never deep) * Sport contacts (team sports or martial arts) * Horse riding, skating, skiing, climbing and others, which increase fall risk			* Train with infection, fever or fatigue * Competition events * Contact sports * Quick changes of direction (ligamentous laxity) * Anaerobic exercises * Stop training with symptoms, such as pain, bleeding, etc.
Environment	* Avoid high temperatures			
Nutrition and Supplementation	Adequate nutrition and hydration			* Dehydration
Periodization	* Supine position during the first quarter; start the training program first quarter	– Begin with 15 min and progress to 30 min – From 3 days/week to 5 days/week		– 3 days/week in the first and third quarter – 5 days/week in the second quarter

Abbreviations: *, this symbol indicate practices must be avoided; HR_{max} maximal heart rate; VO_{2max} maximal oxygen uptake; *RPE* rate of perceived exertion; *bpm* beats per minute (heart rate). Created from Paisley, et al., 2003, Wolfe & Davies, 2003 and Liguori 2018 [80, 86, 156]

neonatal outcomes [151, 156, 163]. That being said, more research examining HR ranges for specific modalities of exercise, and sport are needed to understand training limits [88, 150].

Estimation and exercise prescription using metabolic/energy expenditure data require VO_{2max} assessment, which is unpractical during pregnancy. Several methods exist to estimate VO_{2max} in simple testing and are traditionally useful in

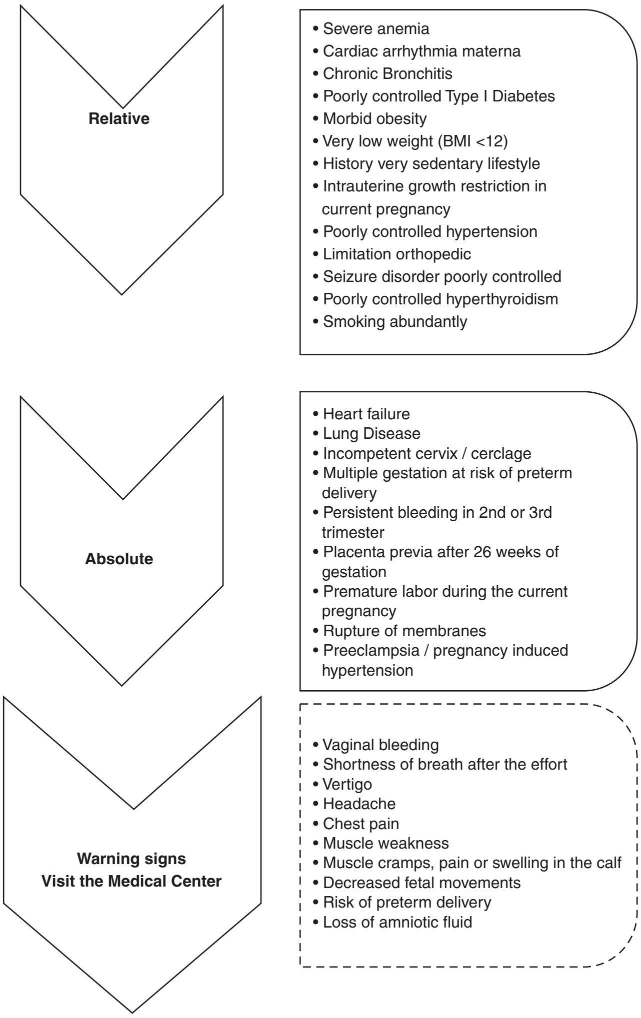

Fig. 27.1 Absolute and relative contraindications for and during practice exercise. (Adapted from Artal & O'Toole, 2003) [13]

clinical and field settings to avoid time consuming and expensive laboratory tests. Bike tests using external load and the Astrand nomogram are widely applied by exercise physiologists, clinicians, and coaches [80, 165]. However, the Astrand nomogram has been shown to overestimate the VO_{2max} by about 9% in pregnant women. Other methods using linear regression from the relationship between VO_2 and HR during submaximal loads overestimate the value around 6%. There are few well-validated methods of estimating VO_{2max} during pregnancy; one of the successful protocols utilized a single constant workload (SCW). The SCW measures HR after 6 min of constant, steady-state exercise on a bike. Afterward, Eqs. (27.1) and (27.2) are used to estimate VO_{2max} [166]:

$$\%\mathbf{VO_{2max}} = (\mathbf{0.634 \bullet HR}) - \mathbf{30} \quad (27.1)$$

$$\mathbf{VO_{2max}} = \mathbf{VO_2} / \%\mathbf{VO_{2max}} \bullet \mathbf{100} \quad (27.2)$$

Another key element of prescribing exercise during pregnancy is the mode or modality of the activities. There are many aspects to consider in selecting safe exercise; these are summarized in Table 27.4. A basic training circuit is illustrated in Panel 27.1.

27.3.4.2 Post-delivery

Following childbirth, the re-establishment of muscle fitness, the quality of breastfeeding, and mother's return to pre-pregnancy body weight can all be important factors in postpartum recovery. The initial and primary recovery goal is *strengthening of perineal muscles and abdominal* region. During the first 4 weeks of recovery, several physiological changes continue at the cardiorespiratory level, prompting several specific temporal guidelines to be suggested [13, 159, 167]:

- Within a few hours of delivery, pelvic floor exercises may be initiated.
- The first aim is to perform exercise focused on recovering strength of perineal muscles.
- During the first 3 weeks, isometric exercises to recover abdominal wall *tonus* should be performed. Limit aerobic exercise training.
- Moderate aerobic activities outdoors, jumping or running must be delayed until after 8–12 weeks after birth (risk of trauma for the pelvic floor).
- Hypotension is common. Avoid sudden changes of position.
- Restart strenuous or competition activity only 8 weeks after delivery and begin gradually.

Regarding weight control, *excessive weight gain* during gestation is the strongest predictor of postpartum weight retention. Adherence to recommended guidelines for weight gain during pregnancy can reduce postpartum weight retention [157, 165]. In addition, it has been reported that weight retention after delivery and low PA may also contribute to obesity [157]. It has recently been suggested that individualized diet and exercise training plans are need in order to manage a healthy weight loss [157]. However, more important than weight loss is an enhanced body composition profile, since exercise training preserves fat free mass, while dieting alone reduces fat mass and fat free mass, the best results are ensured when both strategies are used.

Excessive PA and poor energy intake may impoverish milk production and quality, which may prevent adequate weight gain in the breastfed infant. Thus, it is important to balance exercise energy expenditure and energy intake in order to ensure adequate quality and quantity of breastmilk. General guidelines encourage mothers to intake fluid and nutrients to meet increased energy requirements as conse-

1 WARM UP			
			
BACK MOBILIZATION (CAT-COW OVER FITBALL)	TRUNK LATERAL MOVEMENT, HIP STABILIZATION	HIP LATERAL MOVEMENT TRUNK STABILIZATION	VERTICAL AXIS TWIST
3 x 8 to 10 reps	3 x 8 to 10 reps	3 x 8 to 10 reps	3 x 8 to 10 reps
2 CORE TRAINING			
			
SCAPULAE ADDUCTION	HAMSTRING BRIDGE	BRIDGE OVER FITBALL	GLUT BACK KICK
2 to 3 sets x 8 to 10 reps	2 to 3 sets x 8 to 10 reps	2 to 3 sets x 8 to 10 reps	2 to 3 sets x 8 to 10 reps
3 STRENGTH TRAINING			
			
CHAIR SQUAT	KETTLEBELL ROW	SUMO LIFT	SINGLE ARM TRICEPS
1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps
			
HIP EXTENSION PLUS STABILIZATION	CHEST PRESS	SHOULDER PRESS	DOUBLE ARM TRICEPS
1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps	1 to 3 sets x 8 to 10 reps
4 STRETCHING			
			
SPINE TWIST PLUS SHOULDER STRETCH	UPPER BACK STRETCH	LEG ADDUCTORS PLUS BACK STRECTH	HAMSTRING PLUS LOWER BACK STRETCH
2 x 15 sec	2 x 15 sec	2 x 15 sec	2 x 15 sec

Panel 27.1 Example of a training circuit during pregnancy

quence of PA [13]. In addition, nursing women are advised to feed babies before exercise in order to diminish the discomfort of engorged breasts [13] and to prevent increaed acidity of milk due to lactic acid accumulation [89]. Reduction of postpartum depression symptoms is an additional benefit of exercise, which has been widely reported and reviewed above.

27.4 Future Directions

Although the knowledge of exercise during pregnancy has been improved widely during the last few decades, several concerns remain to be investigated. The effects of exercise training on the future physiological function and body composition of children are not completely elucidated; thus, longitudinal studies need to be designed in order to investigate this relationship. In addition, data on the dose–response relationship between exercise training load and health outcomes have not been extensively studied. Finally, improved methods to assess maternal physical fitness and body composition need to be developed in order to improve exercise prescriptions in field settings.

27.5 Concluding Remarks

PA and exercise training provide several health benefits for both mother and fetus, including improved blood pressure control, blood glucose regulation, healthy birth weight, prevention of excessive maternal weight gain, and maintenance of physical fitness. Nevertheless, there appears to be some risks (hyperthermia, hypoglycemia, chronic fatigue, hypertensive responses, etc.) associated with excessive or unhealthful exercise as well as exercising in extreme environmental conditions. Globally, obstetricians and gynecologists have come to a consensus and developed guidelines to facilitate safe exercise training recommendations for pregnant women. Following delivery, exercise prescription must consider the physiological changes and demands of pregnancy and delivery in order to ensure a full physiological and psychological recovery.

The information presented in this chapter should only be used as guidelines. Pregnant woman should be monitored closely to adjust training load as a function of body mass, blood markers, and fetal development. Individual prescription should be based on energy requirements, individual exercise experience, and health. Communication should be established between gynecologist, nutritionist, and exercise physiologist in order to maximize benefits to both the fetus and the mother. The first aim of the exercise program must be to guarantee the safety of the mother and the fetus more than performance or esthetic outcomes during pregnancy and after delivery. Hence, a checklist of risks along with relative and absolute contraindications must be kept in mind when planning PA goals and prescribing training loads.

Pregnant women should maintain a precise exercise record including recall of volume, intensity, and type of exercise in addition to physical and clinical assessment outcomes to monitor and modify PA programs. This will allow professionals to understand the individual dose–response relationship in each specific case and the need for individualized exercise prescription in order to maximize the health benefits for both the mother and the fetus.

Chapter Review Questions

1. During pregnancy, peripheral vascular resistance decreases by approximately 35–50%. A consequence of reduced peripheral vascular resistance that occurs during pregnancy is:
   (a) Increased plasma volume
   (b) Decreased diastolic blood pressure
   (c) Hemodilution
   (d) Increased HR
2. Maternal hyperventilation results in which of the following:
   (a) Decreased CO_2 in blood
   (b) Increased pH
   (c) Respiratory alkalosis
   (d) All of the above
3. Increased ______________ is the main factor causing increased release of T4 during pregnancy?
   (a) Increased weight gain
   (b) Estrogen
   (c) Progesterone
   (d) HCG
4. Which of the following are true regarding pregnancy?
   (a) Plasma triglycerides increase by threefold
   (b) Pancreatic insulin secretion is reduced
   (c) Cortisol is reduced
   (d) All of the above
5. Recommended total weight gain for a woman who is in the normal weight BMI category before pregnancy is _______________ while recommended total weight gain for a woman who is in the overweight BMI category is _________________.
   (a) 12.5–18 kg, 7 kg
   (b) 11.5–16 kg, 7–11.5 kg
   (c) 11.5–16 kg, ≤7 kg
   (d) 12.5–18 kg for both
6. It is recommended that a pregnant woman increase caloric intake by _____________ kcals per day during pregnancy.
   (a) 100
   (b) 300

   (c) 500
   (d) 650
7. Which of the following are true regarding the benefits of exercise in pregnant women?
   (a) VO_{2max} can be maintained during pregnancy in exercising women
   (b) Pre-pregnancy exercise can lower the risk of gestational diabetes
   (c) Exercise during pregnancy can lower the risk of gestational diabetes
   (d) All of the above
8. What amount of PA is suggested for reduction of risk for preeclampsia?
   (a) >100 bouts per month
   (b) >50 bouts per month
   (c) >25 bouts per month
   (d) >10 bouts per month
9. Which of the following are effects of exercise during pregnancy?
   (a) Increases resting HR
   (b) Increases constipation
   (c) Increases insulin sensitivity
   (d) Increases risk for cesarean section
10. Which of the following are true regarding the effects of exercise on pregnancy or labor and delivery?
   (a) Increased placental volume
   (b) Decreased birth weight
   (c) Lower APGAR score
   (d) Lower infant HR
11. Which of the following is an absolute contraindication to exercise in pregnant women?
   (a) Severe anemia
   (b) Poorly controlled seizure disorder
   (c) Placenta previa (after 26 weeks gestation)
   (d) All of the above
12. Which of the following are true regarding exercise during pregnancy?
   (a) Pregnant women should avoid exercising in the heat
   (b) Pregnant women should accumulate at least 150 min of moderate exercise per week
   (c) Excessive exercise can cause low birth weight
   (d) All of the above

Answers

1. b
2. d
3. d
4. a
5. b
6. b
7. d
8. c
9. c
10. a
11. c
12. d

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