Physical Activity and Exercise in Pregnancy

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Summary  The benefits of exercise in the general population have been well-recognized. There is ample evidence to demonstrate that moderate exercise in a healthy pregnancy results in no adverse effects and provides consequential benefits.

Despite anatomical and physiological changes in pregnancy, women with healthy pregnancies and without contraindications can combine aerobic and resistance elements in their workouts. Clinical evaluation by an obstetrician is recommended before beginning an exercise program. Consideration must be given to the type, intensity, duration, and frequency of exercise when providing the patient with an exercise prescription. Scuba diving and contact sports or exercises with a high risk of falling or abdominal trauma should be avoided. Women who are beginning an exercise program during pregnancy should start slowly and gradually increase to moderate intensity. Women engaging in strenuous physical activities require additional medical supervision.

The nutritional needs of active pregnant women are not clearly defined; however, it should be recognized that there is an additional caloric allowance for increased metabolism and greater energy expenditure both during and after activity. Pregnant women use carbohydrates at a higher rate than do nonpregnant women; this is further increased during exercise, thus adequate carbohydrate intake is essential. Adequate fluid intake helps control the core body temperature and is essential to replace fluid loss during exercise.

Because habits adopted during pregnancy can result in persistent lifestyle improvements, exercise during pregnancy could significantly reduce the lifetime risks of obesity, chronic hypertension and diabetes—not only for pregnant women, but also for their families as well. Overall, a woman whose exercise habits have become firmly entrenched during pregnancy stands a much better chance of maintaining them after her child is born.

Keywords: Physical activity, exercise, nutrition, pregnancy

3.1 INTRODUCTION

Pregnancy is a unique time in a woman’s life in which health awareness increases, and she may be more inclined to accept medical advice to either adopt or continue an active lifestyle. Exercise is considered safe for most women during pregnancy as long as
there are no medical or obstetrical complications [1]. Although physical activity is often considered part of a healthy lifestyle and leisure time activity, some pregnant women may choose to participate in highly competitive sports.

While the health benefits of physical activity are well recognized in the general population [2–6], exercise is still not adequately accepted as a benefit for pregnant women. Healthcare providers remain cautious and often reluctant to encourage exercise during pregnancy, despite the well-recognized benefits. The hesitation is set in conservative ideas that pregnancy is a time of confinement. With abundant evidence to show that moderate exercise in healthy pregnancies results in benefits and without adverse maternal or fetal outcomes, exercise recommendations made by healthcare providers should be a top priority. It is well recognized that healthy lifestyle behaviors adopted in pregnancy can result in persistent lifestyle modifications that could significantly reduce risk factors associated with obesity, chronic hypertension, and diabetes—not only for the pregnant mother, but also for all members of her family.

In this chapter, we review physiological changes that provide the basis for exercise guidelines and nutritional recommendations in pregnancy, as well as maternal and fetal responses to the potential risks and benefits associated with exercise in pregnancy.

### 3.2 PHYSIOLOGICAL CHANGES IN PREGNANCY

Under the influence of estrogen, progesterone, and elastin, pregnancy is associated with generalized connective tissue laxity, potentially leading to ligament and joint instability [1]. Additional strain on the musculoskeletal system comes from the change in the body’s center of gravity, resulting in progressive lordosis (accentuation of the lumbar curvature of the spine) and kyphosis (curvature of the upper spine) [7]. The change in center of gravity requires greater muscular effort with certain movements, such as rising from a squatting or sitting position or changing directions quickly. The progressive lordosis in pregnancy frequently results in lower back pain, which could be prevented by improving posture and muscular strength preferably prior to pregnancy [8]; such preventative measures are also effective during pregnancy [9]. Providing exercise guidelines to increase core strength prior to pregnancy minimizes these injuries.

Special consideration must be given to changes that occur during each trimester of pregnancy that could result in injury from physical activity in pregnancy. Physical activity in pregnancy can be affected by the following progressive anatomical and physiological changes: change in center of gravity, increased connective tissue laxity resulting in joint instability, lordosis and kyphosis, generalized edema possibly resulting in nerve compression syndrome, increase in blood volume, tachycardia, hyperventilation, and reductions in cardiac reserve and residual lung capacity [10]. Figure 3.1 lists the etiology for potential injury that can occur during exercise in pregnancy and the gestational age during which the injury is most likely to occur. The goal of exercise is to maintain physical fitness within the physiological limitations of pregnancy. Exercise prescriptions should be geared towards muscle strengthening to minimize risk of joint injury and towards correcting postural changes thus diminishing lower back pain.

Physical activity may increase uterine activity (contractions). The effect of exercise on uterine activity has little or no change during the last 8 weeks of pregnancy [11]. While there are no studies reporting that strenuous activity results in preterm labor, until the impact is fully studied, women at risk of preterm labor should be advised to reduce
activity in the second and third trimesters [12]. There is a link between strenuous physical activity and the development of intrauterine growth restriction in the presence of dietary restrictions. Mothers with physically demanding and repetitive jobs were reported in several studies to deliver early and give birth to small-for-gestational-age infants [13–15]; meanwhile, other studies on vigorous exercise found no difference [16] or an increase [17] in infant birth weight. It appears that infant birth weight is not affected by exercise if energy intake is adequate [18], and that fetal weight can be maintained with adequate nutritional intake.

### 3.3 HYPERThERMIA

An increase in body temperature during exercise is directly related to the intensity of the activity. During moderate intensity exercise in normal temperature conditions, the body’s core temperature tends to rise an average of 1.5°C during the first 30 min of activity, followed by a plateau if the same level of activity continues [19]. Heat is dissipated predominantly through the skin. If heat production exceeds heat dissipation—which can occur if exercise takes place in hot humid conditions, with vigorous exercise, if there is exposure to hot tubs, saunas, or if the woman is running a fever—the core temperature continues to rise. Animal studies have shown that an increase in core temperature greater than 39°C during embryogenesis from 3 to 8 weeks gestation can result in congenital malformations [20–22]. For humans, the association of hyperthermia and congenital malformations is primarily acknowledged in case studies, which suggests a relationship but
does not prove causality [23–25]. One prospective study using 165 women exposed to hyperthermia during the first trimester failed to confirm teratogenic effects [26]. As the risk of hypothermia is a concern, pregnant women should be advised to avoid hyperthermic conditions during the entire pregnancy, and particularly the first trimester.

3.4 CARDIOVASCULAR AND RESPIRATORY ADAPTATIONS IN PREGNANCY

During exercise, there is a redistribution of blood flow away from the visceral organs and toward the exercising muscles. The redistribution of blood away from the uterus is related to the intensity and duration of exercise. However, in pregnancy there are corresponding adaptations that are characterized by an increase in blood volume, compensated for by increased venous capacity and decreased peripheral vascular resistance [27]. Although fetal oxygen and substrate availability could be counterbalanced by an increase in the amount of oxygen and substrate taken from the maternal blood supply, the question remains as to whether the redistribution of blood flow during regular or extended physical activity impacts transplacental transport of oxygen, carbon dioxide, and nutrients.

Exercise intensity is usually expressed in terms of demand on the cardiovascular system as percentage of maximal heart rate. The values for volume of oxygen consumed during exercise at maximum capacity (% VO$_{2\text{max}}$), metabolic equivalents (METs), and maximal heart rate (% HR$_{\text{max}}$) for the average nonpregnant woman can be found in Table 3.1 [10]. Maternal heart rate response to strenuous exercise is blunted and does not follow a linear relationship; this is the reason why target heart rates cannot be used for exercise prescriptions in pregnancy. In order to track the level of intensity during physical activity, pregnant women may make use of the following easy-to-use methods. First, the talk test may be used to monitor level of intensity. A subject who is exercising at a moderate intensity (3–4 METs) should be able to comfortably hold a conversation; however, if winded or out of breath during the activity, she may be exercising too vigorously. Another helpful method for measuring intensity is the Borg Scale Rating of Perceived Exertion (RPE) [28]. The RPE is a subjective measure that correlates to a person’s physical perception of exercise intensity including heart rate, respiration, perspiration, and muscle fatigue. The Borg RPE scale ranges from a level of 6, which is no exertion at all, to a level of 20, which is maximal exertion. An RPE level of 12–14 would be perceived as “somewhat hard,” which corresponds to moderate activity. If exertion were reported as 19 or “extremely hard” on the Borg scale, decreasing to a lower intensity would be beneficial, thus modifying the intensity according to maternal symptoms. To estimate an individual’s heart rate during exercise, RPE can be multiplied by 10 (i.e., an RPE of 12–14 × 10 = a heart rate of 120–140 beats per minute). Increased energy expenditure may be estimated using METs, a unit of resting oxygen uptake. One MET is equivalent to 1 kcal per kg of body weight per hour. For example, if a 70-kg woman walks at a brisk pace of 3–4 METs for a half hour, she would increase her caloric requirement by 70–105 kcal (2–3 MET increase over resting × 70 kcal × 0.5 hrs.

Cardiovascular response to body position should be considered. After the first trimester, the supine position results in relative obstruction of the venous return due to the enlarging uterus [29]. Pregnant women may experience a decrease in cardiac output reflective of symptoms associated with this supine hypotensive syndrome.
Pregnancy is associated with profound respiratory changes: minute ventilation (tidal volume × breaths/minute) increases by approximately 50%, primarily as a result of increased tidal volume (volume of gas inhaled and exhaled during one respiratory cycle) [30, 31]. Because of the increased resting oxygen requirements and the increased work of breathing caused by pressure of the enlarged uterus on the diaphragm, there is decreased oxygen availability for performance of aerobic exercise during pregnancy. Thus, both workload and maximum exercise performance are decreased [31, 32].

### 3.5 FETAL RESPONSE TO MATERNAL EXERCISE

One of the main concerns related to exercise in pregnancy is the effect of maternal activity on the fetus, whereas any maternal benefits may be offset by adverse fetal outcomes. The potential concerns, although theoretical, are related to the selective redistribution of blood flow during exercise and the resultant effects on the transplacental transport of \( \text{O}_2 \), \( \text{CO}_2 \), and nutrients. Studies addressing fetal heart response to exercise have focused on fetal heart rate changes before, during, and after exercise. Moderate exercise appears to cause a minimal to moderate increase in fetal heart rate by approximately 10–30 beats/minute over baseline [62].

### 3.6 EXERCISE GUIDELINES FOR HEALTHY PREGNANCIES

The exercise recommendations from the American College of Obstetricians and Gynecologists (ACOG) mirror those of the Center of Disease Control (CDC), and the American College of Sports Medicine (ACSM). The ACSM recommends moderate intensity exercise for 30 min or more on most days of the week as part of a healthy lifestyle in the nonpregnant population [4]. A moderate level of exertion for 30 min duration has been associated with significant health benefits decreasing risk of chronic diseases including coronary heart disease, hypertension, type 2 diabetes mellitus, and osteoporosis [33]. Women who are sedentary prior to pregnancy should gradually increase their duration of activity to 30 min. Those who are already fit should be advised that pregnancy is not the time to greatly enhance physical performance and that overall activity and fitness tend to decline during pregnancy. Pregnant women should exercise caution in increasing intensity, especially when an exercise session extends beyond 45 min because body core temperature may rise above safe levels, and

**Table 3.1**

<table>
<thead>
<tr>
<th>Intensity</th>
<th>%( \text{VO}_{2\max} )</th>
<th>METs</th>
<th>%HR( \max )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>15–30</td>
<td>1.2–2.7</td>
<td>40–50</td>
</tr>
<tr>
<td>Moderate</td>
<td>31–50</td>
<td>2.8–4.3</td>
<td>51–65</td>
</tr>
<tr>
<td>Heavy</td>
<td>51–68</td>
<td>4.4–5.9</td>
<td>66–80</td>
</tr>
<tr>
<td>Very heavy</td>
<td>69–85</td>
<td>6–7.5</td>
<td>81–90</td>
</tr>
<tr>
<td>Unduly heavy</td>
<td>86+</td>
<td>7.6+</td>
<td>90+</td>
</tr>
</tbody>
</table>

From [10] % \( \text{VO}_{2\max} \) = percentage of aerobic capacity, METs = metabolic equivalent, % HR\( \max \) = percentage of maximal heart rate. Adapted from [10]
energy reserves could become depleted. The ACOG guidelines [1] for exercise during pregnancy are established for pregnant women without maternal or obstetrical complications. These recommendations are summarized in Table 3.2. Clinical evaluation by an obstetrician is recommended prior to prescribing an exercise program during pregnancy, with special consideration given to the type and intensity of the exercise—as well as the duration, frequency of the sessions, the level of fitness, and familiarity with the various activities.

In some circumstances, uterine activity has been shown to occur during and after physical activity in pregnancy; however, it could have potential for clinical significance only in those at risk for premature labor. Women who are at risk or have a significant history of premature labor should be advised to refrain from exercise during pregnancy. Table 3.3 lists the absolute and relative contraindications for exercise in pregnancy, and Table 3.4 lists warning signs to terminate exercise while pregnant [1].

Safety is the primary concern for exercise during pregnancy and caution should be implemented. Contact sports and recreational activities with increased risk of falling and abdominal trauma, such as hockey, soccer, baseball, gymnastics, skiing, horseback riding, and racquet sports, should be limited or avoided. Exercise in water has several advantages for the pregnant woman: the safety from the buoyancy of the water, a shift in extracellular fluid back to the vascular system, which can decrease edema, thermoregulation of the core body temperature, less fetal heart rate change as compared to other activities, and increased uterine blood flow [34]. Increases in circulating blood volume are proportional to the depth of immersion, resulting in lower maternal heart rate and

Table 3.2
Excerpts from ACOG Recommendations for Exercise during Pregnancy and the Postpartum Period

1. In the absence of either medical or obstetric complications, 30 min or more of moderate exercise a day on most, if not all, days of the week is recommended for pregnant women.
2. Recreational and competitive athletes with uncomplicated pregnancies can remain active during pregnancy and should modify their usual exercise routines as medically indicated.
3. Generally, participation in a wide range of recreational activities appears to be safe during pregnancy. Each sport should be reviewed individually for its potential risk. Activities with a high risk of falling or risk of abdominal trauma should be avoided. Scuba diving should be avoided.
4. Inactive women and those with medical or obstetric complications should be evaluated before recommendations for physical activity are made. Women engaging in strenuous exercise require close medical supervision.
5. Women with a history of or risk of preterm labor or fetal growth restriction should be advised to reduce activity in the second and third trimesters.
6. Exercise in the supine position, after the first trimester, and prolonged periods of motionless standing should be avoided as much as possible.
7. Exercise during pregnancy may provide additional health benefits to women with gestational diabetes mellitus (GDM) including reducing insulin resistance, postprandial hyperglycemia, and excessive weight gain.
8. Prepregnancy exercise should be gradually resumed postpartum because the physiological changes of pregnancy may persist 4–6 weeks postpartum.

Adapted from [1]
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Table 3.3
Contraindications for Exercise during Pregnancy

<table>
<thead>
<tr>
<th>Absolute contraindications:</th>
</tr>
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<tbody>
<tr>
<td>• Hemodynamically significant heart disease</td>
</tr>
<tr>
<td>• Restrictive lung disease</td>
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<tr>
<td>• Incompetent cervix/cerclage</td>
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<tr>
<td>• Multiple gestation at risk for premature labor</td>
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<tr>
<td>• Persistent second- or third-trimester bleeding</td>
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<tr>
<td>• Placenta previa after 26 weeks of gestation</td>
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<tr>
<td>• Premature labor during the current pregnancy</td>
</tr>
<tr>
<td>• Ruptured membranes</td>
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<tr>
<td>• Preeclampsia/pregnancy-induced hypertension</td>
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Relative contraindications (patients may be engaged in medically supervised programs):

<table>
<thead>
<tr>
<th>Relative contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Severe anemia</td>
</tr>
<tr>
<td>• Unevaluated maternal cardiac arrhythmia</td>
</tr>
<tr>
<td>• Chronic bronchitis</td>
</tr>
<tr>
<td>• Poorly controlled type 1 diabetes</td>
</tr>
<tr>
<td>• Extreme morbid obesity</td>
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<tr>
<td>• Extreme underweight (BMI &lt; 12)</td>
</tr>
<tr>
<td>• History of extremely sedentary lifestyle</td>
</tr>
<tr>
<td>• Intrauterine growth restriction in current pregnancy</td>
</tr>
<tr>
<td>• Poorly controlled hypertension</td>
</tr>
<tr>
<td>• Orthopedic limitations</td>
</tr>
<tr>
<td>• Poorly controlled seizure disorder</td>
</tr>
<tr>
<td>• Poorly controlled hyperthyroidism</td>
</tr>
<tr>
<td>• Heavy smoker</td>
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</tbody>
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From [1]

Table 3.4
Warning Signs to Terminate Exercise While Pregnant

<table>
<thead>
<tr>
<th>Warning Signs</th>
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<tbody>
<tr>
<td>• Vaginal bleeding</td>
</tr>
<tr>
<td>• Dyspnea before exertion</td>
</tr>
<tr>
<td>• Dizziness</td>
</tr>
<tr>
<td>• Headache</td>
</tr>
<tr>
<td>• Chest pain</td>
</tr>
<tr>
<td>• Muscle weakness</td>
</tr>
<tr>
<td>• Calf pain or swelling (need to rule out thrombophlebitis)</td>
</tr>
<tr>
<td>• Preterm labor</td>
</tr>
<tr>
<td>• Decreased fetal movement</td>
</tr>
<tr>
<td>• Amniotic fluid leakage</td>
</tr>
</tbody>
</table>

From [1]

blood pressure in comparison with land exercises. Water aerobics for 30-min sessions have been shown to be as beneficial as static immersion in relieving edema [35]. Scuba diving should be avoided because this puts the fetus at risk for decompression sickness secondary to the inability of the fetal pulmonary circulation to filter bubbles.
In the past, weight lifting in pregnancy was unheard of; however, since women often do not want to give up their prepregnancy routine, they need to learn how to lift weights safely [10]. Weight training is a beneficial way to stay fit during pregnancy, while keeping in mind that the fitness goals should be geared toward maintenance instead of dramatic gains. The use of lighter weights to avoid overloading joints that are loosened by the hormones of pregnancy, along with more repetitions will assist in maintaining muscle mass without stressing the joints. Caution should be executed by avoiding walking lunges that could strain connective tissue. Protecting the abdomen from swinging weights could prevent harm to the fetus. Women should be advised not to lift weights while laying flat on the back, which puts pressure on the vena cava, thus restricting blood flow to the heart. Use of an incline bench would assist with the position change. Proper breathing technique such as exhaling during a lift can lessen the risk on transient hypertension associated with the Valsalva maneuver, seen in inexperienced weight lifters who forcibly exhale air against closed lips and a pinched nose. Any program that works the entire body to promote tone and fitness can be incorporated into a physical activity routine with certain limitations.

Moderate exercise in a low-risk pregnancy does not result in adverse fetal or maternal outcomes but instead helps to maintain fitness and well being in the mother [36]. An exercise prescription for the improvement and maintenance of fitness in nonpregnant women consists of activities recommended to improve cardiorespiratory capacity (aerobic exercise), muscle tone (resistance exercise), and flexibility [37]. These activities include walking, low-impact aerobics, stationary biking, and swimming. In pregnant women, a similar prescription can be made; however, additional consideration should be given to the type and intensity of exercise along with duration and frequency to achieve health benefits minimizing any potential risks to the mother and fetus [18]. Aerobic exercise consists of activities that use large muscle groups in a continuous rhythmic fashion, such as walking, jogging, swimming, stationary biking, or dancing. Indeed many women have familiarity with these activities, and most are able to comply with recommendations to incorporate aerobic activities into their daily schedules. Women should be advised to wear comfortable shoes and avoid activities that may result in falling.

The prevalence of leisure activity among pregnant women in the United States is 66%, compared with 73% in nonpregnant women; however, when examining whether women meet the recommended amounts of physical activity per week, the prevalence was lower at 16% in pregnant women compared with 26% in those not pregnant [38]. The most common leisure time activity reported was walking, followed by swimming, weight lifting, gardening, and aerobics. While women report that exercise positively impacts pregnancy, the greatest influence on whether a woman exercises during her pregnancy was reported to be the encouragement provided by her physician and healthcare provider [39]. Sedentary women, prior to beginning an exercise program, should receive clinical and obstetrical evaluation.

3.7 THE ELITE ATHLETE

The elite athlete experiences limitations and physiological changes in pregnancy similar to the recreational athlete, including ligament relaxation, change in posture, and weight gain. These changes may in turn impact a woman’s competitive ability and increase her desire for strenuous training, making her more prone to injury [12]. The
elite athlete should be aware that pregnancy is not a time for improving competitive fitness, but instead she should focus on remaining physically active, modifying her exercise routine if medically indicated. Caution and careful evaluation by an obstetrician is essential with high-intensity, prolonged, frequent exercise during pregnancy, since there is evidence of low birth weight and greater risk of thermoregulatory complications associated with this type of exercise regimen.

3.8 NUTRITIONAL REQUIREMENTS FOR THE ACTIVE PREGNANT WOMAN

Although the nutritional needs of active pregnant women are not clearly defined, nutritional needs in pregnancy have been well researched. Energy requirements during the second and third trimesters of pregnancy are an average of 300 kcal a day above prepregnancy requirements [40]. A wide variability in metabolic energy expenditure in pregnancy makes it difficult to set standards for energy requirements [41]. Exercise during pregnancy requires an additional caloric allowance for increased metabolism and greater energy expenditure both during and after the activity. Other factors affecting caloric requirements in pregnancy include prepregnancy body mass index, maternal age, and appetite. Estimation of caloric needs is further complicated by pregnancy changes in maternal extracellular fluid, maternal fat stores, the weight of the fetus and supporting tissue (uterus, placenta, amniotic fluid, and mammary glands), as well as changes in fat-free muscle mass due to variations in activity during pregnancy. Level of activity may either increase or decrease caloric requirements. For example, a competitive athlete who decides to reduce the intensity of the activity may have lower caloric needs in pregnancy compared with prepregnancy needs, while a sedentary person who has started a moderate exercise program may have increased calorie needs above those of normal pregnancy requirements.

Estimation of body composition is more complicated in pregnancy. As gestational age progresses, body water continues to increase, while fat mass stays relatively constant. Changes in hydration, along with errors in measures used to estimate percent body fat, make it more difficult to provide reliable measures of body composition [42].

The Dietary Reference Intakes (DRIs) for macronutrient and micronutrient intakes have not been defined for the active pregnant woman compared with those who are sedentary. Protein requirements in pregnancy have been estimated at 1.1 g/kg/day (71 g/day for someone 163 cm tall, weighing 65 kg.), while in active people there is a slightly higher estimated requirement of 1.2 to 1.4 g/kg body weight per day [43]. The 2005 Dietary Guidelines for Americans recommend 20–35% of calories from fat, with most coming from polyunsaturated and monounsaturated fatty acids, while limiting intake of saturated fats to less than 10% of calories and keeping trans fatty acids as low as possible. Fat intake should not be restricted to less than 15% of energy requirements because fat is important not only as a source of calories, but also to aid in the absorption of fat-soluble vitamins and provides essential fatty acids [44]. Carbohydrate intake of 40–55% of energy requirements is needed to replace the muscle glycogen stores lost during exercise, minimize maternal hypoglycemia, and limit ketonuria. All pregnant women and athletes should strive to consume foods that provide at least the RDA/DRI for all vitamins and minerals in pregnancy and lactation, as discussed in Chap. 1 (“Nutrient Recommendations and Dietary Guidelines for Pregnant Women”) [43].
Women who are diet conscious often do not obtain the necessary nutrients required to maintain a normal pregnancy. Inadequate nutritional intake along with the increased energy requirements for exercise may lead to poor weight gain and fetal growth restriction. Although the data linking low birth weight and maternal exercise are conflicting, for pregnant women who exercise, it is unclear if adequate energy intake can offset a decrease in fetal weight [44]. A meta-analysis of 30 research studies concluded that vigorous exercise during the third trimester of pregnancy has been associated with a 200- to 400-g decrease in fetal weight [45]. When deficient energy intake occurs in combination with chronic strenuous exercise during pregnancy, fetal growth may be adversely affected.

Since pregnancy and exercise place higher demands on oxygen requirements, women who exercise during pregnancy should be monitored for suboptimal iron status and inadequate intake. Many women enter pregnancy with depleted iron stores, as discussed in Chap. 16 (“Iron Requirements and Adverse Outcomes”). This, along with expansion of maternal blood volume and increased fetal demand for oxygen, makes it more of a challenge for many women to achieve adequate iron status. If a woman enters pregnancy with iron deficiency anemia, repletion of iron stores may be difficult. Prenatal vitamin and mineral supplements are routinely prescribed to provide additional iron and folic acid. However, these should not replace a healthy balanced diet containing a variety of foods from all food groups so as to ensure adequate intake of antioxidants, fiber, and the necessary nutrients to support maternal health and growth of the fetus [46].

Oftentimes, active women enter pregnancy underweight, with increased awareness of body image and may resort to caloric intake below recommendations to prevent weight gain in pregnancy. To compensate for nutrient deficiencies, women may over compensate by taking large amount of vitamins or minerals. Although vitamin and mineral supplementation may be beneficial, women should be counseled to avoid excessive micronutrient intake, particularly of the fat-soluble vitamins A and D, which can lead to fetal malformations. Excessive amounts of vitamin D can result in congenital anomalies consisting of supravalvular aortic stenosis, elfin facies, and mental retardation [47]. Women taking high amounts of vitamin A >10,000 IU in supplement form showed higher rates (1 infant in 57) of cranial–neural crest tissue defects [48]. The use of dietary supplements is further discussed in Chap. 14 (“Dietary Supplements during Pregnancy: Need, Efficacy, and Safety”).

Athletes may choose to consume nutritional ergogenic aids and dietary supplements to enhance athletic performance with hopes of boosting their competitive edge. Nutritional supplements are a multibillion-dollar industry targeting a wide range of populations, including women of childbearing age. Supplement companies are not required to prove supplement safety, effectiveness, and potency before a product is placed on the market as long as the supplement makes the claim that it has not been evaluated by the US Food and Drug Administration (FDA), and that the product is not intended to diagnose, treat, mitigate, cure or prevent disease [43]. Many may believe that since these products are natural and legal that they are safe; however, there is little scientific evidence demonstrating the safety or effectiveness of these products for the general population. Women of childbearing age should be counseled or warned that supplements and nutritional ergogenic aids have not been shown to be safe and therefore should be avoided prior to and during pregnancy. The reader is also directed to Chap. 13 (“Popular Diets”).

Water is a critical yet often forgotten nutrient for healthy pregnancies. Exercise induces significant fluid loss and places the woman at higher risk of dehydration. Weighing
before and after exercise can help monitor fluid balance. Weight loss of 2 lb is equivalent to approximately a 1-liter fluid loss. Pregnant women should be encouraged to drink 8 to 12 cups of hydrating fluids per day, with water being the preferential source. Sports drinks help replenish carbohydrate, fluid, and electrolyte losses during exercise sessions lasting 30–45 min. Drinking 1–2 cups of water prior to exercise, replacing fluids every 15–20 min. during activity, and replacing fluids lost after exercise helps maintain hydration and keeps body temperature within normal limits.

Physical activity and diet quality are interconnected behaviors. Individuals following a suboptimal diet tend to be more sedentary, less educated, not married, and non-Caucasians [49]. Hormonal alterations during pregnancy have been shown to cause a 1.5- and three-fold increase in maternal cholesterol and triglyceride levels, respectively by the mid-third trimester [50]. One study examined the relationship between recreational physical activity in early pregnancy and found reductions in total cholesterol and triglyceride levels in women who spent a greater amount of time (12.7 h/week) on recreational physical activity [51]. Results of this study, along with others conducted in the nonpregnant population suggest that physical activity in pregnancy may lessen pregnancy-associated dyslipidemia.

3.9 FUEL UTILIZATION IN EXERCISE AND PREGNANCY

Measurements by indirect calorimetry reveal preferential use of carbohydrates during exercise in pregnancy [53]. The respiratory exchange ratio (RER) reflects the ratio between CO₂ output and oxygen uptake (VO₂). The RER provides information on the proportion of substrate derived from various macronutrients. For carbohydrate to be completely oxidized to CO₂ and H₂O, one volume of CO₂ is produced for each volume of O₂ consumed. An RER of 1 indicates carbohydrates are being utilized, while an RER of 0.85 indicates mixed substrate. Assessment of fuel utilization during pregnancy is important because of the possible effect of exercise-induced maternal hypoglycemia [53]. Such events are unlikely to occur during 45 min of moderate exercise, but could occur after 60 min of continuous moderate to strenuous exercise (Fig. 3.2). The tendency for higher respiratory exchange ratios during pregnancy and during exercise in pregnancy suggests a preferential utilization of carbohydrates. Soultanakis et al. [53] found that with exercise greater than 20 min in length, both glucose and glycogen stores were depleted, resulting in higher levels of ketones and free fatty acids being used as fuel sources. Increased carbohydrate metabolism along with lower glycogen stores may further predispose women to hypoglycemia during pregnancy. Protein utilization in pregnancy during exercise does not increase above nonpregnancy levels, and since most people in the United States get more than the required amount of protein in their diets, additional/supplemental dietary protein is unnecessary fuel during moderate bouts of exercise [54].

3.10 CLINICAL APPLICATIONS FOR EXERCISE IN PREGNANCY

Results from the National Health and Nutrition Examination Survey (NHANES) reveal that from 2003–2004 an estimated 66% of adults (over age 20) were either overweight or obese [55]. The obesity rate in women of childbearing age is increasing. In 2003, 19.6% of US women of reproductive age (18–44 years) were classified as obese (BMI > 30) [56]. Whether this trend in weight status is associated with the liberalization of the weight gain
guidelines in pregnancy is unclear. However, data show that with each subsequent pregnancy, there is a greater risk of postpartum weight retention [57]. A greater focus is needed to prevent excessive weight gain in pregnancy; this may be accomplished in part through exercise. One study revealed that women who gained excessive weight and failed to lose weight by 6 months postpartum were 8.3 kg heavier 10 years later [58]. A 15-year follow up study to determine the effects of weight gain in pregnancy revealed that the 1-year postpartum timeframe was the greatest predictor of long-term weight retention, regardless of weight gain in the pregnancy or prepregnancy BMI [59]. O’Toole et al. reported that a 12-week comprehensive exercise and nutrition intervention program resulted in greater postpartum weight loss than a single 1-hr educational session [60]. Although weight loss is usually not recommended in pregnancy, losing excess weight prior to pregnancy and a gradual weight loss postpartum may be beneficial in overweight and obese women, as described in Chap. 5 (“Obesity and Pregnancy”). Lactating women should not attempt to lose more than 2 kg/month [61].

Gestational diabetes mellitus (GDM) is a condition of glucose intolerance that is first detected during pregnancy. The elevated hormonal response more commonly found in the second and third trimesters of pregnancy further amplifies the reduction in insulin peripheral sensitivity. Through the use of exercise, both insulin sensitivity and the effectiveness of insulin may increase. Exercise has been recognized as an adjunctive and alternative therapy to assist with glycemic control in patients with type 2 diabetes mellitus [62], and this is further discussed in Chap. 10 (“Diabetes and Pregnancy”).

The American Diabetes Association endorses exercise as adjunctive therapy for GDM when glycemic control is not achieved with diet alone [63, 64]. Women diagnosed with GDM during pregnancy are at increased risk of developing type 2 diabetes within the first 5 years after delivery [65]. Studies have shown that through exercise and diet therapy, glycemic control can be achieved and may prevent the onset of type 2 diabetes [66, 67]. Epidemiological data [63] suggest that obese women with a BMI > 30 kg/m² can lower the incidence of GDM with exercise during pregnancy compared with obese women who

![Fig. 3.2. Glucose concentrations during prolonged exercise: pregnant versus nonpregnant. *p<0.05. (From [19])](image)
do not exercise (Fig. 3.3). These studies demonstrate that exercise as prescribed may be beneficial in the primary prevention of GDM in overweight and obese women. Aerobic exercise plays a role in decreasing the hyperinsulinemia associated with obesity along with decreasing fasting and postprandial blood glucose levels.

Based on the findings of several studies, exercise has been prescribed to improve carbohydrate tolerance and avoid insulin therapy. These studies have been aimed at assessing maternal and fetal safety along with efficacy of the exercise prescription. Artal et al. [68] advised 20 min of bicycle ergometry at 50% VO2max after each meal at least 5 days/week for 6 weeks prior to the expected day of delivery. Jovanovic-Peterson et al. [69] recommended 20 min of arm ergometry at less than 50% VO2max daily for 6 weeks prior to delivery. Bung et al. [70] utilized 45 min of bicycle ergometry at 50% VO2max three to four times a week for 6 weeks prior to delivery. These studies demonstrated exercise, as prescribed above, was sufficient to maintain euglycemia. Therefore, exercise should be viewed as a viable option for women with GDM to improve glycemic control and pregnancy outcomes.

Physical activity offers benefits to those at risk for developing gestational hypertension and preeclampsia, which is characterized by hypertension and proteinuria in pregnancy. Preeclampsia and cardiovascular disease share similar pathways including hypertension, dyslipidemia, insulin resistance, and obesity [71]. Women engaging in physical activity early in pregnancy reduced their risk of preeclampsia by 35% compared with inactive women [72].

### 3.11 POSTPARTUM

Many of the physiological and morphological changes of pregnancy persist 4–6 weeks postpartum. Therefore, exercise routines should be resumed gradually only when medically and physically safe. Weight loss is often desired during the postpartum period, a time when women are often anxious to resume exercise routines quickly after delivery. Exercise complements the benefits of restricting calories and limiting portion sizes. Exercise...
helps achieve increased lean body mass, increased fat loss, and improved cardiovascular fitness. Women will be more successful at postpartum exercise if they have a plan and are confident in their ability to carry out the plan [73]. Healthcare providers can help women to identify barriers to exercise, including inclement weather, safety issues, lack of transportation, childcare, time, and cost, and to develop strategies to overcome these obstacles.

3.12 LACTATION

During the postpartum period, many women are eager to lose weight and improve muscle tone. Of concern to many women is whether an energy deficit will affect the quality of breast milk, thus impairing infant growth. Aerobic exercise performed four to six times per week at a moderate intensity of 60–70% maximal heart rate for 45 min per day does not appear to affect breast milk volume and composition [74]. The Institute of Medicine recommends lactating women should lose no more than 2 kg/month [75]. However, one study reveals that short-term weight loss of approximately 1 kg/week through a combination of aerobic exercise and dietary energy restriction helped preserve lean body mass without affecting lactation performance [76].

3.13 CONCLUSION

Women should obtain medical advice from their healthcare providers about the type of activity they should engage in during pregnancy. There is ample evidence that moderate exercise in women with healthy pregnancies is beneficial and has no adverse effects on the mother or the baby. Pregnant women should be encouraged to include 30 min of physical activity into their daily lifestyle on most, if not all days of the week. Despite profound physiological changes in pregnancy, women with healthy pregnancies may engage in a combination of aerobic and resistance training in their workouts. Contact sports, scuba diving, and exercise with a high risk of falling or of abdominal trauma should be avoided. Women who exercise for the first time should start slowly, gradually increasing to moderate-intensity workouts. The elite athlete should be aware that pregnancy is not the time to enhance physical fitness performance. Strenuous exercise with intense workouts or sessions lasting longer than 45 min could raise the body core temperature to levels that could be harmful to the fetus. Energy requirements vary during exercise in pregnancy due to the variability in metabolic energy expenditure and the frequency, intensity, duration, and level of the physical activity.

Exercise habits prior to and during pregnancy may decrease the risk of gestational hypertension and GDM. Because habits adopted during pregnancy can result in persistent lifestyle changes, exercise during pregnancy could significantly reduce lifetime risks for obesity, chronic hypertension, and diabetes. Women whose exercise habits have become firmly engrained before and during pregnancy stand a much better chance of maintaining them after the child is born, and these exercise habits can positively impact the entire family.

REFERENCES