Exercise and Sporting Activity During Pregnancy

Evidence-Based Guidelines

Rita Santos-Rocha
Editor

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Foreword

Exercise and a healthy lifestyle during pregnancy are key to preventing chronic disease risk in both mother and her developing fetus [1]. Maternal benefits of exercise include improved fitness [2], prevention of excessive pregnancy weight gain [3], weight retention and potential obesity [4], gestational diabetes [5], hypertension [6], maternal depression [7], and reduction in cesarean section rates [1]. Maternal exercise has also been linked to appropriate birth weight [8] and prevention of chronic disease development in the offspring [4]. When these benefits are considered, it is surprising that many healthcare providers do not advocate a healthy lifestyle for pregnant women. The first two chapters present information regarding education of healthcare providers and fitness professionals of the importance of health promotion during pregnancy (Chap. 1) and the importance of psychological and behavioral support necessary for women to be successful in beginning or maintaining physical activity during pregnancy (Chap. 2). Lack of information and social support are two reasons why pregnant women may not be engaged in physical activity. Knowledge of benefits of prenatal exercise may lead to a more favorable attitude toward exercise among women, healthcare providers, and exercise professionals from an international perspective (Chap. 7).

Pregnancy affects every system of the body and it is important to understand the physiological changes (Chap. 3), body composition alterations (Chap. 4), and the biomechanical adaptations (Chap. 5) to pregnancy and the implications for physical activity. In addition, pregnancy alterations to the musculoskeletal system (including the pelvic floor, pelvic girdle, and lower back) may increase risk factors for musculoskeletal disorders (such as diastasis recti), impairments (such as urinary incontinence), and pain in the lower back and pelvic girdle (Chap. 6). Recommendations for treatment and guidance for recovery of functional capacity related to potential impairment and disorders of the musculoskeletal system are also important features of Chap. 6. Prenatal exercise can also be used as a therapy for musculoskeletal health in order to improve and restore physical function (Chap. 10).

Medical screening is an important component to ensure that pregnant women have a low-risk pregnancy before engaging in exercise. Guidelines for exercise testing and prescription for pregnant and postpartum women are presented in Chap. 8, followed by suggestions for programming exercise classes that includes steps for planning and conducting classes, and monitoring pregnant women for safe physical activity (Chap. 9). Lastly, a healthy lifestyle would not be complete without nutrition requirements for pregnant women who exercise. Dietary intake before, during, and after maternal exercise is important to monitor in order to maintain adequate energy availability while avoiding unhealthy behaviors such as alcohol or drug use (Chap. 11).

Each of these chapters are written by experts in their respective fields with a summary of up-to-date evidence-based literature and presented in a well-rounded format that can be used by healthcare providers and fitness professionals to assist and engage women who wish to be physically active and follow a healthy lifestyle throughout pregnancy.

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Preface

For many years I had the opportunity to work as an exercise professional in the health and fitness context with populations of all ages, including pregnant and postpartum women. I believe in exercise, and I have always been enthusiastic about working with pregnant women, both as an exercise professional and later as a mother. As a professor and researcher, I have devoted my efforts to the field of exercise and sporting activity during pregnancy and the postpartum period, by means of lectures, workshops, conferences, thesis supervision, and publications.

The current evidence leaves no room for doubt that physical activity and exercise should be part of a healthy lifestyle during pregnancy. Moreover, physical activity and exercise are beneficial for the health and fitness of both mother and fetus. However, too many pregnant women still give up or limit their exercise due to undue fear of losing a child or complications during pregnancy and childbirth. On the other hand, sometimes neither the women nor the professionals know what types of exercises are the best, the safest, and the most effective.

Sport and exercise during pregnancy is a quite demanding field of knowledge and practice. Exercise professionals must be aware of the many physiological, biomechanical, and psychosocial adaptations caused by pregnancy, as well as the pregnancy-related health conditions, symptoms, and discomforts, bearing in mind the proper pre-exercise and basic fitness evaluations, individualized exercise prescription, exercise selection, adaptation, and safety, while conducting prenatal exercise programs. Healthcare professionals must develop appropriate health screening, ongoing medical monitoring, and specific treatment as necessary, as well as monitor potential contraindications for exercise, having in mind the quite prevalent health conditions (such as excessive weight gain, gestational diabetes, low back and pelvic girdle pain, urinary incontinence, and diastasis recti). They must also be active agents in the health promotion process by providing counseling on the benefits of physical activity, recreational exercise, sports, and therapeutic exercise, and other aspects of health, such as nutrition and behaviors to be avoided. Thus, a team approach is of particular importance, and the communication between the exercising or sporting women, the medical doctors (obstetricians, gynecologists, general practitioners, or other), the midwives, the exercise professionals (exercise specialists and exercise physiologists), the physical therapists, the nutritionists, the psychologists, among others, is fundamental.

My personal goals were to gather international researchers and practitioners focused on the field of sports and exercise during pregnancy, to provide practical and evidence-based knowledge on the topic. This book is intended to fill the gap between evidence-based knowledge on the benefits of physical activity in pregnancy and practice in the implementation of exercise in pregnant women, bridging the gap between science and practice, between researchers and health and exercise professionals, and between women and exercise. The ultimate goal is to help both exercise professionals and healthcare professionals to provide better care to pregnant women by means of sport and exercise.

I want to thank from the bottom of my heart all the authors that shared their knowledge and devoted some of their busy schedules to the present publication, as well as to all models.

These authors have different academic and practice backgrounds in gynecology, physiotherapy, nursing, nutrition, psychology, and sports and exercise sciences, and come from countries such as Argentina, Australia, Canada, England, Lithuania, Norway, Poland, Portugal, Spain, and The Netherlands. Thus, for the first time, authors from different countries have decided to present a collective release of their scientific or practical experience in this topic.

This is a comprehensive and multidisciplinary volume structured in eleven chapters. The book combines research and exercise/clinical applications and provides a real standard reference in this specific field for medical, health, sports and exercise professionals, as well as students and researchers.

Chapter 1 will give an overview regarding the concepts of physical activity and exercise and health promotion aspects for the pregnant exerciser and the pregnant athlete. Chapter 2 addresses the current evidence surrounding the psychosocial aspects of an active pregnancy and provides recommendations for providing psychological and behavioral support to women to become or remain active throughout their pregnancy. Chapters 3, 4 and 5 address, respectively, the physiological, body composition, and biomechanical changes during pregnancy, the main forms of assessing these parameters, and their implications for physical activity and exercise. Chapter 6 addresses the most prevalent musculoskeletal impairments during pregnancy, such as urinary incontinence, diastasis recti abdominis, pregnancy-related low back pain, and/or pelvic girdle pain, and provides recommendations on how to recover functional capacity. Chapter 7 reviews the current evidence-based and practice-oriented guidelines for exercising during pregnancy in different countries, regarding the contents related to prenatal exercise programs. Chapter 8 is focused on the components of pre-exercise evaluation, exercise testing, and exercise prescription for pregnant exercisers and athletes. Chapter 9 is practice-oriented regarding the exercise selection and adaptations during pregnancy. Chapter 10 is practice-oriented to therapeutic exercise for the musculoskeletal health of the pregnant exerciser. Finally, Chap. 11 addresses the nutritional requirements for the pregnant exerciser and athlete.

The following features of the book should be highlighted:

1. Multidisciplinary volume
2. Combines research and exercise/clinical applications
3. Practice-oriented
4. It is the first international collective, evidence-based book on exercise in pregnancy

Hopefully, this book will attract health professionals, exercise and sports professionals, researchers, and students and will increase the recognition of the need for further research on the broad area of sport and exercise during pregnancy.

This book is dedicated to the memory of Elisa Geranio, Editor at Springer, that I had the pleasure to meet in Vienna, in July 2016, during the Congress of the European College of Sport Science. Elisa Geranio challenged me to this editorial project and provided support until it was submitted.

Lisbon, Portugal Rita Santos-Rocha

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Rita Santos-Rocha (Lisbon, 1971) is associate professor at the Sport Sciences School of Rio Maior (ESDRM—Escola Superior de Desporto de Rio Maior)—Polytechnic Institute of Santarém, Portugal, that she supervised as director between 2011 and 2015. She is the program director of the Master's Degree in Physical Activity in Special Populations and Professor of the Bachelor's Degree in Sport, Fitness and Health (ESDRM), in Exercise Testing and Prescription, and Public Health and Physical Activity.

Professor Santos-Rocha is a researcher of the Neuromechanics of Human Movement Group of the Interdisciplinary Centre for the Study of Human Performance (CIPER)—Faculty of Human Kinetics (FMH)—University of Lisbon. Her research interests are mainly focused on gait biomechanics and physical activity and exercise programs for pregnant and postpartum women, and other special populations.

She was the leader of the EuropeActive's Educational Standards for the Pregnancy and Postnatal Exercise Specialist published in 2016, which refers to European Qualification Framework. Professor Santos-Rocha has been collaborating with the Professional Standards Committee of EuropeActive (former European Health and Fitness Association) since 2010 and holds a seat on the Scientific Board of the Gymnastics Federation of Portugal since 2006. She is a founder member of the Portuguese Association of Exercise Physiologists.

In the past, she worked as a fitness instructor, gymnastics and physical education teacher, and exercise physiologist. She continues to work in the fitness industry as a training provider and supervisor of exercise science students and professionals.

She holds a BSc in Sports Sciences (1996), an MSc in Exercise and Health (2000), and a PhD in Human Movement—Health and Fitness (2006).

Physical Activity, Exercise, and Health Promotion for the Pregnant Exerciser and the Pregnant Athlete

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Mireille van Poppel, Katrine Mari Owe, Rita Santos-Rocha, and Hélia Dias

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Abstract
Currently there seems to be a consensus that maintaining light to moderate physical activity during an uncomplicated pregnancy has several benefits for the health of the woman and the fetus. Pregnancy provides good opportunities for promoting women's health and an active lifestyle. The purpose of this chapter is to provide exercise and healthcare professionals a basic understanding of the importance of an active lifestyle and health promotion and education during the different stages of pregnancy, emphasizing the benefits, the correlates, and the patterns of physical activity during pregnancy. We highlight the importance of healthcare professionals in promoting the benefits of physical activity and advising women on a healthy and active lifestyle during pregnancy, referring them to a prenatal exercise specialist.

Keywords
Pregnancy · Postpartum · Health promotion · Education for health Physical activity · Exercise

1.1 Introduction

Currently there seems to be a consensus that maintaining light to moderate physical activity during an uncomplicated pregnancy has several benefits for the health of the woman and the fetus [1–5]. In the last two decades, scientific evidence has clearly supported the importance of physical activity and exercise during pregnancy [6–11]. In the first place, one should clarify the meaning of these terms, because sometimes the terms physical activity and exercise are used interchangeably, and there is no clear consensus on the definitions of fitness or exercise prescription [5].

Physical activity is defined as any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase in caloric requirements over resting energy expenditure [5, 12]. *Exercise* is a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve and/or maintain one or more components of physical fitness [12] and/or prolong life [13]. In other words, exercise is a subcategory of physical activity. Although energy expenditure is increased during physical activity, it does not always reflect exercise and should not be confused with fitness [14]. Thus, physical activity can be categorized either in different contexts, such as leisure time, exercise, sports, occupational, household, and transportation activities, or by intensity, i.e., light (less than 3 METs—metabolic equivalents[1]), moderate (between 3 and 5.9 METs), and vigorous (6 METs or more) [14]. The World Health Organization (WHO) guidelines recommend for adults at least 30 min of intentional physical activity of moderate to vigorous intensity, in addition to usual activities, over 5 or more days per week for good health and reduction of several diseases [15].

[1] MET = Multiple of resting metabolic rate, used as a measure of exercise intensity [19].

On the contrary, *sedentary behavior* involves activities that are no more than 1.5 METs [16], and *physical inactivity* is a behavior state of not achieving, on a regular basis, a certain minimum standard of physical activity [14], i.e., not meeting the WHO recommended level of physical activity required for good health. Physical inactivity is the fourth leading cause of death worldwide [17] and considered the biggest public health problem of the twenty-first century [18].

Maternal physical inactivity during pregnancy may be a significant public health[2] issue due to its prevalence and connections with adverse pregnancy and birth outcomes, as well as the risk for several chronic diseases for mother and offspring. Although both exercise and health professional organizations have discipline-specific and endorsed guidelines, whether interventions exist that translate health evidence into practice remains unknown.

The purpose of this chapter is to provide exercise and healthcare professionals a basic understanding of the importance of an active lifestyle and health promotion[3] and education[4] during the different stages of pregnancy, emphasizing the benefits, the correlates, and the patterns of physical activity during pregnancy.

1.2 Education for Health and Lifestyle During Pregnancy

1.2.1 Pregnancy as an Opportunity to Promote Health

Assuming the importance of professional health intervention in the perspective of low-risk pregnancy surveillance, the main components are defined as prenatal care, health education, and preparation for childbirth and parenting [22]. The integration of learning and information sharing must permeate all pregnancy care from a health education perspective. Health education is understood as "all intentional activities conducive to learning related to health and disease [...]; can facilitate the acquisition of skills; may also lead to changes in behavior and lifestyles" [23]. In other words, health education can be defined as the processes through which people learn about personal health concepts and behaviors [20]. It is necessary here to identify the indicators of differentiation in adulthood that fit the perspective of adult education. Those indicators should be considered in the operationalization of the different components of pregnancy surveillance, in a logic that is assumed of self-development and learning. This perspective is supported by the principles that guide learning within the andragogical model that Knowles defined in the 1970s: the need to know,

[2] Public health is a field that encompasses many disciplines in an effort to promote and protect health and prevent disease and disability in defined populations and communities [20]. In other words, it is the science and art of promoting health, preventing disease, and prolonging life through the organized effects of society [21].

[3] Health promotion is the process of enabling people to increase control over the determinants of health and thereby improve their health [21].

[4] Health education can be defined as the processes through which people learn about personal health concepts and behaviors [20].

the concept of self, the role of experience, the willingness to learn, the orientation of learning, and the motivation [24, 25]. Adults are only predisposed to start and develop a learning process as long as they recognize its applicability, that is, a process that guides them to solving problems and tasks that they encounter in their life. Since pregnancy is a period of profound physical and psychological changes in a woman's life, it is an opportune moment to change lifestyles for healthier behaviors, based on a philosophy of "woman-centered care" [26, 27].

Thus, for health education during pregnancy and in the postpartum period, the goal of health professionals should be to increase health literacy and develop parental skills; make learning and information sharing components of each prenatal and postnatal surveillance visit with the pregnant woman/couple and family; establish a relationship of trust that facilitates the expression of expectations, fantasies, beliefs, myths, feelings (positive or negative), and competencies related to pregnancy, birth, and parenthood; and promote the right to adequate information for a free and informed decision.

Moreover, a routine health promotion program, encompassing education, advice, and general health assessment in the prepregnancy period, can be developed for improving pregnancy outcomes by encouraging behavioral change or allowing early identification of potentially modifiable risk factors, such as smoking, drinking excess alcohol, and poor nutrition [28], as well as physical inactivity.

1.2.2 Preparing for Childbirth and Parenting

The preparation for childbirth and the operationalized parenting in formal courses is a modality that exemplifies previous ideas and integrates one of the descriptive statements—health promotion and quality standards of specialized nursing care in maternal, obstetric, and gynecological health [29]. These courses allow women/couples to experience pregnancy and, from their needs, sharing, expressing, and clarifying fears, doubts, and anxieties, in a group environment and mutual support, in order to enable them to the tasks that pregnancy and parenting require. They contemplate a theoretical component and a practical component. According to Recommendation 2/2012 of the Board of the College of Maternal and Obstetrical Health Nursing Specialty [30], the theoretical component includes the following topics: labor, labor analgesia, breastfeeding, puerperium, and born, among others. In the practical component, the following are worth highlighting: exercises to promote the attachment of the pregnant woman/companion/baby during pregnancy; comfort techniques during labor; and the role of the companion to promote the comfort of the parturient, placements during labor and delivery, and the pelvic floor toning exercises. It should be noted that this descriptive statement also refers to the creation/use of opportunities in the preconception, pregnancy, and puerperium periods to promote healthy lifestyles, which reinforces the importance of a care centered on the needs of each woman and structured based on the philosophy of the andragogical model.

1.2.3 Health and Lifestyle Promotion

There is growing evidence that regular physical activity during pregnancy contributes positively to physical and psychological health. Moreover, physical activity significantly impacts public health as it reduces the risk of chronic diseases and provides numerous protective factors during pregnancy. On the contrary, adverse consequences of inactivity may be an especially important problem among pregnant women.

Pregnancy is a period par excellence to identify, modify, and adopt habits and behaviors at the level of healthy lifestyles. The pregnant woman is motivated to learn when she understands the advantages and benefits of learning. The health professional should seek the congruence between the adult's learning process, its particularity, and the need for personal development within the life cycle. Moreover, the promotion of physical activity may represent an important prevention strategy for public health, and it implies an interaction among several professionals from health and well-being settings [31].

We stress the importance of healthcare professionals in promoting the benefits of physical activity and advising women on a healthy and active lifestyle during pregnancy, referring them to a prenatal exercise specialist. It is also necessary to show that exercise specialist and instructors are well informed regarding the implementation of tailored exercise programs or the inclusion of pregnant women in regular group fitness classes. The best service is for sure provided by multidisciplinary professional groups, including exercise professionals, midwives, physiotherapists, and doctors, who can influence pregnant women to exercise properly.

However, a recent review by Nascimento et al. [32] reported that most pregnant women are not receiving physical activity and exercise guidance from healthcare providers, during prenatal care meetings, and some pregnant women were told to stop exercise [33]. In this regard, the most frequent guidance method is individualized conversations with a physician during prenatal care, and other approaches involving groups, leaflets, video, and other health professionals (e.g., physical therapists, physical educators, nurses) were minimal [33]. During each prenatal care visit, medical professionals must address multiple issues, leading to a low prioritization of exercise and pointing to the lack of a multidisciplinary team in prenatal care [32]. Furthermore, Nascimento et al. [32] provide suggestions to improve the quality of exercise guidance for pregnant women including the participation of a multidisciplinary team in providing educational strategies, support groups, and education about exercise benefits and safety for both pregnant women and medical professionals involved in prenatal care.

Exercise guidance and recommendations given to pregnant women in prenatal care are a particular issue in health and lifestyle promotion, since women who received some counseling were three times more likely to exercise than those who received no guidance [33]. Indeed, Krans et al. [34] found that the probability that a woman exercised during pregnancy was increased if her obstetrician encouraged her to exercise.

1.3 Public Health and Physical Activity During Pregnancy

1.3.1 Impact of Maternal Physical Activity on Chronic Disease Risk

The recommendations for physical activity in pregnancy are mostly based on evidence that maternal physical activity reduces the risk of pregnancy and birth complications. Sufficient physical activity in pregnancy may reduce the risk of varicose veins, deep vein thrombosis, fatigue, stress, anxiety, and depression [35, 36].

However, for public health, not only pregnancy and birth outcomes are of relevance but also the long-term health of both mother and offspring. Although physical activity has beneficial effects for some pregnancy outcomes as mentioned above, in this part the focus will be on four health parameters that are highly relevant for public health: weight status, glucose metabolism, cardiovascular health, and quality of life. The first three are influenced by both pregnancy and physical activity. Quality of life is related to the other health parameters and therefore indirectly influenced.

Pregnancy is obviously associated with weight gain. Gestational weight gain (GWG) is comprised of the accretion of water, protein (fat-free mass), and fat mass in the fetus as well as the placenta, uterus, and amniotic fluid and expansion of maternal blood volume, mammary gland, and maternal adipose tissue [37]. How much weight women gain, and are recommended to gain, is dependent on their prepregnancy body mass index (BMI = weight (kg)/height $(m)^2$) [38]. However, many women gain more than the recommended weight, especially overweight and obese women [37]. Excessive GWG in pregnancy is associated with a reduced risk for preterm birth but increases the risk for cesarean section, large for gestational age, and macrosomia [39]. Furthermore, excessive GWG is related to a higher risk of obesity in the offspring [40]. The prevention of excessive GWG is therefore relevant for both mother and child. There is a high level of evidence that a higher level of physical activity in pregnancy is related to a lower risk of excessive GWG [41–43].

From a public health perspective, it is especially worrying that excessive GWG is also associated with more weight retention postpartum. Weight retention is the difference between prepregnancy and postpartum weight. Women with excess GWG retain the most weight postpartum, and the excess weight gained in pregnancy is still retained up until 20 years later [44]. Therefore, limiting GWG in pregnancy has a long-lasting effect on the weight development of women and reduces the risk of becoming overweight or obese [45]. Since physical activity in pregnancy reduces the risk of excessive GWG, it seems logical to assume it will also reduce postpartum weight retention. However, currently, there is no convincing evidence that physical activity interventions in pregnancy are effective in reducing weight retention, with some studies finding reduced weight retention after antenatal intervention [46, 47] and others finding no reduction [48, 49]. However, there are relatively few studies that evaluated physical activity interventions that were initiated in pregnancy for the effect on postpartum weight retention. In contrast, there is good evidence that physical activity interventions initiated postpartum are effective in reducing weight retention [50].

Insulin sensitivity is highly influenced by pregnancy (see Chap. 3, [51], physiological changes). When women cannot "cope" with the increased insulin resistance in pregnancy with a sufficient increase in insulin secretion, they develop gestational diabetes mellitus (GDM). Women who start pregnancy with increased insulin resistance (e.g., due to obesity), or those with compromised insulin secretion, are at higher risk of developing GDM [52]. Pregnancy is therefore considered a metabolic "stress test," and women who had GDM during pregnancy have an elevated risk of developing type 2 diabetes postpartum [53].

Many studies on the prevention of gestational diabetes have been conducted in recent years, most of them evaluating an intervention that included a physical activity component. Systematic reviews and meta-analyses of these studies generally conclude that physical activity interventions in pregnancy are effective in reducing the risk of gestational diabetes [43, 54]. However, there are some indications that interventions initiated in the first trimester are effective, but those initiated in the second trimester or later are not [55]. Prevention of GDM does not automatically mean that women will not develop type 2 diabetes later in life, but it stands to reason that they will have a reduced risk of type 2 diabetes when they maintain their increased physical activity levels. Therefore, continued support and counseling on physical activity after a pregnancy complicated by GDM are needed. Unfortunately, this is not routinely implemented in clinical care, and the most effective strategy is unclear yet. A recent review reported inconsistent findings of the 12 studies that addressed the effectiveness of postpartum interventions for the prevention of type 2 diabetes among women with a history of GDM [56].

Also for the cardiovascular system, pregnancy is a stress test. Gestational hypertensive disorders, including gestational hypertension and preeclampsia, are one of the leading causes of maternal morbidity and mortality [57]. Women who develop preeclampsia are at increased risk for chronic hypertension and cardiovascular disease in later life [58]. There is evidence that physical activity interventions in pregnancy reduce the risk of hypertension in pregnancy [42, 59], but have no effect on the risk of preeclampsia [59]. In contrast, observational studies show that physical activity before or in early pregnancy might be related to a lower risk of preeclampsia [60].

Given the evidence of beneficial effects of physical activity in pregnancy on maternal health, it is not surprising that it also has a positive effect on quality of life of the women during pregnancy. Physical activity has been reported to have a positive effect on quality of life, mainly with regard to physical and pain components [61–63], and maternal perception of health status [64]. Whether physical activity in pregnancy also influences the quality of life later in life is unknown, since no information on the long-term consequences for maternal quality of life is available.

1.3.2 Impact of Maternal Physical Activity on Offspring Health

Also in this part, the focus is mostly on the long-term consequences of maternal physical activity on offspring health, since this has the most implications for public health. Important neonatal outcomes, related to health outcomes in later life, are preterm birth (e.g., [65, 66]), small or large for gestational age (SGA and LGA, respectively) [67, 68], and body composition [69].

Physical activity in pregnancy is related to a reduced risk of preterm birth [42, 70–72]. Physical activity might also be related to birth weight, although results might depend on the intensity level. A recent meta-analysis found a small increase in mean birth weight for moderate levels of physical activity and a reduction in high levels of physical activity compared to lower levels [73]. Structured exercise interventions reduced birth weight a little and reduced the risk of LGA, without influencing the risk of SGA babies [74].

No conclusive evidence is available for an effect of physical activity on neonatal body composition, mostly because it is studied relatively little [73]. Observational studies indicate that maternal physical activity might reduce neonatal body fat mass at birth [75–78]. However, one intervention study with high compliance with the exercise intervention did not find a change in offspring fat mass but a reduced lean mass in the intervention group [79].

Long-term relationship of maternal physical activity in pregnancy with offspring obesity [80, 81] or fat percentage [76] has been reported. Other long-term health effects of maternal physical activity are plausible, for instance, through epigenetic changes in the offspring; however, such effects have not been demonstrated in humans yet.

1.4 Correlates of Physical Activity Among Pregnant Women

Given its numerous health benefits for both pregnant women and their children, national and international guidelines have recommended regular physical activity (PA) for all healthy pregnant women since the 1980s [82]. However, only a small proportion of women achieve the recommended levels of PA during pregnancy [33, 83]. In addition, longitudinal studies have shown a decline in PA levels as pregnancy progresses, and PA levels are also lower in pregnant women compared to their non-pregnant counterparts [84, 85].

Therefore, identifying and understanding the factors that explain why some women are regularly physically active during pregnancy, while others are not, is of utmost importance to public health research. Physical activity is a complex behavior determined by the interaction of a large number of personal, social, and environmental factors specific to populations, setting, and type of physical activity. Furthering the understanding of the factors that influence physical activity behavior in specific populations such as pregnant women will aid the development of effective, tailored intervention strategies aimed at increasing the prevalence of physical activity among the pregnant population.

The terms *correlates* and *determinant* are often used synonymously in the literature. *Correlates* are factors statistically associated with or predictive of physical activity but do not imply a causal relationship. *Determinants* are defined as causal factors and derived from experimental or longitudinal studies [86, 87]. Most studies including pregnant women have only assessed the impact of individual correlates (i.e., psychological and biological) on physical activity during pregnancy [88]. Information on interpersonal, societal, environmental, and policy and global factors have barely been studied in pregnant populations.

Correlates and determinants of physical activity may change as pregnancy progresses due to massive bodily changes associated with pregnancy. If we assume that most women reduce their physical activity levels toward the end of their pregnancy, we may also expect correlates of PA to change. It seems that pregnant women shift from high-intensity exercise (i.e., running, ball games, fitness training) to moderate- and low-intensity exercise such as swimming and bicycling.

1.4.1 Identifying Physically Active Pregnant Women

Women who are regularly physically active before pregnancy are much more likely to continue to be regularly physically active during pregnancy [88–93]. Physically active pregnant women also tend to be older and primiparous and have higher education [91, 92, 94–98], compared to those not meeting the recommended levels of physical activity or who are inactive during pregnancy. In addition, overweight or obesity status before pregnancy and pregnancy-related weight gain are shown to be independently associated with regular exercise during pregnancy [90, 91, 97].

In nonpregnant populations, a negative association between age and physical activity has repeatedly been documented [86]. Depending on the outcome of interest, studies including pregnant women have reported both positive and negative associations with maternal age and physical activity [94, 99, 100].

1.4.2 Identifying Physically Inactive Women

Pregnancy-related factors such as gestational duration, multiple pregnancies, pelvic girdle pain, nausea with or without vomiting, assisted reproduction, subfecundity, sick leave, and other musculoskeletal pain are found to be associated with less likelihood of regular physical activity during pregnancy [91, 93, 96].

Only one study to date has reported on correlates of sedentary behavior among pregnant women [101]. Evenson et al. [101] found that women who smoked during pregnancy were more sedentary compared to non-smokers and that sedentary behavior decreased with increasing maternal age.

1.5 Physical Activity Patterns Among Pregnant Women

There is a lack of information on the specific guidelines and real strategies of adaptation of several recreational and sports activities that might be adapted to healthy pregnant women. These issues are further addressed in Chaps. 7, 8, and 9 [102–104]. However, we believe that in order to better develop safe and effective exercise programs, it is necessary to understand, among other variables, the physical activity patterns of pregnant women, the motivations for exercise during pregnancy, and the characteristics of proper exercise. This information will be useful to develop recommendations for pregnancy-specific exercise programs.

Some studies report the prevalence of physical activity during pregnancy, but little references in the literature report the pattern of exercise and leisure time physical activity using well-validated measures [83, 85, 88, 91, 95, 105–114]. Although there are international guidelines for physical activity during pregnancy recommending regular physical activity for healthy pregnant women, either sedentary or previously active, the results of such studies conducted in different countries are not favorable. A deep review of these studies is out of the scope of this chapter, but the respective analysis in general allows to formulate key ideas, as follows.

Regarding the prevalence of physical activity, a high percentage of pregnant women are sedentary; few pregnant women are meeting the international guidelines for physical activity during pregnancy (i.e., completing the minimum of 150 min of aerobic exercise per week); and there is an increasing decline of exercise and leisure time and work-related physical activities across pregnancy, in comparison with the prepregnancy period, especially in the first and third trimesters. Considering that the prevalence of PA is lower in the first and the third trimesters, and higher in the second trimester, only few women remain active throughout pregnancy, in accordance with the latest review on the topic, by Nascimento et al. [115]. Tavares et al. [116] and Linch et al. [117] reported that women tend to replace moderate-intensity activities with light-intensity or sedentary activities during pregnancy. Furthermore, the reduction in physical activity level occurred not only in the level of exercise but also in daily activities, such as housework, childcare, transportation, and occupational activities [115]. According to Gaston and Vamos [33], results indicate that promoting physical activity during pregnancy should remain a public health priority.

Regarding the pattern of physical activity and exercise during pregnancy, walking is the most commonly reported form of exercise, followed by water exercise, swimming, and aerobics. Nevertheless, other types of exercise are also reported, such as dancing, cycling, jogging, resistance training, Pilates, yoga, stretching, and pelvic floor exercises. Although there is insufficient data in the literature to assess the specific effects of these types of exercise, there seems to be a consensus that they are safe and effective and allow a broad span of intensity and complexity to be adapted to pregnant women. Further development of this topic is provided in Chaps. 7, 8, and 9 [102–104].

1.6 Further Research

Although beneficial effects of physical activity in pregnancy on maternal and offspring health are established, some open questions remain. First and foremost, no consensus is reached on the type and intensity of physical activity required, especially for women who start pregnancy obese or very unfit. Second, there is some evidence that the timing of physical activity (intervention) is relevant, with better outcomes for early physical activity (intervention). However, this needs to be researched more systematically. Furthermore, most studies in this field are from developed countries, and voluntary physical activity might have different effects on pregnancy outcomes than nonvoluntary physical activity (e.g., at work or for transport). Reducing physical activity levels according to developing pregnancy and possible pregnancy complaints is not always an option for women from low- to middle-income countries (LMIC). Whether this type of physical activity in pregnancy has the same beneficial effect on maternal and offspring outcomes is grossly understudied.

Although there are international guidelines for physical activity during pregnancy recommending regular physical activity for healthy pregnant women, little is known about the pattern of exercise and physical activity of pregnant women worldwide. Well-designed longitudinal investigations reporting pregnancy-related changes in physical activity by trimester of pregnancy would help to fill this gap. Not only the various designs but also the various instruments used in the studies limit comparisons of studies on the practice of exercise during pregnancy. It would be of particular importance that researchers would use the same precise, reliable, acculturated, and validated instruments for physical activity and exercise measurement, in what concerns to quantity and quality.

Moreover, results indicate a need for more information and motivation for moderate exercise before and throughout pregnancy. Promoting physical activity remains a priority in public health policy, and pregnant women or those planning a pregnancy should be encouraged to maintain an active lifestyle or to adopt a tailored exercise routine during pregnancy in order to avoid sedentary- and obesity-associated risks.

Research on better and more effective physical activity and exercise interventions that improve long-term compliance to a physically active lifestyle during pregnancy is needed. The methods of increasing physical activity in this special population must be developed, implemented, and evaluated.

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Psychological, Social and Behaviour Changes During Pregnancy: Implications for Physical Activity and Exercise

2

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Abstract

Pregnancy is often cited as a time in a woman's life when motivation towards having a healthy lifestyle increases, including a desire to pursue physical activities and improve physical fitness. There is also a growing body of evidence which demonstrates the potential for physical activity to positively influence psychological well-being during pregnancy. However, pregnancy is also a period of intense physical and psychological change. Alongside the many established social and cultural beliefs associated with pregnancy, these changes contribute significant complexities to women's adoption and maintenance of exercise during this time. In this chapter we will examine the current evidence surrounding the psychosocial aspects of an active pregnancy and provide recommendations for providing psychological and behavioural support to women to become or remain active throughout their pregnancy.

Keywords

Pregnancy · Physical activity · Exercise · Psychosocial factors · Behaviour change

2.1 Psychological and Social Changes During Pregnancy

Pregnancy is undoubtedly a unique period in a woman's life. As with the physical changes to a woman's body, pregnancy induces a number of non-physical changes, which may be temporary or endure long after the pregnancy is completed.

2.1.1 Identity

A woman's first experience of pregnancy often causes significant shifts in self-identity [1]; however every pregnancy can be associated with either temporary or permanent changes in perceived roles and identity. During pregnancy women often describe transitioning to a new mothering identity, which in turn disrupts or diminishes existing identities. For example, there may be a change to the woman's perception of her role as a working professional or as a sexually attractive partner [2]. While some women welcome or adapt easily to this new identity, others may have more difficulty accepting these changes or balancing their new role alongside existing ones [3]. These shifting identities have the potential to both positively and negatively influence a woman's engagement with physical activity during her pregnancy. For example, if a woman feels that being sexually attractive is less important to her during pregnancy, she may feel reduced motivation to exercise to maintain a healthy weight or toned physique. Women have reported that pregnancy is a time when they feel 'excused' from striving for the socially constructed ideal aesthetic of the female body [2, 4]. Alternatively, women's behaviour can be driven by a desire to retain elements of their pre-pregnancy self-identity [5]. Hence women who were active pre-pregnancy may wish to continue to exercise if this is important to their sense of self. The new mothering identity may also positively influence women's engagement with an active lifestyle. For example, the desire to protect and nurture their unborn child, as well as an awareness of parents as role models to their offspring, can increase a woman's intentions towards exercise during pregnancy [6]. Women may also experience, consciously or unconsciously, social pressure to outwardly demonstrate their commitment to their unborn child by restructuring their lifestyle, such as eating healthily and reducing alcohol consumption, and generally taking care of their bodies [7]. However, these internal drivers and societal expectations towards doing the best for the baby can also reduce motivation towards being active. For example, concerns over the safety of physical activity and beliefs about the need to rest during pregnancy are often cited as reasons for reducing or ceasing exercise [8].

Case Study: Yolanda

I've been active all my life, and I knew all the benefits of exercising when you're pregnant, so I really wanted to continue with my running and teaching my indoor cycling classes, for as long as I was healthy and felt able to. As soon as my bump started showing, some of the people in my classes said to me, 'Should you still be doing this?' I was a bit shocked that they would say that to someone they didn't really know very well, but even though I knew I wasn't doing anything wrong and my baby was safe, it still made me question myself. And then I thought, if that makes me question if I should be doing those activities—a qualified fitness instructor, who has done all the research and had expert advice about exercising during pregnancy—how would an 'ordinary' woman without that knowledge respond to comments like that? It's no wonder so many women just give up!

2.1.2 Loss of Control

Although women have reported being in awe of the functional adaptations made by their body during pregnancy [2, 9], many women also describe a sense of losing control over their bodies [10] or of their bodies becoming autonomous, automatically and independently doing what is required to create and support a new life [9]. Both the lack of familiarity with their body and the feeling that their body knows best can reduce women's confidence to be physically active. They may no longer be certain how their body will respond to exercise or may interpret the physical sensations they experience during pregnancy as indicating that some activities are not safe or appropriate [5]. Additionally, women may embrace the opportunity to relinquish control over their bodies, viewing pregnancy as a time when it is socially acceptable to reduce their usual self-restraint and to allow nature to take its course [11], for example, reducing exercise and gaining weight. Conversely, some women who have lost or controlled their weight pre-pregnancy report finding the inevitable weight gain associated with pregnancy distressing, expressing feelings of guilt and disappointment at losing their pre-pregnancy shape [12].

While some women describe feeling that their body has 'taken over', research also suggests that some women feel that they are fully responsible for the outcome of their pregnancy, and should anything goes wrong, this will be as a result of their choices and actions [9]. This sense of personal responsibility which is often heightened when achieving pregnancy has not been straightforward, resulting in the woman making significant efforts to seek information and make deliberate behavioural choices aimed at maximising the chances of a successful outcome [5]. This pressure to exert control over their pregnancy can both increase and decrease motivation towards being physically active, depending on whether a woman perceives exercise and activity to be beneficial or risky to her pregnancy.

2.1.3 Cognitive Function

Many women report experiencing some form of cognitive deterioration during pregnancy. For example, women describe being more forgetful or experiencing difficulties in concentrating on a task or performing their usual work-related activities. Although systematic reviews [13] and prospective studies [14] have concluded that there is only limited evidence for impairment of memory or other cognitive functioning during pregnancy, this research does provide some corroboration of women's accounts of 'baby brain'. Several potential causes of these perceived changes in cognitive function have been proposed, including biochemical changes, lifestyle factors and cultural stereotypes [13]; however more research is needed to identify both cause and effect. Regardless of whether the reported effects can be measured objectively, the perceived changes in a woman's mental capacity can be distressing and add to the sense of being less 'herself' since becoming pregnant. This in turn can contribute to changes in a woman's motivation and perceived capability for regular exercise.

2.1.4 Behaviour Changes

Women may seek to adopt or change many behaviours once they become pregnant. Based on local guidelines, antenatal healthcare professionals will advise women on a variety of areas including nutritional supplements, alcohol consumption, smoking and diet. Women may also seek or receive lay advice from friends, family or online communities, as well as information or guidance from websites, books, magazines and other media [15]. In fact, many pregnant women report 'information overload', especially in early pregnancy. Due to the cognitive demands of attempting multiple behaviour changes, it is likely that some changes will be more successful than others, and research suggests that women may view physical activity as low priority [16]. As such, even when motivation to be active during pregnancy is high, women may find pursuing this to be challenging while dealing with so many other changes.

Key Points

- The experience of pregnancy can involve significant psychological, social and behavioural change, which can influence a woman's engagement with physical activities.
- Women may experience social pressure to adopt lifestyle changes which are viewed as nurturing or protective. Beliefs about the relative benefits and risks to the pregnancy of physical activity will influence exercise behaviour.
- A sense of losing control over her body, or experiencing the natural changes to her body, can be disconcerting for women and may reduce confidence to pursue pre-pregnancy activities.

2.2 The Influence of Physical Activity and Exercise on Psychological Well-Being During Pregnancy

The benefits of physical activity on mental health and well-being for the general population have been well documented [17, 18]. For men and women of various ages and life stages, physical activity has been shown to be beneficial for reducing depressive symptoms [18] and anxiety symptoms [19] as well as improve sleep [20] and overall well-being [21]. But what about during pregnancy? Do the same psychological benefits of exercise exist? Let's look at the current level of evidence that has investigated the relationship between physical activity and the aforementioned psychological factors (e.g., depressive and anxiety symptoms, sleep and overall well-being).

2.2.1 Depressive Symptoms

Pregnancy is a time in which women may be at high risk of experiencing depression and/or depressive symptoms [22]. Considering antenatal depression can lead to premature labour, higher infant stress hormone levels and reduced attachment and mother-child bonding [23], it is important to identify strategies to prevent and/or manage depressive symptoms during pregnancy. Pregnant women are sometimes reluctant to use or be prescribed antidepressant medication during pregnancy due to concerns about potential side effects [24] and therefore seek out alternative therapies to alleviate depressive symptoms, which may include physical activity.

Unlike that of the general population, there is currently limited evidence which investigates the link between physical activity during pregnancy and risk of depression (either antenatal or postnatal depression). A recent systematic review of intervention studies [25] identified just six studies that have investigated the effectiveness of exercise trials on antenatal depression and concluded a small to moderate effect of physical activity on reducing depressive symptoms during pregnancy. Further, a previous narrative review identified six observational studies that investigated the association between physical activity during pregnancy and depression [26], with most of those studies demonstrating an inverse association between physical activity during pregnancy and depressive symptoms (i.e. physical activity was linked to lower risk of depressive symptoms during pregnancy). Moreover, one other systematic review suggested that there is a small body of evidence that shows that leisure time physical activity during pregnancy may be linked to lower risk of depression in the postpartum period [27].

Although further research investigating the link between physical activity and depression in pregnancy is required, it is noteworthy to mention that of the studies reviewed to date, no studies suggested that physical activity during pregnancy would increase the risk of depression. Rather, both reviews suggested that while there is some evidence to suggest that physical activity during pregnancy may be linked to lower risk of depressive symptoms for the mother, clear-cut conclusions regarding the overall effectiveness of physical activity for preventing and/or treating depression could not be made due to the limited number of studies, as well as the relatively low to moderate quality of existing studies.

2.2.2 Anxiety Symptoms

Anxiety disorders are particularly common during pregnancy [28] and have been shown to be linked to preterm birth and poor neurodevelopmental outcomes (e.g., learning, motor development and behaviour) of children [29]. Like that of depression, anxiety during pregnancy can be managed through medication, counselling and psychotherapy. Yet physical activity/exercise has been suggested as a possible alternative to these treatments. So how effective is physical activity for preventing and/or managing anxiety during pregnancy? While there is some evidence to suggest that physical activity is linked to lower levels of anxiety symptoms in the general population [19], a narrative review of observational studies suggested that there is a very small body of research (i.e. just two studies) to show that physical activity during pregnancy may be linked to lower risk of anxiety/anxiety symptoms [26]. Given that physical activity may benefit mental health through psychological pathways such as *distraction* from negative thoughts and *mastery* of skills and goals [30], it is certainly plausible that physical activity during pregnancy would help to prevent and manage anxiety symptoms. However, further research is needed in order to make clear-cut conclusions.

Case Study: Alana

When I fell pregnant, I was going through an extremely stressful time in my life. I was working full time in a demanding job, in the process of moving house and had other personal issues I was working through. I had always been an active person, and so I used exercise as a way to reduce my stress and anxiety during this time. Before work each morning, I would go for a half-hour walk around a park which was surrounded by bushland and wildlife. Prior to pregnancy I would run 4–5 times per week; however, I felt quite uncomfortable running when I was pregnant and so 'took up' brisk walking instead. As my belly grew, my pace certainly slowed down (particularly up the steep hills!), but I always felt a sense of calmness, happiness and satisfaction after completing my walks. I'm not sure if it was the fresh air, natural environment, music tunes I was listening to or physical activity itself, but I feel that walking is what kept my mental health in check when I was pregnant.

2.2.3 Sleep

Sleep disturbances are often experienced by women during pregnancy, potentially due to hormonal and physiological changes (e.g., discomfort, more frequent urination) [31] as well pregnant women being predisposed to certain sleep disorders (e.g., insomnia, restless leg syndrome) [32]. As an alternative to sleeping pills, which often lead to dependence and other negative effects, physical activity has been proposed as a safer method to improve sleep quality in the general population [33]. Although some studies suggest that vigorous-intensity exercise is linked to better sleep [34], other studies have shown that physical activity undertaken at light to moderate intensity, such as walking, was linked to improved sleep [20, 35], with bouts of activity of 1 h or more linked to longer sleep duration [20].

Amongst pregnant women, the link between physical activity and sleep quality and/or duration has largely not been studied, and evidence is still inconclusive. Cross-sectional studies have shown weak to no evidence of an association [36, 37], while one prospective study has shown that exercise during early pregnancy was linked to greater continuity of sleep [38]. Very few intervention studies have examined the effects of physical activity on sleep during pregnancy, yet of those studies, results have shown that aerobic exercise [39] and yoga [40] were beneficial in improving sleep quality (e.g., reducing insomnia symptoms, increasing continuity of sleep). It is clear that further studies are needed to enable evidence-based conclusions regarding physical activity and sleep in pregnancy to be made. However, given that those with the strongest study design (i.e. experimental studies) have shown positive results on the effect of physical activity and sleep quality in pregnancy, physical activity could be a promising method for improving sleep in pregnant women.

2.2.4 Summary

Although evidence is somewhat promising regarding the potential of physical activity for the prevention/treatment of mental health problems and sleep disorders during pregnancy, further research is required to make clear-cut conclusions in this population group. In particular, research is needed to investigate the specific dose (e.g., duration, intensity) and domain (e.g., leisure time, domestic, work, travel) of physical activity for preventing and/or managing symptoms of depression, anxiety and sleep problems during pregnancy, in order to provide guidance on recommendations during the antenatal period.

Key Points
- Much evidence in the general population suggests that leisure time physical activity is beneficial for mental health (i.e. depression and anxiety) and sleep quality.
- Although there is some evidence of positive effect of physical activity on antenatal depressive and anxiety symptoms, very little research has investigated the link between physical activity and depressive and anxiety symptoms during pregnancy.
- Only a handful of studies have investigated the link between physical activity and sleep in pregnant women, with conflicting findings.
- However, no detrimental effects of physical activity on mental health or sleep have been observed within the current body of evidence.

2.3 Psychosocial Barriers and Facilitators to Being Active During Pregnancy

In the general population, adults report a large number of factors that influence their physical activity levels. These factors can be modifiable (i.e. we can change or influence these as health practitioners) or non-modifiable (i.e. we cannot change/influence these as health practitioners, e.g., demographic factors such as age, education, income) and are often categorised as individual, social, physical environmental and policy factors, according to the ecological model of behaviour change [41]. Some pregnant women may report lots of barriers to being active, while others may just report one or two. So let's look at some of the most commonly reported 'modifiable' influences (either barriers or facilitators) on being active during pregnancy.

2.3.1 Individual Factors

Individual factors have been shown to be the most commonly cited barriers to physical activity amongst pregnant women [8, 42]. Physical symptoms of pregnancy, lack of time, and misinformation (about health-related outcomes of antenatal exercise) are amongst the list of key individual factors that influence participation in physical activity during pregnancy.

2.3.2 Physical Symptoms

2.3.2.1 Fatigue

We have already discussed how physical activity may affect sleep. On the flip side of the coin, lack of sleep and fatigue have been cited as barriers to being physically active during pregnancy [42, 43], with one study suggesting that pregnant women rated sleep as more important than being physically active [42]. Another qualitative study showed that 'feeling tired' either due to work or the physical changes experienced in pregnancy was the second most commonly cited barrier to being active during pregnancy [8].

2.3.2.2 Nausea

Experiencing nausea, most commonly as 'morning sickness', has been cited as a key barrier to being physically active during pregnancy [8, 43]. During severe morning sickness, women may not be physically capable of being active. However, some researchers have suggested that being active during pregnancy may potentially help alleviate symptoms of morning sickness [44]. Since the direction of the relationship between morning sickness/nausea and exercise is still unclear, further studies are required to determine the causal pathways.

2.3.2.3 Discomfort, Physical Limitations and High-Risk Pregnancies

The physical demands of pregnancy lead to most women experiencing some level of physical discomfort as their pregnancy progresses, and symptoms such as shortness of breath and musculoskeletal pain or soreness are commonly cited as barriers to being physically active [42]. While these symptoms are normal in healthy pregnancy and may not be considered contraindications to physical activity by exercise professionals, they certainly provide a significant psychological barrier. It should also be noted that a proportion of pregnant women may experience pregnancy-related physical limitations such as severe pelvic and back pain or may be classified as having a 'high-risk' pregnancy (e.g., previous foetal death, reproductive tract abnormalities [45]) which is likely to prevent them from being as physically active as pregnant women without physical limitations or complications [8]. These are important factors to consider when designing physical activity programmes for pregnant women, as a 'one-size-fits-all approach' will never be appropriate (see Chap. 8 for guidance on contraindications and modifications to exercise during pregnancy).

2.3.2.4 Lack of Time

Like that of the general population, having a lack of time to be active is a commonly cited barrier amongst pregnant women [8, 43]. This is often explained by pregnant women having family, childcare and/or work commitments [8, 43] that tend to be prioritised over their own health and well-being. The perceived lack of time during pregnancy may also be linked to the tiredness mentioned above, as women have described having 'shorter days' to fit everything in during pregnancy, due to the increased need for sleep [42].

2.3.2.5 Motivation

Having a lack of motivation to be active is often cited by pregnant women as a barrier to exercise [8, 42]. It may be that the fatigue from the pregnancy and lack of time contribute to lowering motivation levels of pregnant women. Women also appear to defer motivation for physical activity to the postnatal period, as they feel that they will be keen to lose weight after the baby is born, and exercise would contribute to this [42, 46].

On the other hand, some pregnant mothers are motivated to be active in order to protect and nurture their baby [47] or because they perceive labour will be easier if they are fit/physically active [48].

2.3.2.6 Beliefs

Lack of knowledge about the importance of physical activity for health during pregnancy, a lack of understanding of how much and how to exercise safely in pregnancy, is a common barrier to antenatal physical activity [8, 42, 43]. Likewise, often pregnant women suggest that they aren't physically active due to concerns about harming their unborn child [8, 42]. Providing clear, evidence-based information to women about the benefits and 'dispelling myths' [43] of physical activity during pregnancy may be imperative for antenatal health.

2.3.3 Social Factors

Social factors such as social support from friends, family and GPs have been shown in the general population to be important for influencing physical activity. When examining the social factors that may predict physical activity during pregnancy, findings are relatively similar, with perhaps a little more emphasis on GPs and social norms.

2.3.3.1 Social Norms

Social norms refer to behaviour that is seen as socially 'acceptable'. Often pressure is placed on pregnant women by others to ensure that they are 'rested' and 'not overdoing it' or they simply follow what their family and friends have done in their pregnancies [48]. Similarly, women may form perceptions of the type and amount of exercise that are 'good for pregnancy' by observing others' behaviour long before experiencing their own pregnancy [5]. Social norms related to antenatal physical activity can vary amongst cultural groups [43], and therefore information and interventions may need to be tailored to the cultural background of women.

2.3.3.2 Healthcare Professional Advice

Pregnant women often suggest that being provided with a lack of information (or even misinformation) from their doctor has prevented them from being active during their pregnancy [8, 43]. One qualitative study found that women without any health- or pregnancy-related complications were told by their doctor to limit or even discontinue physical activity while they were pregnant [24]. Further, research in South Africa has shown that most (83%) medical practitioners were unaware of what the physical activity recommendations during pregnancy were and very few practitioners (19%) provided women with informational brochures on physical activity during pregnancy [49]. This finding is of concern, given that doctors/GPs are a trusted source of information and are seen as the best mode of providing health-related information to women during pregnancy [50].

2.3.3.3 Social Support

Social support to be active is viewed as an important determinant of antenatal physical activity. Studies suggest that being provided with emotional (e.g., working out together) or informational (e.g., being told by friends that exercise is good during pregnancy) support from friends and/or family acts as a facilitator to antenatal physical activity [48]. On the contrary, a lack of emotional (e.g., no one to exercise with) and of informational social support has been suggested to be a barrier to physical activity during pregnancy [33, 42].

Case Study: Estelle

When I was pregnant, I was well aware of the physical activity guidelines for pregnant women. I was a PE teacher, with a keen interest in sports and exercise, and kept up to date with research in the area. However, when I attended the antenatal education classes run at the hospital, I was told that pregnant women were not to be as active as other women and rather just exercise at a low intensity a couple of times per week. I was quite shocked by the misinformation nurses were providing to women.

2.3.4 Physical Environmental Factors

Environmental factors that are linked to physical activity during pregnancy haven't been as widely cited, nor studied, as individual or social factors [8]. However, physical environmental determinants such as access to transport and facilities, as well as non-modifiable determinants such as the weather [42, 48], have been suggested to influence physical activity amongst pregnant women.

2.3.4.1 Transport

Having a lack of transport (e.g., not owning a car) has been linked to increased physical activity in pregnant women, as they are required to walk or cycle from place to place [42], and some women choose to walk rather than drive as a means of staying active [48]. Therefore, promoting active transport may be a particularly useful strategy for pregnant women, given that they often cite a lack of time to be active in leisure time. Having said that, women also find a lack of transportation to be a barrier [42], as they are reliant on partners or friends to drive them to facilities (see below). Weather has also been shown to be an influencing factor [48], suggesting that active travel may be a less appealing option during cold and wet seasons.

2.3.4.2 Access to Facilities

Access to facilities that are safe, aesthetically pleasing and inexpensive has been suggested by pregnant women to be an important factor in being physically active [42, 48]. As with the general population, many pregnant women perceive the costs of attending exercise classes or facilities to be unaffordable [51]. Provision of free-to-use facilities such as pleasant walking trails or subsidised access to gyms/leisure centres may be effective methods of supporting women to be active during their pregnancy [48].

2.3.5 Summary

There are a broad range of factors that influence physical activity during pregnancy, which encompass the individual, social and physical environmental constructs of the ecological model for behaviour change. Targeting these constructs and, in particular, focussing on the key barriers/facilitators to antenatal physical activity are important when designing programmes and interventions to enhance physical activity in pregnant women.

Key Points

- Pregnant women report a range of individual, social and environmental influences on physical activity.
- These include factors such as lack of time, physical symptoms of pregnancy, misinformation (from friends, family and health professionals) and social norms.
- Targeting these factors in the design of antenatal physical activity programmes/interventions will increase the chance of changing physical activity behaviours.

2.4 Behaviour Change Strategies

As this chapter has detailed, there are unique and significant challenges to achieving an active lifestyle during pregnancy. However, the psychological and physical benefits (see Chap. 3) provide substantial incentives for women to strive for an active pregnancy and for health and exercise professionals to support those efforts. The following section outlines the evidence from a variety of behaviour change interventions aimed at promoting and supporting physical activity during pregnancy. The following section combines this evidence with theoretically derived behaviour change strategies to suggest a number of practical techniques which could be implemented to support women to achieve their personal physical activity goals.

2.4.1 Systematic Reviews

Only one systematic review to date has specifically examined the effectiveness of behaviour change interventions aimed at maintaining or increasing physical activity during pregnancy [52]. Since physical activity usually declines during pregnancy, increasing physical activity and preventing declines in physical activity levels were both considered 'desirable' outcomes. The review found that eight of the ten interventions reporting changes in physical activity showed a desirable difference between participants in the intervention and those in the control group. In regard to the format of successful physical activity interventions during pregnancy, it was observed that, most ($n = 5$) involved regular face-to-face meetings, half ($n = 4$) focused solely on physical activity (as opposed to an intervention aimed at changing multiple behaviours), and only three were offered over a long time period (i.e. 20 weeks or more). With regard to specific behaviour change techniques employed, all five of the interventions that used 'goals and planning' demonstrated desirable physical activity outcomes. Results were more mixed for other behaviour change techniques (e.g., 'repetition of desired behaviours and substitution of unwanted behaviours' and 'comparison of outcomes/pros and cons'), while two interventions did not use any recognised behaviour change techniques but still demonstrated favourable physical activity outcomes through education alone. The authors concluded that the lack of high-quality intervention studies hampered the ability to draw conclusions about intervention effectiveness [52]. However, by examining the evidence from intervention studies conducted to date, we can gain some insight into potential strategies to support women to remain active during pregnancy.

2.4.2 Walking Interventions

Walking is one of the most commonly reported forms of exercise amongst pregnant women and is recommended as a low-moderate intensity, safe exercise during pregnancy that almost all women should be able to perform. As a natural movement that most women undertake in their everyday activities, many of the psychological barriers to exercise often do not relate to walking, such as concerns about injury, uncertainty about how to perform it or social pressure to avoid overexertion. Walking also requires no specialist equipment or facilities and can be more easily incorporated into a busy lifestyle than attending sessions at a fixed time and location, thereby reducing the pragmatic and financial barriers to exercise.

It is therefore surprising that only a few behavioural interventions have focused on walking as the primary exercise modality. Two short-term (8–10 weeks) trials of unsupervised walking programmes resulted in good adherence to the recommendation to walk for 30 min, three times per week [53, 54]. A trial of a more structured and intensive walking programme (40 min, five times per week) resulted in higher daily steps at 28 weeks of gestation after 10 weeks of intervention; however the effect was no longer significant at 36 weeks [55], suggesting that women found it difficult to maintain recommended levels of walking in late pregnancy. In another trial, women who were overweight or obese, and had low activity levels, were advised to walk 30 min on most days of the week for 20 weeks, starting at between 12 and 15 weeks in gestation [56]. Although women were advised to perform the walking in any setting, they were also provided with treadmills for unsupervised home use. Although results showed some positive outcomes, such as higher frequency and duration of walks in late pregnancy in the intervention group, overall total step counts were not higher in the intervention group compared to controls. The impact of being provided with a treadmill at home is unknown, and the lack of difference in overall step counts between intervention and control may indicate that if women were using the treadmill at home, they may have reduced other forms of walking.

These combined results suggest that provision of a relatively simple exercise programme that can be performed in or around the home, with or without specialist equipment, may be beneficial in supporting women to maintain an active pregnancy.

2.4.3 Supervised Individual or Group Exercise

As previously mentioned, many women are uncertain about how to exercise safely during pregnancy, and concerns about harming the baby are often cited as reasons for reducing or ceasing activity. It is perhaps therefore unsurprising that interventions which provide closely supervised exercise sessions are some of the most successful at increasing and maintaining activity levels during pregnancy. Several trials have shown significant increases in physical activity at completion of the intervention and significantly higher physical activity levels than control groups. These have included the following:

- Walking sessions three times per week for sedentary women. Sessions were supervised by physical education professionals and medical and physiotherapy students, and women wore heart rate monitors throughout [57].
- One 60-min group exercise session per week delivered by a physiotherapist, comprising low-impact aerobics, body weight-based strength exercises and abdominal and pelvic floor exercises, plus a structured home exercise programme of endurance training, strength and balance exercises [58].
- A weekly group exercise session in a community venue, delivered by licenced fitness trainers, comprising aerobic, stretching and strength exercises, plus a rec-

ommended home-based exercise programme and instruction video designed by an exercise physiologist [59].
- Twice weekly 60-min exercise classes at a local gym, delivered by trained instructors [60].
- Supervised stationary cycling sessions three times per week for women with overweight and obesity, including both steady state and interval training [61].
- Two 70-min moderate-intensity exercise sessions per week, delivered by a certified fitness instructor and with a nurse present, plus educational and motivational support [62].

It is likely that these types of interventions are successful because the level of supervision and monitoring reduces women's fears and anxieties around the safety of exercise for her baby. When performed in groups with other pregnant women, participants may also be receiving social support and encouragement from similar others. Additionally, participating in a trial may simply have provided an opportunity to attend a pregnancy-specific exercise session that may not otherwise have been available. It is interesting to note the success of these face-to-face interventions given the previously mentioned findings that lack of time to exercise is a common barrier to being active during pregnancy. These results suggest that while finding the time to attend a supervised exercise session may be challenging, women who do attend may be more successful at remaining active through their pregnancy than those who attempt to be active on their own.

2.4.4 Information and Behavioural Counselling

Some of the successful interventions which have focused on delivering advice about the benefits of being active during pregnancy have also employed behavioural counselling techniques, aimed at facilitating changes to some of the psychosocial determinants of physical activity and exercise behaviour. For example, Jackson et al. [63] successfully used a behavioural assessment, a 'video doctor' computer program and an educational worksheet to deliver tailored nutrition, diet and weight gain education using principles from motivational interviewing. However, Smith et al. [64] tested and found no effect on overall light physical activity or total MET-minutes of exposure to a web-based behavioural intervention based on social cognitive theory [65] on women with low pre-pregnancy activity levels. The intervention included modules on goal setting and action planning, an exercise tracker and a community forum and was compared to exposure to a website which only provided general diet and physical activity guidelines. These mixed results suggest that a digital intervention may have the potential to support women to achieve an active pregnancy, but further research and development are needed.

Other brief interventions include a leaflet [66] or slide show [67] based on protection motivation theory (PMT). Both were intended to increase participants' perceived vulnerability to and severity of negative outcomes associated with low physical activity during pregnancy, by presenting factual information regarding these risks. The leaflet and slide show also included information regarding the benefits of exercise, and practical exercise suggestions, to increase participants' response efficacy (their perception of how effective being physically active will be at reducing the risk of negative outcomes) and self-efficacy (their perception of their own ability to do the required amount of physical activity), respectively. A goal setting section aimed to facilitate participants' implementation of their intentions and the slide show also included planning activities. Results of both trials demonstrated a significant effect on physical activity levels and showed that the interventions had been effective at manipulating most of the PMT constructs. These results indicate that relatively brief interventions which target some of the health beliefs around exercise in pregnancy, and provide tools to help women plan and overcome barriers, may be successful at both increasing and maintaining activity levels during pregnancy.

In contrast, more complex and longer duration interventions have shown mixed results. In a trial of a comprehensive lifestyle advice programme for women with overweight or obesity [68], those in the intervention group received information and advice on diet and physical activity and were encouraged to use goal setting, identification of barriers, problem-solving and self-monitoring as behavioural strategies, over multiple 121 sessions between 20 and 36 weeks of gestation. Some women were also given access to supervised walking sessions. The trial results demonstrated that women in the intervention group had significantly increased their total physical activity, compared with women in the control group. The authors noted that the increase represented an additional 15- to 20-min brisk walking on most days of the week. However this was largely comprised of overall increase in household activity, and access to the supervised walking sessions appeared to have no effect on overall physical activity. In a similar trial comprising both dietary and physical activity elements, women in the intervention group were again encouraged to use goal setting, self-monitoring, problem-solving and identification of barriers, during a series of eight weekly group sessions, and were also provided with tools such as a pedometer, log book and DVD of a pregnancy-specific exercise regime [69]. The results of this trial showed no increase in physical activity in either the intervention or control groups [70]. Thus, in women who have excess weight during pregnancy, alternative strategies may be needed to encourage participation in sport or exercise.

2.4.5 Combined Interventions

A few trials have combined a significant element of behavioural counselling with detailed exercise programmes. Ko et al. [71] tested an intervention which included gym-based exercise sessions with an instructor, a structured home-based exercise programme and a number of behaviour change techniques delivered both face to face and through the mail. At the end of the trial, women in the intervention group showed a slower decline in activity levels as pregnancy progressed, with higher MET-hours per week, and a smaller percentage reported no physical activity, compared to those in the control group. Simmons et al. [72] trialled a behavioural coaching intervention for women with obesity which included face-to-face, telephone and email coaching sessions based on motivational interviewing, a detailed exercise prescription and provision of pedometers and exercise bands. Results showed significantly higher moderate- to vigorous-intensity physical activity in women in the intervention group. Similar results were demonstrated in another intervention which combined free access to a fitness centre, supervised group exercise sessions and coaching by a physiotherapist to help women to integrate physical activity into their daily lives [73].

2.4.6 Summary

In summary, the evidence from interventions to date is far from conclusive and demonstrates that a range of support options may be beneficial, as women are likely to have different experiences, needs and characteristics. Additionally, most trials have focused on women who were inactive or had overweight or obesity prior to becoming pregnant. Therefore, evidence regarding interventions to support active women to maintain their pre-pregnancy activity levels is lacking. However, the research evidence does give some indication that the most successful strategies involve face-to-face support, over a relatively extended time period, and includes behavioural counselling, detailed exercise prescription and provision of specialised equipment or training sessions.

Key Points

- Some women may need and/or want support to adopt or maintain positive physical activity/exercise behaviours during their pregnancy.
- Support strategies should be tailored for the individual woman's preferences and needs. Detailed information and instruction on how to perform safe exercises, ongoing monitoring and feedback from healthcare and/or exercise professionals and access to specialised exercise sessions and/or equipment are likely to be beneficial.
- Interventions may be more successful if they are provided face to face and over the duration of the pregnancy.

2.5 Using Theory to Support Physical Activity in Pregnancy

In this chapter so far we have seen that pregnancy as a life stage can induce unique sets of both motivating factors and barriers for physical activity. Hence while pregnant women may be keen to participate in physical activities for their own well-being and their baby's health, they may struggle to carry out those good intentions. These women may benefit from additional support from their healthcare or exercise professional or even from friends and family. By utilising behaviour change theory, we can identify strategies and tools that are likely to both increase women's motivation and ability to get or stay active during their pregnancy.

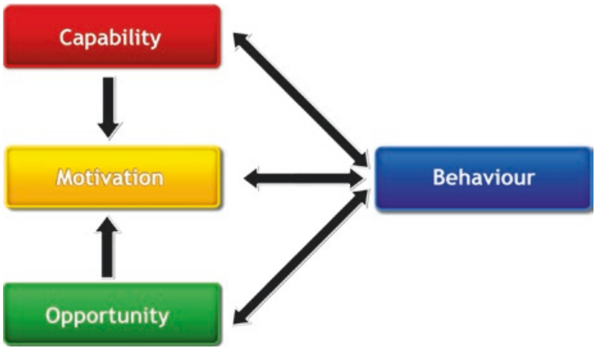

Fig. 2.1 The COM-B model

2.5.1 The COM-B Model

The COM-B model [74] (Fig. 2.1) is a simplified model of behaviour, based on the Theoretical Domains Framework (TDF) [75] which itself was derived from a large number of established theories of behaviour change, with the intention of simplifying and improving the use of theory in informing behaviour change services and programmes. As such the COM-B provides a simple method of understanding the factors which influence a behaviour and identifying specific behaviour change techniques (BCTs) which can affect these factors to increase the likelihood that the desired behaviour will be performed.

The model posits that, in order for a behaviour to occur, an individual must have:

- The capability to do it—this includes both the physical ability and the psychological ability such as knowledge and the ability to work out how to perform the behaviour.
- The opportunity to do it—this includes having physical resources such as time, money, facilities, etc. and the right social environment, e.g., the behaviour is perceived as acceptable or beneficial amongst the individual's social circle.
- The motivation to do it—this motivation may be reflective, based on reasoned assessment of relative value of doing the behaviour compared to not doing it or doing something else, or it may be less conscious more automatic motivation such as internal desires, impulses or reflex reactions.

As shown in the diagram above, perceptions about capability and opportunity can also influence motivation levels. Additionally, an individual's past experience and current behaviour also influence motivation and perceptions of capability and opportunity, which in turn influence the likelihood of undertaking the behaviour in the future. For example, if a pregnant woman learns that exercising is good for her and her baby, she may have increased motivation for being active. However, if she was not good at sports in school and has avoided sport and exercise ever since, her motivation to get active will likely be reduced because she is worried that she will not be good at it. Although the combination of these factors will be unique to every individual woman, we can use the evidence outlined above for the most common barriers and facilitators for physical activity in pregnancy to identify which of these factors will be important and to identify appropriate methods to support women who may otherwise struggle to maintain activity levels through their pregnancy (Table 2.1).

Table 2.1 Common barriers to physical activity during pregnancy and cognitive behavioural strategies to overcome these based on the COM-B constructs

COM-B construct	Common issues	Strategies
Physical capability	Aches and pains, increased weight and other physical symptoms of pregnancy can restrict the types of activities women can participate in	Understand what restrictions (actual or perceived) the woman is facing, and: • Suggest alternative exercises or activities • Provide information regarding which exercises and activities are safe (or not) for her personal situation
	Fatigue, breathlessness and sleep problems can reduce energy levels leaving women feeling less able to exercise	Ask the woman what types of activities she feels able to undertake, and: • Suggest low-intensity activities and activities which can be done in small bouts • Suggest the woman starts with small amounts of low intensity and slowly increases duration, frequency and/or intensity each week
Psychological capability	Lack of knowledge about safe and/or beneficial exercises can reduce women's confidence to be active	Understand the woman's current knowledge, and provide: • Detailed instructions on frequency, intensity, time and type of physical activity. Where possible, include diagrams, videos or demonstrations • Easy-to-understand information about recommendations for an active pregnancy and the benefits to the mum and baby
	The combination of tiredness, mood changes and general cognitive overload can decrease the ability to work through the mental processes needed to carry out physical activity, e.g., making plans or even simply remembering to do it	Reassure the woman that it is normal to experience these physical and/or mental symptoms, and provide: • Planning tools to enable the woman to make specific plans for her physical activity. Encourage her to include as much detail as possible, e.g., when, where, with whom, for how long, etc. Self-monitoring tools like an exercise diary, pedometer or a wearable or smartphone fitness tracker may also be helpful • Suggestions to 'prompt' the woman to be active, for example, reminders in her calendar/on her phone, arranging for a friend or relative to remind/ask her about exercise, etc.

(continued)

Table 2.1 (continued)

COM-B construct	Common issues	Strategies
Physical opportunity	Lack of accessible facilities or pregnancy-specific activities	Reassure the woman that almost all types of physical activity are safe and beneficial and can be accumulated throughout the day in small bouts • Help the woman to identify opportunities within her daily routine to be active, such as walking to work, playing games with her children, doing squats while waiting for a pot to boil, etc. • Provide home-based activities/workouts, which require no specialist equipment and minimum space
	Lack of time and/or money	Where possible: • Provide vouchers or subsidised access to local classes or facilities • Provide classes or activities at times when women are not working or too tired, with childcare facilities
Social opportunity	Social norms are to rest and/or avoid activity during pregnancy	Reassure the woman that being active is recommended for her during pregnancy, and: • Help her to identify a friend, family member or colleague who is willing to exercise/be active with her—encourage her to make arrangements for regular activity sessions together • Encourage her to attend groups/sessions specifically for pregnant women and/or arrange meeting with other pregnant women in an active way, e.g., walk, swim, take children to the park • Encourage providers of activities to promote these to pregnant women • Provide role models who are similar or aspirational and who were active in their pregnancies
Reflective motivation	Inaccurate information or beliefs about exercise during pregnancy	Provide information about the benefits of being active during pregnancy and the increased risks of being inactive. This should be: • Proactively provided, as many women will not ask for it • From a credible source • Easy to understand, consistent and non-judgemental • Focused on all types of physical activity, not just sport or exercise • Not just aimed at pregnant women—e.g., provided preconception or between pregnancies

(continued)

Table 2.1 (continued)

COM-B construct	Common issues	Strategies
Automatic motivation	Women follow the same behaviour of their previous pregnancies, or retain their low activity pre-pregnancy lifestyle, through habit	Encourage the woman to think of this pregnancy as an opportunity for change • Suggest making a list of the 'pros and cons' of being active during this pregnancy • Suggest keeping an exercise diary or using an activity monitor to raise awareness of current activity levels
	Women unconsciously replicate the activity levels/behaviour of their mothers, aunts, sisters and friends	Assure the woman that every pregnancy is unique • Encourage her to try an activity and make a note of how she feels afterwards • Suggest that the woman arranges a reward for herself for achieving her exercise goals

2.6 Conclusion

In this chapter we have examined both the influence of psychosocial factors on women's physical activity during pregnancy and the effect of physical activity on a woman's psychological well-being during her pregnancy. This highlights not only the complexities of achieving and maintaining an active pregnancy but also the significant benefits. Subsequently we examined the evidence for successful strategies to support women's behavioural goals and suggested techniques to remove barriers and increase a woman's ability to stay active during her pregnancy. As every woman is unique, it is vital that interventions and support strategies are tailored to a woman's individual needs. However, an understanding of the multiple psychosocial factors at play is clearly imperative in enabling healthcare and exercise professionals to provide women with appropriate care and advice throughout their pregnancy.

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3 Physiological Changes During Pregnancy: Main Adaptations, Discomforts, and Implications for Physical Activity and Exercise

María Perales, Taniya Singh Nagpal, and Ruben Barakat

Contents

Abstract

Almost the entire female body naturally modifies and changes during pregnancy, and in many cases these modifications occur normally; however there may be imbalances that occur that can cause complications or pathologies.

In fact, pregnancy is known as the most changing period in a human life as there is no other time that produces the same quantity and quality of bodily modi-

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fications. Due to the varied changes the body experiences, pregnancy and childbirth can determine the future well-being of the mother and her child.

The pregnant body must work for 40 weeks to achieve adequate fetal growth and development, and this causes a constant effort to maintain balance in all organs and systems. In summary, due to the many modifications that occur during pregnancy, exercise during pregnancy should be given unique and special considerations when compared to nonpregnant populations. However from a scientific point of view, none of these modifications contradicts exercise in healthy pregnant women without obstetric contraindications.

Keywords
Pregnancy · Physiology · Cardiovascular · Hematologic · Metabolic · Physical activity · Exercise

3.1 Introduction

Almost the entire female body naturally modifies and changes during pregnancy, and in many cases these modifications occur normally; however there may be imbalances that occur that can cause complications or pathologies.

In fact, pregnancy is known as the most changing period in a human life as there is no other time that produces the same quantity and quality of bodily modifications. Due to the varied changes the body experiences, pregnancy and childbirth can determine the future well-being of the mother and her child.

The pregnant body must work for 40 weeks to achieve adequate fetal growth and development, and this causes a constant effort to maintain balance in all organs and systems. In summary, due to the many modifications that occur during pregnancy, exercise during pregnancy should be given unique and special considerations when compared to nonpregnant populations. However from a scientific point of view, none of these modifications contradicts exercise in healthy pregnant women without obstetric contraindications.

3.2 Cardiovascular Changes

The human body during pregnancy changes day by day to continuously adapt its functions to ensure the development of an independent individual [1]. It is essential to optimize maternal health during this period.

The fetus is completely dependent on the mother. In a normal pregnancy, the maternal cardiovascular system undergoes essential changes in its structure and function which are necessary to support fetal demands, and this leads to a considerable amount of stress on the maternal heart [2]. These changes (see Table 3.1) begin around the fifth week of pregnancy and continue until 1 year after delivery [3, 4].

Table 3.1 Main cardiovascular changes during pregnancy

			Trimester		
	Change	Magnitude	First T	Second T	Third T
Hemodynamic changes					
Vascular resistance	↓	30%	↓	↓	↑
Blood volume	↑	40–45%	↑	↑	–
Cardiac output	↑	30–50%	↑	↑	NC
Heart rate	↑	15–30%	↑	↑	↑
Stroke volume	↑	20–30%	↑	↑	NC
Systolic blood pressure	–	–	–	–	–
Diastolic blood pressure	↓	10 mmHg	↓	↓/=	↑
Structural changes					
Aorta artery elasticity	↑	30%	↑	–	–
Heart size	↑	30%	↑	↑	↑
Left atrial	↑	16–40%	↑	↑	↑
Left ventricular					
Left ventricular diastolic dimension	↑	20%	↑	–	–
Left ventricular systolic dimension	↑	10%	↑	↑	↑
Left ventricular wall thickness	↑	15–25%	↑	↑	↑
Left ventricular stress	↑	17%	↑	–	↓
Left ventricular mass	↑	50%	↑	↑	↑
Systolic function	NC				
Diastolic function	↓		↑	↑	↓

NC no consensus

General hemodynamic changes include an increase in maternal heart rate (30%) [5, 6] and blood volume (40–45%) [7]. Red blood cells also increase during pregnancy but less than blood volume (18–25%) [8], and this produces a decrease in hematocrit known as physiological anemia of pregnancy [5].

Hemodynamic alterations continue to occur throughout pregnancy with different changes taking place in each trimester. Total maternal vascular resistance decreases around 30% up to 28 weeks of pregnancy, and then there is a considerable increase until term [6, 9]. This change leads to a reduction in maternal blood pressure (specifically diastolic blood pressure) during the first and second trimester and a normal increase during the third trimester [10, 11].

There is general consensus that maternal cardiac output and stroke volume increase by 30–50% and 20–30%, respectively, in the first and second trimester. However previous literature has been inconsistent on what occurs during the third trimester as some authors report a decrease in cardiac output and stroke volume [5, 6], while there is also research supporting an increase [11, 12] or no variation at all [13–15]. Furthermore it is important to note that most of these hemodynamic changes depend on maternal parity, age, and body mass index (BMI; [16, 17]).

Hemodynamic modifications on the maternal heart persist for a longer time than other hemodynamic and functional changes that occur during pregnancy. The increase in stroke volume is attributed to an increase in blood volume and preload, as demonstrated by the increase in left atrial and left ventricular end-diastolic dimensions, and consequently the size of the heart gradually increases by approximately 30% [5, 18]. A slight increase in the left ventricular systolic dimension is also observed in a normal pregnancy [19].

To minimize stress on the heart, the walls of the heart increase in thickness beginning in the first weeks of gestation [2]. This response leads to a change in geometric left ventricular patterning usually toward eccentric hypertrophy, and this is typically associated with an exercise stimulus and pregnancy. Abnormal structural adaptations may also lead to concentric remodeling or concentric hypertrophy, and this may cause health complications during and after pregnancy [20].

Additional structural modifications include the aorta artery which increases in its flexibility by approximately 30% [21], in response to the normal reduction in total maternal vascular resistance [2].

In regard to maternal heart function, literature has been inconsistent on what potential changes occur with some research suggesting an improvement in systolic function [19]. However there are also reports of impaired systolic function [22] or no change taking place [6, 9]. As pregnancy progresses the heart's capacity to relax increases which implies an enhancement in diastolic function up to the beginning of the third trimester. Following this, a normal decline in diastolic function until labor has been observed [11, 15].

3.2.1 Implications of Exercise During Pregnancy on the Maternal Heart

The changes that occur in the maternal heart during pregnancy are reversible in healthy women, but it is estimated that approximately 1% of pregnancies are complicated by heart disease in Europe [23]. There are some risk factors associated with an unhealthy lifestyle during pregnancy that may compromise maternal and fetal health.

A growing body of evidence supports that adopting or continuing a sedentary lifestyle during pregnancy increases the risk for developing gestational hypertension or diabetes and gaining excessive weight, and these are considered risk factors for heart failure and cardiovascular dysfunction [24]. During labor, physically inactive women show limitations in the intensity and duration of pushes which leads to greater stress on the maternal heart, and this may increase the risk for developing cardiovascular disease later in life [25].

Maintaining or starting to exercise during pregnancy may have great physiological benefits for the mother and the newborn. However it is important to keep in mind some exercise considerations to accommodate for the naturally occurring maternal cardiovascular response to pregnancy and in order to avoid any additional stress on the maternal heart.

3.2.2 Maternal Cardiovascular Response to Exercise

During aerobic exercise vascular resistance is reduced, and this produces an increase in cardiac output, stroke volume, and heart rate [26]. This hemodynamic response depends on gestational age, intensity, modality, and fitness level [27].

Importantly, maximal maternal heart rate is lower in pregnant women compared to nonpregnant women during submaximal exercise [28]. The physiological increase in maternal heart rate at rest, and the maximal heart rate reduction, produces a decrease in maternal heart rate reserve [29]. Exercise programs for pregnant women should control the intensity of the activity not only by a heart rate monitor but also by using the Borg Scale of Perceived Exertion [30] to ensure the safety of the woman.

Maternal position during exercise also plays an essential role in the cardiovascular response. Aortocaval compression occurs when the gravid uterus compresses the maternal abdominal aorta and inferior vena cava. This impedes on venous return which decreases cardiac output and stroke volume and may reduce uteroplacental perfusion resulting in fetal acidosis [31]. This phenomenon occurs in 90% of pregnant women when they adopt a supine position or are lying on their right side [31].

3.2.3 Maternal Cardiovascular Adaptations to Exercise

There is limited evidence on the cardiovascular adaptations that occur in response to exercise during pregnancy [32, 33]. Findings from both studies were consistent, especially in the third trimester where results showed that the effects of exercise are hidden by the physiological pregnancy adaptations. No significant improvement in hemodynamic, functional, or structural results was observed; however authors clarify that moderate regular exercise from late first trimester to term does not produce an additional changes or adverse impact on the maternal heart [32, 33].

A nonsignificant trend was found in regard to maternal heart structure. Sedentary women tend to increase the proportion of abnormal left ventricular patterning, particularly concentric remodeling, which was not observed in active women [33]. This result is potentially relevant because cardiac remodeling during pregnancy is associated with a higher risk for maternal and fetal complications such as preeclampsia, hypertension, and preterm delivery [20].

Regular moderate exercise has also shown to be effective for the prevention of important cardiovascular risks during pregnancy such as antenatal depression and excessive gestational weight gain [33].

Further studies related to cardiovascular adaptations during pregnancy in response to exercise are necessary to clarify the most effective dose of exercise required based on maternal characteristics for the most physiological benefit overall.

3.3 Hematological Changes

Hematological modifications occur in response to pregnancy to meet the bodily requirements for both the mother and growing fetus such as nutrient transport to maintain fetal well-being [34].

Blood volume increases by 45% (1800 ml), and this includes an increase of blood volume or plasma (around 1500 ml) and polycythemia (around 350 ml). This "hemodilution" will maintain adequate uteroplacental flow [35].

An additional gram of iron (daily) is required during pregnancy due to the increase in red blood cells (polycythemia) and fetal-placental iron requirements. This need is more essential from the second half of gestation (extra caution is recommended when engaging in strenuous physical activity) [36].

During pregnancy hemoglobin concentration below 11 g/100 ml is considered anemia. Normal pregnancy in a woman with a deficit of iron reserves can lead to iron deficiency anemia [36].

During pregnancy, there is a decrease in folates, which are essential for fetal development. It is advisable for a woman who is trying to conceive to take a certain amount of folic acid a few months before pregnancy [37].

There is also a state of hypercoagulability (increased fibrinogen and other factors of coagulation). These changes are required for coagulation at the time of delivery. Increase of plasma fibrinogen justifies the elevation for the rate of globular sedimentation. A mild leukocytosis is established in 20% of pregnant women. Lymphocytes decrease in number and in absolute percentage especially at the beginning of pregnancy and continue throughout [36].

3.4 Respiratory Changes

The physiological requirements and normal modifications that occur during pregnancy include a relevant interaction between cardiovascular and respiratory functions. During exercise this interaction also exists [34].

Oxygen and carbon dioxide are transported in both directions between the atmosphere and maternal and fetal cells. This is a complex process with challenges and anatomical and physiological implications that occur due to pregnancy [35].

The changes in the respiratory system cause alterations in anatomical and functional structure. These changes occur in early pregnancy due to hormonal influence and small volumetric alterations. These modifications include variations in lung dimension and capacity and respiratory mechanisms [35, 38].

The upper respiratory tract is (in some cases) affected by changes in the mucosa of the nasopharynx, for example, hyperemia, edema, and excessive secretion. This generates obstructive symptoms for normal breathing functions [36].

Furthermore, as a result of the expansion of the uterus, the average diaphragmatic position when the pregnant woman is standing is elevated by 4 cm [39].

As pregnancy progresses, the growing uterus significantly increases intra-abdominal pressure, and this causes the ribs to become more horizontal. However the ribs compensate for this by increasing the anteroposterior and transverse diameters of the rib cage by approximately 2 cm. The substernal angle is also increased by about 70° in the first trimester and 105° in the final stage of gestation, and the circumference of the thoracic cage increases by about 5–7 cm [39].

At the beginning of pregnancy, the woman breathes more deeply but not more frequently, primarily due to an increase in progesterone. The consequence of this is that alveolar ventilation increases above pregestation values. As there is higher tidal volume, the volume of expiratory reserve decreases, but vital capacity is maintained by a slight increase in inspiratory capacity [36].

Another characteristic of pregnancy at the respiratory level is the increase of oxygen consumption by 10–20% and a reduction in PCO_2. This increases the tidal volume while decreasing the residual volume and functional residual capacity. The combination of reduced residual functional capacity and increased oxygen consumption results in reduced oxygen reserves. There is also an increase in oxygen uptake when breathing due to an increase in diaphragmatic work [36].

The ventilation/minute also increases, resulting in respiratory alkalosis, again in this case due to progesterone and additionally by the increase in estrogen. Despite this respiratory alkalosis, the acid-base state is maintained by compensatory metabolic acidosis. The arterial pH remains at 7.44 as a result of primary respiratory alkalosis and compensatory acidosis. The main purpose of these maternal respiratory mechanisms is to reduce arterial PCO_2 and thus generate a mild maternal alkalosis that ensures placental gas exchange and prevents fetal acidosis [36, 40].

3.5 Metabolic Changes

The body's goal during pregnancy is to ensure fetal growth and development, and this generates continuous adjustments in the maternal metabolic system throughout the 40 weeks of gestation. From a general point of view, normal metabolic processes are altered during pregnancy to adapt to the exact needs of the developing fetus [34, 35, 41].

During pregnancy the protein content in body tissue is increased. Carbohydrates accumulate in the liver, muscles, and placenta. Under the skin fat deposits increase, especially in the chest and buttocks area. The concentration of both types of cholesterol and blood fat is also increased. The pregnant body accumulates salts of various minerals essential for the normal development of the fetus, including calcium, phosphorus, potassium, and iron. In addition, hormonal changes favor the retention of water in tissues [35].

Weight gain is the most obvious change during pregnancy. Usually total maternal weight gain of 10–13 kg was considered as adequate (with many individual variations), although currently the recommendations are based on maternal prepregnancy BMI [34, 42] (Table 3.2).

Many parameters influence maternal weight gain during pregnancy (Table 3.3), including the interstitial fluid and the increase of fatty tissue (deposit).

Maternal weight gain determined by the increase in fat reserves has significant variability. When the total weight gain is 11 kg, the average fat deposit at the end of pregnancy is 1800 g, but it can be much higher (3–4 kg or even more), it can be null or even negative, and this means that the pregnant woman's body consumes the reserve fat that she had previously accumulated [40, 43].

In healthy pregnant women during the first half of gestation (anabolic phase), the weight gain depends mostly on the accumulation of fatty deposits and normal

Table 3.2 Institute of medicine weight gain recommendations for pregnancy

Prepregnancy body mass index category	Recommended intervals of total weight gain (kg)
<18.5	12.5–18
18.5–24.9	11.5–16
25–29.9	7–11.5
≥30	5–9

Table 3.3 Analysis of maternal weight gain during pregnancy [40]

	Weight gain in grams			
	Week 10	Week 20	Week 30	Week 40
Fetus	5	300	1500	3400
Placenta	20	170	430	650
Amniotic fluid	30	350	750	800
Uterus	140	320	600	970
Mamas	45	180	360	405
Blood	100	600	1300	1250
Interstitial liquid	0	30	80	1680
Fat deposits	310	2050	3480	3345
Total weight gain	650	4000	8500	12,500

changes in the maternal body in response to pregnancy. In this phase the contribution that fetal weight has on total maternal weight gain is not significant. As pregnancy progresses, weight gain is primarily due to fetal growth and less due to maternal bodily changes [40].

Fat reserves accumulated in the first half of gestation are used during the third trimester, mainly in the last 4 weeks when the fetus has a rapid increase in body fat percentage. From the biological point of view, maternal weight gain during pregnancy should be lower when prepregnancy BMI is higher; that is, when a woman's fat deposit is higher before pregnancy, her BMI will be greater, and therefore less weight gain is recommended during pregnancy [34].

Metabolism of carbohydrates: In nondiabetic women, pregnancy is associated with profound metabolic changes, which can be studied in both fasting and postprandial situations (after the first intake) [40].

After an overnight fast, glucose levels are lower in pregnant women than nonpregnant women, especially in the second and third trimesters. The decrease in glucose decreases the level of insulin, and this exaggerates ketosis by starvation. Therefore after fasting during pregnancy, the levels of beta-hydroxybutyric acid and acetoacetic acid are higher than in nonpregnant women [40].

When pregnant women are fasting, there is an increase in likelihood for hypoglycemia (very important), hypoinsulinemia, and hyperketonemia. This is due to facilitated diffusion of glucose from the mother to the fetus as a basic mechanism and the existence of a greater volume of maternal distribution for glucose. Thus, in the postprandial state, the maternal response is characterized by hyperinsulinemia, hyperglycemia, hypertriglyceridemia, and decreased sensitivity to insulin (insulin resistance) [40].

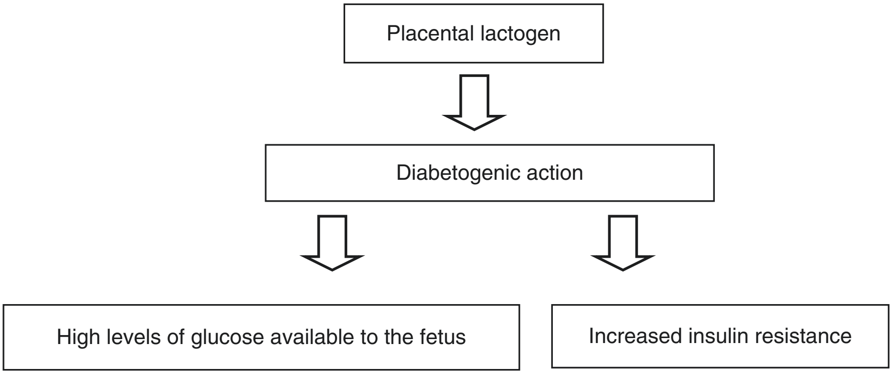

Fig. 3.1 Metabolism of carbohydrates in the second half of pregnancy [40]

Pregnancy is, therefore, a diabetogenic experience. The factors responsible for this diabetogenic effect are placental hormones (placental lactogen), especially in the second half of pregnancy (Fig. 3.1) [34, 35, 40].

Metabolism of fats: Plasma lipids increase in the second half of pregnancy. This increase affects total lipids, cholesterol, phospholipids, and free fatty acids [40].

3.6 Locomotor Changes

Changes in the locomotor system are responsible for many common symptoms during pregnancy. Paresthesia and pain in the upper extremities occur as a consequence of an accentuated cervical lordosis and collapse of the scapular belt. These complications occur more frequently in the third trimester [34, 35, 44].

Traditionally, hyperlordosis has been considered a complication or even a pathology that occurs during pregnancy [34].

Currently, it is considered that this hyperlordosis is only apparent because the pregnant woman compensates for the deviation of her center of gravity, not by means of hyperlordosis but by displacing the entire craniocaudal axis backward (Fig. 3.2). This new position can cause low back pain, especially if there is poor postural hygiene. Occasionally, a lumbosciatica originates due to compression of the sciatic nerve, and this may cause an increase in pain and functional disability [40].

Carpal tunnel syndrome is caused by the compression of the median nerve as it passes through the carpal tunnel on the anterior side of the wrist. It is characterized by pain and paresthesia usually experienced at night in the territory that is innervated by the median nerve, and after delivery this reverts back to its normal state [40].

The rectus abdominis muscles are occasionally separated from the midline, creating a diastasis of the recti of variable extension. Sometimes the uterus is only covered by a thin layer of peritoneum, fascia, and skin [34].

The mobility of the sacroiliac joints increases during pregnancy due to hormonal action, especially due to an increase in relaxin. The increase in joint relaxation can

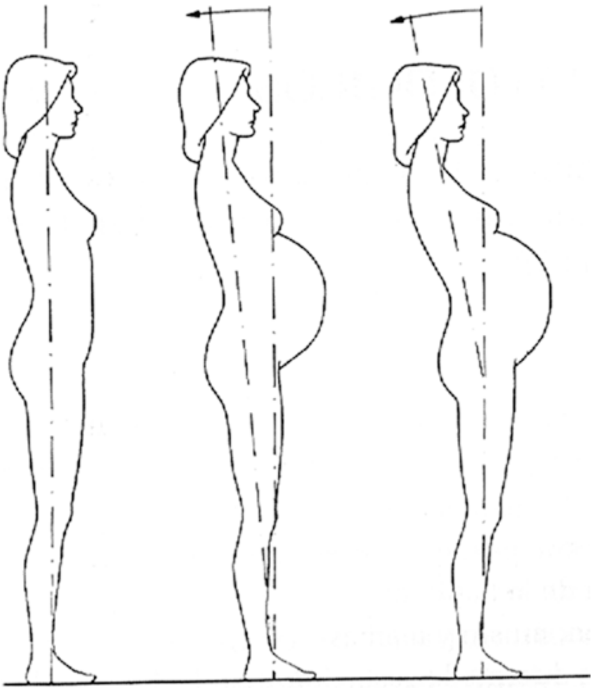

Fig. 3.2 Displacement of the center of gravity [40]

potentially diffuse pain. At the end of pregnancy, paresthesia may occur in the lower extremities (thigh and back of the leg), as a consequence of compressive changes (edema of the sheaths, pressure of the fetal head). In fact this may contribute to the amount and quality of physical activity that a pregnant woman can perform in the final stage of pregnancy [45]. Further development on this topic is in Chap. 5.

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Body Composition Changes During Pregnancy and Effects of Physical Exercise

4

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Abstract

The study of body composition is a fascinating branch of the biological sciences where research and clinical practice go hand in hand. A strong theoretical background is needed to support the assessment and interpretation of body composition measurements, in order to have an impact and usefulness in the clinical setting. Body composition is a key component of health-related fitness with physical, morphological, and particularly important health-related implications during pregnancy. Pregnancy poses a major challenge for the study of body composition, as several techniques and overall methods and related assumptions are often not applicable, and pregnancy therefore requires specific assessment approaches. In the present chapter, we present a look into body composition fundamentals, how body composition can be assessed during pregnancy and what adaptations should be taken into consideration in the assessment and interpretation of body composition data. In the final section of the present chapter, a focus will be put on the effect of exercise on body composition during pregnancy.

Keywords

Pregnancy · Body composition · Assessment · Physical activity · Exercise

4.1 Introduction

The study of body composition is strongly associated to, and sometimes confused for, the study of obesity; however, body composition includes the study of body components far beyond fat mass alone. The present chapter will focus on the challenge of assessing different body composition components in pregnant women and will focus particularly on those components that have been found to show a wide variation during pregnancy and that are associated with health outcomes both during and after pregnancy, for either the mother or the newborn. This includes, of course, body fat (BF), particularly its content and distribution, but also total body water (TBW) and other fat-free mass (FFM) components.

Body composition is considered to be a component of health-related fitness and has physical, morphological, and particularly important health-related implications for the overall, apparently healthy, population [1, 2] including women during and after pregnancy [3–8]. In the final section of the present chapter, a focus will be put on the effect of exercise and its prescription components (frequency, intensity, time, and type plus volume and progression: FITT-VP) on body composition during pregnancy and its body composition-related consequences.

4.2 Body Composition Overview

The field of body composition research can be organized in three interconnecting areas: (1) body composition levels and their organizational rules; (2) body composition methodology; and (3) body composition biological effects [9, 10]. The present chapter focuses on two of these areas: on one hand, this chapter focuses on methodology and aims to highlight the challenge of body composition assessment in pregnancy; on the other hand, this chapter also focuses on the biological effects meaning that it aims to detail the effects of pregnancy and of exercise during pregnancy on body composition and also the effects of variations in body composition on different health outcomes for the pregnant and post-pregnant women and the newborn.

4.2.1 Body Composition Levels

Over the years, a wide variation could be observed in the terminology and methodology used in the study of body composition. The terminology and the five-level model suggested by Wang and colleagues [9] (see Fig. 4.1) was a milestone in the field of body composition research and is still fairly consensual, despite the advances in technology that occurred since. In the five-level model, it is assumed that each component within each level is mutually exclusive and the sum of all components in the same level is equivalent to whole-body mass [9].

The *atomic level* includes 11 major components, including oxygen, hydrogen, carbon, and nitrogen which altogether account for more than 96% of whole-body mass [10]. At the atomic level, the quantification of total body potassium has been widely used in the assessment of body composition in pregnancy [8]. The atoms considered in the mentioned atomic level are the constituents of molecules including water, carbohydrates, proteins, lipids, bone minerals, and soft tissue minerals, which are the six major components at the *molecular level* [10]. This is probably one of the most considered levels in body composition analysis. At the molecular level, it is possible to use multicomponent models for body composition analysis, but the assumptions used in several estimation methods at this level of body composition analysis may prove invalid when used in pregnancy [11], as discussed further in this chapter. The *cellular level* includes three components: extracellular solids,

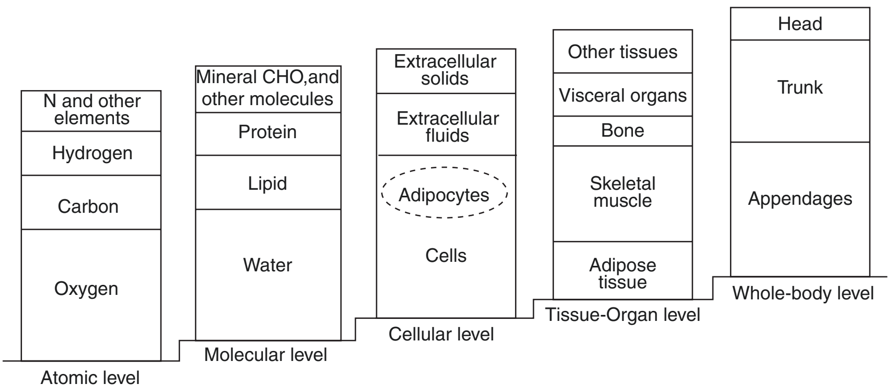

Fig. 4.1 The five-level model in body composition suggested by Wang and colleagues. Adapted from Shen and colleagues [10], pp. 4. *N* nitrogen, *CHO* carbohydrates

extracellular fluids, and cells, which include all body cell mass (including adipocytes). Total body cell mass is often assessed using total body potassium count, as potassium is nearly all intracellular and the estimation of body cell mass can be done from this assumption. The *tissue-organ level* results from the differentiation of cells into tissues and organs, including adipose tissue, skeletal muscle, visceral organs, and bone. To assess body composition at tissue-organ level, image methods are required such as ultrasound or magnetic resonance imaging (MRI). The fifth level, the *whole-body level*, can be assessed using simple measures of weight or height and can also be divided into regions such as the head, limbs, and trunk, which can be assessed with various anthropometric techniques, such as circumferences, skinfolds, and lengths, which are particularly useful in clinical settings.

The five-level model, as proposed by Wang and colleagues [9], presents a clear, consensually accepted framework for the human body composition field (research/analysis/intervention). The biological rationale, criteria, assumptions, and terminology present in the five-level model are assumed as valid for all humans (pregnant and nonpregnant). This is the theoretical framework that is used throughout the present chapter.

4.2.2 Fat and Adipose Tissue

Body fat is a common concern when analyzing human body composition. When one refers to lipids, considered at the molecular level, it is important to acknowledge that this refers to all of such molecules in the body, including essential nonfat lipids (lipids that are not in the form of triglycerides, e.g., phospholipids), both in adipose and other tissues; lipids in the form of triglycerides stored within the adipose tissue; and lipids in the form of triglycerides stored in other tissues. The commonly used word "fat" may be used interchangeably with BF, but is distinguished from adipose tissue. The latter, assessed at the cellular level, refers to the adipocytes, which are cells that comprise BF and nonfat lipids, such as phospholipids, but include also other components essential to the survival and function of these cells (about 80% of adipose tissue is fat and the remainder 20% are water, proteins, and minerals) [12]. The former refers to triglycerides, which are the molecular form in which lipids are stored in the body. BF can be stored in the adipose tissue and in other tissues as well (see Fig. 4.2) [10].

This terminology seems valid in pregnancy and gives a clear approach to these specific components of body composition analysis. This is the biological and terminology framework assumed in the present chapter and considered throughout.

4.2.3 Fat Depots and Adipose Tissue Location

BF distribution analysis started with the study of body shape [13]. At the beginning of the twentieth century, after World War II, insurance companies identified a higher risk of mortality related to certain BF distribution phenotypes [14]. In the conviction

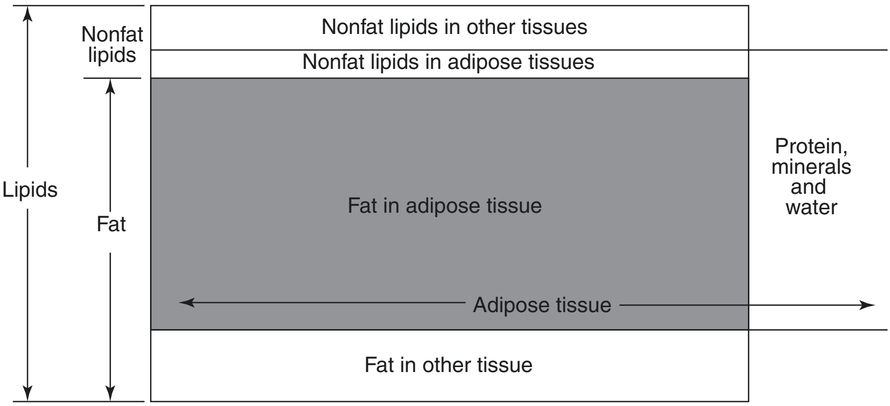

Fig. 4.2 The relationships between molecular-level components lipid and fat and the tissue-organ-level component adipose tissue. Adapted from Shen and colleagues [10], pp. 12

that BF accumulation in different regions of the body could have different predictive values for adverse health outcomes, classifications of BF distribution were developed, such as Vague's classification [15, 16] that distinguished central BF accumulation (android) from peripheral, preferentially lower, BF accumulation (gynoid). BF distribution has long been shown to be related with other adverse outcomes, including diabetes, CVD, and some forms of cancer, besides mortality [14]. BF distribution markers have been suggested to be more consistent and strong predictors of cardiometabolic risk in healthy nonpregnant women, as compared to whole-body markers of generalized adiposity [17], and the potential usefulness of such BF distribution markers for public health has been recognized [18] including in pregnancy [19–22].

Image methods have been assumed as a criterion in the study of BF distribution, yet image methods, often used as reference methods to quantify adipose tissue [23, 24], most often can only assess adipose tissue (as well as other tissues) but not BF [12]. Furthermore, some established image methods, such as DEXA, are prevented from usage during pregnancy due to potentially hazardous radiation exposure [8, 25]. Body composition assessment during pregnancy will be discussed in detail in the next subsection.

Shen and colleagues [12] presented a classification of adipose tissue location, based on image methods, to give coherence to the wide terminology that was being used. In general, adipose tissue is divided into subcutaneous and internal adipose tissue. Significant differences in the biologic behavior of such BF depots have been identified in pregnant as compared with nonpregnant women [26]. Subcutaneous adiposity may be divided into superficial and deep subcutaneous adipose tissue. It has also been given some importance to this division of subcutaneous adipose tissue [27]. Internal adipose tissue can also be further divided into visceral and non-visceral, and these can subsequently be divided into many other specific BF depots, all according to their specific location [12]. Sometimes BF may be stored in the visceral region, outside of adipocytes, near the organs. This is called ectopic fat and seems to have important health implications [28–30]. This terminology was developed using image methods, and some specific adipose tissue locations may prove difficult to assess using other methods (particularly internal adipose tissue), whereas subcutaneous adipose tissue seems fairly accessible for clinical assessment using anthropometric techniques or others.

Along with robust laboratory methods for human body composition assessment, many clinical markers of BF content and distribution have been suggested, including simple anthropometric measurements and resulting calculated body indexes, as discussed ahead in the present chapter. These anthropometric variables and indexes assess body composition at a whole-body level to evaluate body dimensions and morphology and often are used as BF content and distribution surrogates.

4.3 Body Composition During Pregnancy

The study of overweight and obesity has been overwhelming in the field of human body composition research, maybe because of both the pandemic dimension of its prevalence in developed countries [31, 32] and the associated health implications of such widespread condition [14, 33, 34]. The study of body composition in specific subpopulations, such as pregnancy, is not as overwhelming as in the general population or in other specific subpopulations but is still quite enlightening [8]. From the biochemical point of view, pregnancy is, above all, a challenge of body composition in which a being, the mother, is converting a set of nutrients into a new being, the child. The mother is therefore conceiving the first body composition with which her child is going to born with. In order to do that the mother also has to build an adequate milieu in which the fetus can have a healthy development. This includes building up the placenta and increasing body fluid, including amniotic fluid and extra blood volume *to* support the fetus, increasing energy reserves to support the gradual growth and development of the fetus and to support future lactation. All these expansions observed in specific body components during pregnancy have a significant impact on maternal body mass, or weight, and on body composition.

4.3.1 Pregnancy and Obesity

Obesity has been defined as an excess of adipose tissue [1]; however adipose tissue is difficult to assess, requiring expensive and limited access imaging methods such as computed tomography (in which use is prevented during pregnancy due to hazardous radiation exposure) or magnetic resonance imaging [12]. Obesity has also been referred to as an excess of BF [27, 35], which should be easier to estimate than adipose tissue. However the most widely used definition of obesity is “a state of excessive weight” mostly because of the simple and inexpensive marker recommended by most prominent organizations [2, 36–39]: the body mass index (BMI = weight [kg]/height [m]^2). There are no specific BMI cutoffs for the diagnosis of obesity in pregnant women. Obesity must be assessed using prepregnancy

BMI. During pregnancy, for monitoring healthy gestational weight gain, the weight in kilograms is preferred and recommended, instead of BMI. Prepregnancy BMI is usually difficult to assess because most women only attend maternal care after getting pregnant and not before. Prepregnancy BMI is however determinant for defining individual weight gain goals [40]. Individualization for obese women is less specific because healthy gestational weight gain recommendations for each class of prepregnancy obesity are lacking [41].

Obesity is linked to many diseases and morbidities and, ultimately, to higher mortality rates in the nonpregnant [11, 42] and has also been related with hazardous health outcomes during and after pregnancy, both for the mother and the offspring [43]. Pregnancy in women who are obese, as assessed by prepregnancy BMI, is associated with higher risk of gestational diabetes, pregnancy-induced hypertension (including eclampsia and preeclampsia) [44, 45], and hyperemesis gravidarum [46]. Prepregnant obese mothers are also more likely to have fetal deaths [47], stillbirths [48, 49], preterm births [50], neonatal and perinatal death [47], large-for-age neonates [51] and also increased risk of infant death [47], obesity during childhood [52], and congenital heart defects [53] in their offspring. Maternal obesity is also associated with a phenomenon that has been called "developmental overnutrition" of the fetus which is associated with increased fetal skeletal growth and BF accumulation, which may explain the large-for-age neonates and future offspring increased obesity and adiposity levels and, possibly, other adiposity-related cardiometabolic imbalances [54]. It has recently been reported that type 1 diabetes is 20% more common and strikes at younger ages, in children of mothers that were obese as compared to controls, regardless of GWG [55].

Taken together, obesity is a risk factor for women who want to have children as it imposes high risks for both the mother and the offspring both during pregnancy and throughout the life span. This underlies the recommendation of the IOM for overweight and obese women to lose weight before getting pregnant to ensure better health outcomes [40]. The potential for prevention of common diseases in future generations by reducing maternal obesity and excessive weight gain during pregnancy definitely needs to be explored. Nevertheless surplus fat and enlarged adipocytes seem to be the key for altered metabolism and related metabolic impairments in obesity [27, 56, 57], rather than just an excess of body weight alone [58].

4.3.2 Pregnancy and Weight Gain

Weight gain during pregnancy, most often called gestational weight gain (GWG), is expected and important for a healthy pregnancy and pregnancy outcome. Nevertheless, GWG should occur within healthy boundaries. A great deal of importance has been given to GWG, and recommendations exist (Table 4.1) aiming to optimize maternal and offspring health outcomes, as has been reexamined by the Institute of Medicine (IOM) from their original guidelines for weight gain during pregnancy [40]. The importance of having a controlled weight gain during pregnancy has gained increased significance particularly in the current context of

Table 4.1 Recommendation for total and rate of weight gain during pregnancy of singleton fetuses, according to initial BMI

Prepregnancy BMI	Total GWG	GWG in the first trimester	Average rate of GWG in the second and third trimesters	Range rate of GWG in the second and third trimesters
Underweight (BMI < 18.5 kg/m²)	12.5–28.0 kg	0.5–2.0 kg	0.51 kg/week	0.44–0.58 kg/week
Normal weight (BMI = [18.5; 24.9] kg/m²)	11.5–16.0 kg	0.5–2.0 kg	0.42 kg/week	0.35–0.50 kg/week
Overweight (BMI = [25.0; 29.9] kg/m²)	7.0–11.5 kg	0.5–2.0 kg	0.28 kg/week	0.23–0.33 kg/week
Obese (BMI ≥ 30.0 kg/m²)	5.0–9.0 kg	0.5–2.0 kg	0.22 kg/week	0.17–0.27 kg/week

Adapted from the Institute of Medicine [40]
BMI body mass index, *GWG* gestational weight gain

obesity epidemic, mainly because it is recognized that the prevalence of overweight and obesity has increased among women in reproductive age, as has overall BMI and GWG of pregnant women, since the publication of the original guidelines from the IOM in 1990 [59], as acknowledge in their latest review [40], leading to increased risk of adverse pregnancy-related outcomes. It is also recognized that healthy gestational weight gain recommendations for different classes of obesity are lacking [41].

Accordingly guidelines for GWG were published (Table 4.1) presenting recommended GWG ranges and rate, fitted to mother's initial (prepregnant) BMI [40]. Two aspects immediately stand out from IOM guidelines: mothers' prepregnancy BMI is inversely related to recommended GWG, meaning that women with lower prepregnancy BMI may gain more weight during pregnancy than women with higher BMIs and be within GWG guidelines for healthy pregnancies and outcomes; recommended GWG rate tends to be rather slow in the first trimester and increases in a nearly linear fashion throughout the second and third trimesters.

Research has shown prepregnancy BMI to be inversely associated with GWG, meaning that women with higher prepregnancy BMI tend to experience lower GWG [60, 61]. However, conflicting results have been found as well, showing higher GWG (consistently above IOM guidelines) in women with higher prepregnancy BMI, as compared to medium or low prepregnancy BMI women [62]. Taken together, this highlights the importance of an individualized approach and follow-up of pregnancy, regardless of prepregnancy BMI, to keep GWG within a healthy range.

It is important to acknowledge that these guidelines apply only to singleton pregnancies, and specific guidelines should be used for women with a multiple pregnancy. Furthermore, alternative guidelines for whole GWG at pregnancy term have been suggested for pregnant women of twins (Table 4.2), but, in this case, healthy

Table 4.2 Recommendation for total and rate of weight gain during pregnancy of twins, according to initial BMI

Prepregnancy BMI	Total GWG, kg
Underweight (BMI < 18.5 kg/m^2)	12.5–28.0
Normal weight (BMI = [18.5; 24.9] kg/m^2)	17.0–25.0
Overweight (BMI = [25.0; 29.9] kg/m^2)	14.0–3.0
Obese (BMI ≥ 30.0 kg/m^2)	11.0–19.0

Adapted from the Institute of Medicine [40]
BMI body mass index, *GWG* gestational weight gain

recommendations for underweight women, as assessed by prepregnant BMI, are not yet known and, therefore, have not been disclosed [40]. These guidelines reflect the GWG observed between the 25th and 75th percentiles of mothers of twins with ≥2500 kg at term (37–42 weeks of gestation). This means that these guidelines are based on Gaussian normality rather than sound risk-related assessment and healthy outcomes. Furthermore it has been recognized that the study of overall GWG in multiple pregnancies has been considerably neglected [63].

According to IOM guidelines, women who fall outside the recommended GWG experience higher risk of maternal and offspring adverse outcomes [40]. Excessive GWG has been shown to be associated with increased risk of undesired outcomes, including gestational diabetes and resulting fetal macrosomia [64], preterm delivery [65, 66], complications during labor, postpartum weight and BF retention and subsequent maternal obesity [62], and increased risk of unsuccessful breastfeeding [25, 40]. High GWG also seems to increase the risk of obesity in offspring during childhood, but high prepregnancy BMI has a stronger influence [52]. Insulin resistance tends to be higher in pregnant women due to changes in pregnancy-related hormones [67]. This seems to result from a normal adaptation caused by the increase of production of placenta growth hormones which have an insulin resistance effect on the mother [68], possibly to ensure that glucose is available for the fetus and is not all accounted for by the mother. The association of GWG with hypertensive pregnancy disorders is not consistent, and contradictory results have been published [40]; however, it has recently been shown that GWG in the first two trimesters was independently associated with the development of hypertensive pregnancy disorders [69]. Nevertheless, prepregnancy BMI seems to be the strongest correlate with such disorders [69].

It has recently been reported that pregnant women with normal prepregnancy BMI who fall outside the GWG Institute of Medicine guidelines (either gaining too much or too little weight) do not present a higher risk of infant mortality in the first year of life as compared to the ones whose GWG falls within guidelines [70]. It is admitted that higher attention has been given to excess GWG; however, low GWG has been shown to be associated with preterm delivery [65]. To this concern, despite the increasing concordant results in diverse populations of pregnant women [66], conflicting results exist, particularly in under and normal weight pregnant women [71].

As mentioned before, IOM's guidelines recommend less GWG in the first trimester and near linearly increases throughout the second and third trimesters [40].

But not all women follow such a standard pattern within each trimester's recommended GWG and/or GWG rate boundaries and may diverge along part or all of the pregnancy course [72]. Regardless of the total amount of GWG or the GWG rate per specific trimester, less but pertinent attention was given to the pattern of GWG [72]. Because, as elegantly explained by Widen and colleagues [72], two pregnant women can exhibit the exact same amount of total GWG but one may have had a low GWG in early pregnancy and then have a steep increase in GWG later in pregnancy, while others may have had a steady GWG, within IOM's guidelines, throughout the course of pregnancy. Apparently women who show medium to high rate of GWG in the second trimester and high rate of GWG in the third trimester have associated higher gains in BF, estimated to be within 3–5 kg [72]. Regarding the offspring outcomes, women who showed high GWG in the second trimester tend to have bigger newborns at birth, approximately 1 cm more in length and 350 g in weight [72].

The health risks associated with obesity or overweight or even with GWG, including its amount, rate, or pattern, are often attributed to excess or increasing BF in these women. The study of body composition and the composition of GWG is not well explored in pregnancy [72] mostly because assessment is challenging [11], as will be discussed ahead in the present chapter. The next subsection of this chapter will focus on existing literature regarding the variation and correlates of different body components during pregnancy. Furthermore, the study of the composition of GWG is not well explored in pregnancy and warrants further research [72].

4.3.3 Pregnancy and Body Components

As widely mentioned, GWG is expected and important for healthy pregnancies and healthy pregnancy outcomes for the mother and the newborn throughout the life span. However GWG does not occur proportionally in all body components. It has been shown that, on average, FFM tends to increase more than BF through the course of pregnancy (58% vs 42%, respectively), but FFM weight gain is also more reversible than BF after delivery [62]. Increases in total body water (TBW) and FFM, but not BF, were shown to be highly correlated with the birth weight of offspring [62, 73]. This can be a contributing factor for explaining offspring with different birth weights and sizes from mothers with the same prepregnancy BMI and/or GWG, but maybe different pregnancy-related body composition changes. The increase in TBW, protein, and FM seems to be linearly correlated with GWG, but different patterns can be observed [62]. But not all body components show an increase during pregnancy. Bone mineral content (BMC) decreases during pregnancy, resulting in lower values postpartum as compared to prepregnancy [62]. This seems more evident in lower as compared to higher prepregnancy BMI mothers [62]. One could think that pregnant women could recover from this reduction in BMC after delivering, but results show the opposite; BMC tends to continue decreasing after delivery at least up to the 27 weeks postpartum [62]. Furthermore, BMC losses during 9 months of lactation may be fourfold higher than the losses observed during pregnancy [74]. This has been recognized as a significant risk for osteoporosis and morbidity [75]. Regardless of this significant reduction in BMC, it has been shown to be mostly a transient condition, and women frequently recover to their initial BMC [76]. Ultimately these results call for the particular attention given to the pregnancy follow-up, particularly in low BMI women. Women should be advised about the suitable amounts of calcium intake to support the mother and the developing fetus and also about the proper osteoblastotropic amount and type of physical exercise [76, 77]. The kinetics of BMC during pregnancy is not available as it is usually assessed by dual-energy X-ray absorptiometry (DXA) in which use is prevented in pregnant women due to the risk of hazardous exposure to radiation; therefore, it is only used prepregnancy and postpartum [62].

As mentioned earlier, GWG tends to be higher in women with lower prepregnancy BMI [60, 61]. However, it was shown that higher or excessive GWG is primarily attributable to excessive BF increases and not to FFM changes [62, 78]. This was found more pronounced in women with higher prepregnancy BMI, as compared with women with lower prepregnancy BMI, but gestational FFM gain showed no differences between different levels of prepregnancy BMI [62, 78]. This underlines the importance of close monitoring and follow-up of mothers, particularly those with higher prepregnancy BMI, regarding BF. An individualized approach may be key to help mothers keep GWG within healthy range throughout the course of pregnancy. This is particularly important as it was also observed that higher weight and BF retention after delivery were observed in mothers who presented higher GWG and BF increases during pregnancy [62, 79]; FFM and TBW gains during pregnancy were not correlated with weight and BF retention after delivery [60, 62, 80]; prepregnancy BMI was not a determinant of weight and BF retention after delivery [62, 79]; women who gained weight above IMO guidelines retained more weight and more BF after delivery [62]. This underlines the important public health message of adhering to IOM guidelines, including the beginning of pregnancy at a healthy weight and keeping GWG within the recommended range.

The pathophysiological pathway that links BF and related morbidities is still not completely disclosed. Nevertheless it seems rather consistent that the altered metabolism associated with excessive BF, rather than body weight alone, plays a key role in obesity [56, 81–84]. The scientific evidence on the association of maternal body composition with different health outcomes during and after pregnancy is fairly less abundant than that relating prepregnancy BMI or GWG with the same outcomes [25]. During the course of pregnancy, mostly in late pregnancy, it is commonly observed an increase in insulin resistance, which is a normal physiological adaptation to pregnancy [85] mostly induced by placental hormones [68] apparently to limit maternal glucose uptake allowing adequate nutrient supply to the growing fetus [86]. The increase in adipocyte fat content results in increased size and number of adipocytes [87], leading to adipocyte functional changes that result in deregulated secretion of pro-inflammatory cytokines (adipokines). This adipocyte deregulation may contribute to increase inflammation and further increase insulin resistance (IR) [88, 89], possibly leading to GDM [67] and other cardiometabolic risk factors and hazardous outcomes [90, 91]. The abnormal adipokine expression associated with increased overall adiposity or BF [27, 57] is also associated with increased risk of adverse maternal hypertensive disorders, including eclampsia and preeclampsia [92–97]. Visceral adipose tissue, but not subcutaneous adipose tissue, seems to be an important predictor of hyperemesis gravidarum, which is known to be a condition characterized by severe nausea, vomiting, weight loss, and possibly dehydration [46]. Taken together, this highlights the importance of carefully monitoring and managing overall body composition, particularly BF, throughout the course of pregnancy to help diagnose and avoid preventable hazardous risks and enhance pregnancy outcomes.

As noticed BF is not the only body component related with hazardous pregnancy courses and outcomes. Low plasma volume, which can be a consequence of low TBW, may undermine cardiac output, and together this can lead to reduced uterine blood flow and fetal growth restriction [31]. On the other hand, high TBW has been found to be associated with hypertensive pregnancy disorders, including eclampsia and preeclampsia, which may also lead to hazardous outcomes [98]. These findings together underline the importance of keeping TBW within a healthy range throughout the course of pregnancy [32]. The next section focuses on the assessment of body composition during pregnancy.

4.4 Body Composition Assessment in Pregnancy

The assessment of body composition in pregnant women has always been a challenge [11, 33]. This can be attributed to three main reasons [25]: (1) the assumptions and standard references used for nonpregnant often prove to be invalid in pregnant women; (2) available methods for use in pregnancy cannot distinguish mother from fetus body composition; (3) not all body composition assessment methods/instruments are considered safe to be used in pregnancy.

During pregnancy, women show a differentiated growth of several body regions and components resulting in gestational weight gain. One of such body components showing an important and steeper growth during pregnancy is total body water (TBW) [62]. It was shown that FFM increment by the term of pregnancy was about 57% of total pregnancy weight gain for mothers with low or high prepregnancy BMI and 67% for mothers with normal BMI [62]. Increments in TBW represented 85% of total pregnancy FFM gain for mothers with low or normal prepregnancy BMI and 83% for mothers with high prepregnancy BMI. In nonpregnant women, TBW is assumed to represent 73.2% of FFM. However, during pregnancy, TBW increases to a higher proportion of FFM instead of the assumed 73.2% [34]. Bone mineral content tends to decrease during pregnancy [62], which together with the increase in TBW leads to a drop in body density. These changes observed in body composition during pregnancy prevent the use of general assumptions during pregnancy. Strategies to overcome such limitations in pregnancy body composition assessment will be discussed ahead.

Another basic limitation in body composition assessment is the difficulty to distinguish between the mother's body composition and gestational weight gain and that of the fetus, as well as the placenta and amniotic fluid [11, 25]. This makes it particularly challenging to assess the mother's weight, body composition, and relative changes, independently. Therefore most assessment methods usually assume and assess pregnant women as a whole not distinguishing either the fetus or the placenta mass from that of the mother (Fig. 4.3).

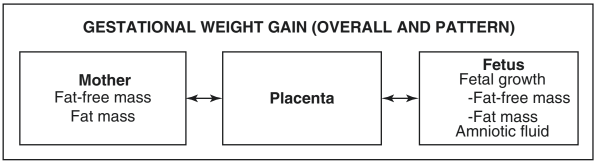

Fig. 4.3 Schematic summary of the components of gestational weight gain [adapted from the Institute of Medicine [40]]

Current methods may help to estimate some components of GWG; particularly up-to-date techniques to estimate fetal mass and body composition based on ultrasound or MRI-based techniques may play an important role to overcome this challenge [99, 100]. However, no significant validation studies have been put out in this field, and the sophistication of such methods, requiring highly specialized professionals and expensive equipment, also limits its broader use [25]. The composition of human placenta has been assessed, and it is known to include on average 87% of water, nearly 11% of protein, and less than 1% of fat [101, 102]. Placenta's composition is substantially different from that of nonpregnant whole-body composition, which underlines the first mentioned limitation regarding profound body composition changes during pregnancy and unusable nonpregnant assumptions during this period. Furthermore placenta molecular composition and mass is hardly assessed during human pregnancy in vivo; it is commonly assessed only at the time of delivery [101, 102]. Current and promising methods will be discussed ahead.

The third reason for body composition assessment to be a challenge during pregnancy lies in the fact that pregnancy is a unique phase of a woman's and new being's life, characterized by a massive and fast cell replication which needs to occur without adverse interferences such as hazardous radiation or others, associated with any assessment-related procedures, that may expose either the fetus or the mother to any avoidable risk [11, 25]. These include mostly imaging methods such as dual-energy X-ray absorptiometry (DXA) or computed tomography (CT) scans [8, 25, 42, 103]. Accordingly, the tools for body composition assessment in pregnancy are limited when compared to what is available and used for the assessment of nonpregnant persons. Considering these challenges and limitations, this section will focus on feasible techniques and methods for the assessment of body composition during pregnancy, particularly on those that are easy and practical for use in clinical practice. A description and brief review regarding each body composition marker will be presented. This subsection is therefore divided into two parts: the first part regards the well-established laboratory methods; the second part regards selected body composition clinical markers such as weight, BMI, body circumferences, and skinfolds.

4.4.1 Instruments and Methods

Different instruments may be required to properly assess body composition during pregnancy. Direct assessment of body composition can only be used in cadavers and is not feasible in humans in vivo. Alternatives to direct assessment of body composition include indirect methods that allow the estimation of specific body constituents.

Based on the previously detailed five-level model presented by Wang and colleagues [9], body composition is assessed in compartment models. The sum of all compartments, in each level, represents the whole-body mass of a person. For each body composition compartment, specific instruments and methods apply. However, it is important to understand that not all instruments and methods are usable during pregnancy mainly for safety reasons but sometimes also for precision reasons. In this section we will discuss the different body composition assessment models and methods and which methods are appropriate to be used during pregnancy in each model.

4.4.2 Laboratory Body Composition Assessment

The five-level model is a cornerstone in the assessment of body composition and is used as a reference [9, 10] including in pregnancy [8, 11]. Accordingly the body is divided into several components or compartments [9]. Most often multi-compartment body composition models analyze body composition at the molecular level, dividing the body into BF, TBW, protein, and minerals. This constitutes the common gold standard four-compartment (4-C) model (e.g., BF + TBW + total body protein + minerals) [10]. But other compartmentalizations can be used under the molecular model: the three-compartment model which usually considers both protein and minerals together in a component that may be called "dry lean mass" (BF + TBW + dry lean mass) and the most widely used two-compartment model (BF + FFM) which is the most often assessed overall [10] but, due to several assumptions implied, proves invalid when using standard conversion factors in pregnancy [25]. The three- and four-compartment models would be better options in terms of precision but are far more difficult and expensive to use and are impractical in clinical settings [8, 25]. These latest multi-compartment models need to be assessed with a combination of laboratory methods [10].

4.4.2.1 Four-Compartment Model

As mentioned earlier, the four-compartment (4-C) model divides the body into four components: BF, TBW, mineral, and protein. The 4-C model is considered to be the reference approach to be used in the validation of other body composition assessment techniques [10]. For the assessment of body components in a 4-C model, it is mandatory to assess at least three components, and the fourth component can be calculated by exclusion, because the sum of all components is equal to whole-body mass [8]. In a 4-C model, each body component needs to be assessed using robust laboratory methods [10].

The reference method for the assessment of TBW uses the dilution principle with stable radiolabeled tracers, or isotopes, such as deuterium dilution [8, 11, 25]. This method needs the collection of a physiologic baseline sample of body fluid, usually urine or saliva. A fixed amount labeled water (e.g., 100 mg/kg of body weight) is then administered. Spot urine samples are then collected. Two methods have been reported for use in the estimation of TBW based on labeled water: the plateau method, which involves the collection of second body fluid sample after a predetermined period (e.g., 4 h) to ensure equilibrium [25, 104], and the back-extrapolation method which involves several collections of body fluid samples during up to 14 days [25, 34, 62]. Collected samples are analyzed using gas-isotope-ratio mass spectrometry [8, 105].

By using a reference method for the assessment of TBW, it is possible to have a considerable amount of confidence that the pregnancy-associated variation in TBW is being controlled and will not introduce significant amounts of error in body composition estimations. However, the assessment of TBW using stable radiolabeled tracers requires highly specialized technicians and expensive laboratory equipment which undermines its feasibility, particularly in clinical settings. Furthermore, pregnant women may not be willing to ingest stable radiolabeled isotopes, which limits the use of this method [25].

Alternative TBW assessment methods have been used during pregnancy, comprising bioelectrical impedance analysis [32, 98, 106] or spectroscopy [107]. However, despite the fact that reference values obtained during pregnancy have been published [32], to our knowledge, validation studies for these techniques against a reference method in pregnant women are lacking [25].

The assessment of body protein in pregnant women is done by calculating cell mass from measurements of total body potassium (TBK) [8]. Gamma radiation spontaneously arises from potassium, and this may be assessed using a whole-body counter [108, 109]. The assessment of gamma radiation allows the quantification of body potassium, and calculations can be done thereafter [8, 110]. Potassium studies do not require administration of exogenous isotopes and do not involve any exposure to exogenous radiation [8, 11] and are therefore considered to be safe and have been used during pregnancy [111]. Whole-body counting requires specific equipment, which is not common and hard to access, and specialized technicians are needed preventing routine usage of this method.

The assessment of body mineral is done using dual-energy X-ray absorptiometry (DXA). Because DXA involves exposure to minimal but potentially hazardous radiation, its use is prevented during pregnancy [8, 25, 42, 103]. Therefore, in order to assess the mineral component of the 4-C model, DXA assessments are made before pregnancy or after delivery, in the assumption that it does not change throughout pregnancy [8, 11, 25, 34]. This assumption however excludes fetal and placenta BMC accretion and does not account for the mother's BMC reduction throughout pregnancy [25, 62]. For this reason the need for further research regarding BMC assessment in pregnancy has been highlighted, and, in the event that significant BMC variation throughout pregnancy is acknowledged, correction factors would need to be developed [25].

Body fat mass may be assessed by exclusion of all other three components from whole-body weight [BF = Body weight − (TBW + Protein + mineral)].

Different approaches to the 4-C model have been used in pregnancy [112]. This includes the use of stable isotopes to assess TBW and pre- or post-pregnancy DXA for mineral and the assessment of body volume to assess body density and BF [113]. Body volume may be assessed using one of two methods: underwater weighing, also known as hydrodensitometry, and air displacement plethysmography (ADP) [25]. Both techniques are well accepted and have been used in pregnancy; however, underwater weighing requires more collaboration from the subject, and ADP has been suggested to be preferable for the assessment of body composition during pregnancy [25, 114]. By using this approach, protein can then be calculated by exclusion [Protein = Body weight − (TBW + Mineral + BF)]. This approach avoids the need of a scintillator for whole-body potassium counting, which may not be available in many labs.

4.4.2.2 Three-Compartment Model

The three-compartment (3-C) model divides the body into three components, usually BF, TBW, and dry FFM (comprising mineral and protein together) [115]. This model, despite being potentially less accurate than the 4-C because it does not account for the ratio between mineral and protein, has the virtue of accounting for variations in TBW which can be the most variable body component during pregnancy [8, 115]. This approach also avoids the need of a scintillator for whole-body potassium counting, which may not be easy to find and use. In this model TBW is assessed as in the 4-C model [8, 11, 25, 60, 115]. The estimation of BF can be done using body density corrected for TBW (Table 4.3) [116]. Dry FFM is calculated by exclusion of the former two components (TBW and BF) from whole-body mass (Dry FFM = body mass − [TBX + BF]) [11, 25, 115].

Other divisions of body components have been used in the 3-C, but usually not in pregnancy, such as that assessed by DXA, which divides the body into BF, mineral, and lean soft tissue (comprising TBW and protein, together).

Table 4.3 Equations for estimation and monitoring of BF, developed and validated for use in pregnancy [116]

Population	Gestational age, weeks	Equations
Pregnant women without edema or with leg edema only	10	BF [kg] = (Weight [kg]/100) × ((496.4/Db [$\times 10^3$ kg/m^3]) − 451.6)
	20	BF [kg] = (Weight [kg]/100) × ((502.2/Db [$\times 10^3$ kg/m^3]) − 458.0)
	30	BF [kg] = (Weight [kg]/100) × ((510.8/Db [$\times 10^3$ kg/m^3]) − 467.5)
	40	BF[kg] = (Weight [kg]/100) × ((522.5/Db [$\times 10^3$ kg/m^3]) − 480.5)
Pregnant women with generalized edema	10	BF [kg] = (Weight [kg]/100) × ((496.4/Db [$\times 10^3$ kg/m^3]) − 451.6)
	20	BF [kg] = (Weight [kg]/100) × ((504.7/Db [$\times 10^3$ kg/m^3]) − 460.8)
	30	BF [kg] = (Weight [kg]/100) × ((518.1/Db [$\times 10^3$ kg/m^3]) − 475.7)
	40	BF [kg] = (Weight [kg]/100) × ((537.3/Db [$\times 10^3$ kg/m^3]) − 497.0)

BF body fat, in kilograms, *Db* body density, in $\times 10^3$ kg/m^3

4.4.2.3 Two-Compartment Model

The two-compartment model divides the body into BF and FFM [10]. Many approaches for the assessment of body composition in a 2-C model use only one instrument to estimate BF and FFM, usually based on the assessment of either body volume [e.g., assessed by hydrodensitometry or ADP [25]] to calculate body density (Body density = Body weight/body volume) and, from there, estimate BF and FFM based on the assumptions of a fixed density of BF (0.9 g/cm^3) and FFM (1.1 g/cm^3) or TBW estimates (e.g., assessed by stable isotope dilution [111] or by bioelectric impedance [107]) that will allow to estimate FFM and, by exclusion, BF based on the assumption of a stable hydration of FFM (TBW = 0.73 × FFM) [10]. As mentioned in previous subsections, several assumptions regarding the relative constancy of FFM composition, used in nonpregnant persons for body composition assessment on a 2-C model, are not valid during pregnancy [115]. The increase in TBW, which is the FFM component with the lowest density (1 g/cm^3), lowers the average overall FFM density. In addition, the decrease in body mineral observed during pregnancy, which is the FFM component with the highest density (about 3.06 g/cm^3), also contributes to a lower average overall FFM density [34, 62]. Taken together, these body composition adaptations to pregnancy limit the use of body density-based methods in a 2-C model. Furthermore, the changes in the proportion of TBW to FFM, which is assumed to be 73% in nonpregnant persons, also make this assumption invalid and therefore not usable during pregnancy, also compromising the use of TBW-based techniques for the assessment of body composition in a 2-C model during pregnancy. Regardless of all the limitations of the 2-C model, it has been reported that, when the estimates of BF are calculated using corrected or gestational age-specific methods, it can produce reliable mean fat estimates for the assessment of larger samples [114, 115]. To account for TBW variation throughout the course of pregnancy, Van Raaij et al. [116] developed a set of gestational age-specific equations to assess FM from assessed body density (Table 4.3). It has recently been recognized that the assessment of BF on a 2-C model using ADP can be reliable in routine assessments also at the individual level [114]. Variations in FFM density have been found to be higher at midpregnancy (week 14) as compared with late pregnancy (week 32) making 2-C model-based assessments more accurate at later stages [103].

4.4.2.4 Non-molecular Model Body Composition Assessment

Different approaches may be used in the assessment of body composition during pregnancy that fall outside the molecular model. Assessments at the cellular level using TBW and TBK or bioelectric impedance, either multifrequency analysis or spectroscopy [107], to assess intra- and extracellular water may give estimates of body cell mass [117]. However, to our knowledge, validation studies for the estimation of body cell mass using these techniques during pregnancy are lacking.

Assessments at the tissue-organ level using imaging methods such as magnetic resonance imaging, or spectroscopy, or even computed tomography may give estimates of local adipose tissue, muscle, and bone area [12]. However, it is important to acknowledge that some image methods involve radiation emissions considered to be potentially hazardous during pregnancy (e.g., computed tomography) and therefore cannot be used to assess pregnant women [8, 25, 42, 103]. The use of ultrasound is widespread during pregnancy to assess mainly fetal development [99, 100], yet it has also been used to assess the mother's body composition, including bone mineral density [118], subcutaneous adipose thickness [119], and visceral fat thickness [120], with promising results. MRI is a reference method to assess different depots of visceral adipose tissue [12], yet has been used in pregnancy mainly to assess malformations or other pregnancy-related problems when other assessments raise suspicion and/or are not conclusive [121]. The advantages of using MRI rely mainly on its confirmed excellent tissue contrast. Although there is no evidence that MRI is harmful during pregnancy, to either the mother or fetus, there still seems to be a lack of consensus as to whether any true risk exists [121]. Recommendations have recognized the acceptance and usefulness of MRI during pregnancy when alternative nonionizing imaging methods are suboptimal or if the information to be obtained by MRI would require more invasive procedures (e.g., biopsy or amniocentesis) [121]. In accordance, to our knowledge, MRI has not been used as a body composition assessment tool in pregnant women, as nonionizing alternatives are available. Furthermore, no significant validation studies have been put out in this field, and the sophistication of such methods, requiring highly specialized professionals and expensive equipment, also limits its broader use [25, 105] making this approach less feasible and desirable [122].

4.4.3 Clinical Markers of Body Composition/Obesity in Pregnancy

This subsection focuses on established and promising clinical markers of body composition including bioelectric impedance, skinfold thickness, body circumferences, as well as body indexes. A description and review regarding each clinical marker will be presented in the following subsections. To better organize the information, this subsection is divided into four parts: the first part regards the well-established BMI; the second part regards the use of bioelectric impedance in clinical settings; the third part focuses on the use of skinfold thickness; and the fourth part reviews selected body circumferences.

4.4.3.1 Body Mass Index

The body mass index (BMI), calculated as weight, in kg, divided by squared height, in meters (BMI = weight [kg]/height [m]^2), is a simple marker of excess body weight, easy to measure, highly precise, and strongly associated with overall fat in nonpregnant people [123]. Accordingly, BMI has been shown to explain 74% and 55% of the variation of whole absolute and relative BF (as assessed by DXA), respectively [124]. Similar results showing a significant relationship between BMI and BF were also found in pregnancy, both in obese [125] and nonobese [126]. The assessment of BMI in pregnancy has however been used mostly to assess hazards in pregnancy, related to prepregnancy obesity [40]. For this reason the recommendations for the assessment and classification of BMI in nonpregnant people should be used for the assessment and classification of prepregnancy BMI [40]. Gestational follow-up and health care usually only begin after the first weeks of pregnancy, and it is sometimes hard to assess prepregnancy BMI. During the course of pregnancy, the progression of body weight, so-called gestational weight gain, has been preferred for follow-up [40], and weight has even been long considered the most feasible and desired measure to use for the monitoring of body composition progression during pregnancy [122].

The endorsement of the use of BMI as a marker for obesity has relied recurrently on same arguments, including the following: BMI measurement is simple, noninvasive, reliable, and inexpensive [127]; BMI is associated with body composition, particularly to fat [128], and is also related with hazardous health outcomes during and after pregnancy for both the mother and the offspring, as reviewed earlier in the present chapter. It is important to acknowledge that BMI assesses body composition at a whole-body level, considering Wang's five-level model [9], and does not assess any specific body composition component, though having, as mentioned, a significant association with generalized fatness [120] but also with different components of lean tissue, such as muscle or bone [21]. Therefore, when assessing obesity, BMI may be deceptive [17]. Even though the usefulness of BMI may be accepted in the assessment of secular trends of the prevalence of obesity at the population level, BMI has been suggested to only provide a crude measurement of total adiposity and does not accurately diagnose obesity, at least at the individual level [124, 129]. The limitations of BMI have been reported extensively [21, 99, 124], and several other markers have been advocated [23, 125, 126], as further detailed.

4.4.3.2 Bioelectric Impedance

Bioelectric impedance has been used during pregnancy, and its usefulness has proven to be encouraging for the assessment of TBW and related impairments [32, 98, 107, 129, 130]. It is important to distinguish between different types of bioelectric impedance devices, despite the fact that all have been used during pregnancy with acceptable results, including single-frequency bioelectric impedance analysis (BIA), which includes the emission of and electric current at a single frequency of 50 kHz [32, 98, 129, 130]; multifrequency BIA, which includes the emission of several electric currents at different fixed frequencies, usually 5 kHz, 50 kHz, 100 kHz, and 200 kHz [127, 128, 131]; and bioelectrical impedance spectroscopy, which uses a spectrum of frequencies usually ranging from 5 kHz to 1 MHz [107]. Bioelectric impedance relies on assumptions and relationships regarding electrical properties of biological tissues and components [25]. It uses a very low amperage electric current that uses the water content of the body as a conductor, to estimate TBW [25]. The bioelectric impedance or resistance offered to the passage of the electrical current through the body tissues allows for estimation of TBW from which estimates of BF and FFM may be derived [25, 116].

Bioelectric impedance has proven to be an inexpensive, fast, simple, and noninvasive method to assess TBW during pregnancy [98, 107, 129, 130], and a prediction model specifically developed to be used during pregnancy for the estimation of

$$TBW = 0.7\,A + 0.051\,B - 0.069\,C - 0.029\,D + 0.043\,E + 2.833$$

A = Height^2 / Impedance

B = Abdominal circumference

C = Weight

D = Reactance

E = Hematocrit

Fig. 4.4 Multiple regression equation to predict total body water (TBW) by using bioelectrical impedance, anthropometric, and biochemical measures specifically in pregnant women (adapted from Lukaski et al. [129])

TWB, using bioelectrical impedance data together with other TBW predictors, was developed based on isotope dilution technique (Fig. 4.4) [129]. Reference values for bioelectric impedance assessments and resulting indexes have also been published for pregnancy [32]. The assessment of TBW, using BIA, may even help to identify, in early gestation, mothers at risk of developing different clinical phenotypes of hypertensive disorders of pregnancy and fetal growth restriction [98, 128]. Estimation of TBW can then be used to assess pregnancy risks (e.g., gestational hypertensive disorders [98] or fetal growth restriction [31]). The use of BIA to directly estimate BF during pregnancy has proven less reliable [114]. In order to assure accurate results and better quality assessments, sound guidelines should be followed for the use of bioelectric impedance [132].

4.4.3.3 Skinfold Thickness

Skinfold thickness (SFT) has been considered a useful clinical tool for the assessment of body composition during pregnancy, particularly in larger samples or in low-resource settings [114]. The use of overall anthropometric methods, including SFT, is considered to be absolutely free from health hazards to the mother and fetus, which is one priority concern, and therefore has been considered to be well accepted by pregnant women [8]. The advantages of SFT have been stated and include being low cost, highly portable, and simple to use and teach [8] and have shown to be considerably accurate as a surrogate of BF during pregnancy [114]. Additionally this technique has the advantage of allowing the monitoring follow-up of local accumulation and distribution of adipose tissue [133]. In spite of all the advantages, the measurement of SFT also has some limitations including the risk of intra- and interobserver errors, which can occur if extensive measurement training and skill is not assured [25]. Nevertheless, it has been reported that, when proper training was present, the measurement of biceps, triceps, and subscapular skinfolds can be reliably obtained, even in overweight and obese pregnant women, by multiple observers, and is suitable for research settings [134]. Another important drawback of SFT in pregnancy is the kinetics of subcutaneous tissue compressibility throughout the course of pregnancy, which is believed to be modified by changed hydration of adipose tissue [8, 25]. Decreased compressibility of SFT in adolescent pregnancy has been reported, resulting in increases in SFT, in spite of no increase in adipose tissue fat content, causing potential BF overestimation [135]. As pregnancy is associated with increasing TBW [62], these decreases in SFT compressibility may be expected to be observed in pregnant women of different ages; however, to our knowledge, this is not yet confirmed.

Despite all limitations of SFT in pregnancy, several SFT sites have been reported to be used during pregnancy, the most established being that of the triceps, biceps, subscapular, and suprailiac [42, 111, 114, 126, 133, 136–145]. In spite of less common SFT sites used in pregnancy, the mid-thigh is also frequently used [42, 140–143, 146]. Several equations, developed in nonpregnant women, for estimation of BF using SFT have been used in pregnancy [136–139], yet equations specifically developed and validated to be used in pregnancy are now available (Table 4.4). Still, available equations are for specific gestational ages, and no equations exist to be used throughout all pregnancy regardless of gestation time. Future studies should focus on establishing sound anthropometric approaches for the estimation of body composition continuously throughout pregnancy and also for the estimation of body composition-related hazards for the mother and the fetus during pregnancy.

Skinfolds tend to increase throughout the course of pregnancy (see Table 4.5). Apparently it is possible to observe increases as soon as early pregnancy and also from this to late pregnancy [146]. This trend has repeatedly been observed but not consistently, as concurring results have also been observed particularly in the upper limbs [42, 148]. Interestingly, women with abnormal glucose tolerance tend to present

Table 4.4 Equations for estimation and monitoring of BF, developed and validated for use in pregnancy

References	Population	Gestational age	Equations
Paxton et al. [42]	White, black, and Hispanic women in New York City, NY, USA	37 weeks	BF [kg] = 0.40 (weight at week 37 [kg]) + 0.16 (biceps SFT at week 37 [mm]) − 0.15 (thigh SFT at week 37 [mm]) – 0.09 (wrist circumference at week 39) + 0.10 (prepregnancy weight [kg]) – 6.56
		14–37 weeks	BF change [kg] = 0.77 (weight change [kg]) + 0.07 (change in thigh SFT [mm]) − 6.13
		14–37 weeks	BF change [kg] = 0.84 (weight change [kg]) − 6.49
Presley et al. [140]	Predominantly white women in Cleveland, OH, USA	30 weeks	BF (kg) = (weight [kg] × 0.33529) + (triceps SFT [mm] × 0.65664) − (subscapular SFT [mm] × 0.4373) + (suprailiac SFT [mm] × 0.43461) − 13.0538
Kannieappan et al. [134]	Overweight and obese women	Between 10th and 20th week	BF (%) = 12.7 + 0.457 × triceps SFT [mm] + 0.352 × subscapular SFT [mm] + 0.103 × biceps SFT [mm] – 0.057 × height + 0.265 × arm circumference [cm]

BF body fat, *SFT* skinfold thickness

Table 4.5 Skinfold thickness dimensions during singleton pregnancy, expressed as mean ± sd (range) [mm, unless otherwise noted]

References	Population	Prepregnancy	<16 weeks	16–28 weeks	>28 weeks
Taggart et al. [111]	Healthy woman from Aberdeen, UK (26.1 ± 3.6 years)	No data	Bic SFT = 7.4 ± 3.1 Tri SFT = 15.7 ± 5.1 Sub SFT = 11.8 ± 4.6 Costal SFT = 11.4 ± 4.7 Thigh SFT = 34.8 ± 10.7 SIliac SFT = 7.9 ± 3.1 Knee SFT = 11.7 ± 3.8 Sum SFT# =	Bic SFT = 8.7 ± 3.8 Tri SFT = 18.0 ± 6.3 Sub SFT = 14.7 ± 4.2 Costal SFT = 16.6 ± 5.5 Thigh SFT = 30.7 ± 11.1 SIliac SFT = 13.6 ± 5.3 Knee SFT = 8.7 ± 2.7	Bic SFT = 8.7 ± 3.8 Tri SFT = 18.0 ± 6.3 Sub SFT = 14.7 ± 4.2 Costal SFT = 16.6 ± 5.5 Thigh SFT = 30.7 ± 11.1 SIliac SFT = 13.6 ± 5.3 Knee SFT = 8.7 ± 2.7
Pipe et al. [111]	Normal weight woman from London, UK (19–40 years)	Normal weight	Sum SFTß = 48.6 ± 10.2	Sum SFTß = 57.7 ± 13.6	Sum SFTß = 59.6 ± 11.5
Catalano et al. [146] [Control]	Healthy lean women from Vermont, USA (control group: *normal* glucose tolerance at baseline)	Sum SFT# = 74.0 ± 14.8 BMI = 20.8 ± 2.3 kg/m^2	Sum SFT# = 89.0 ± 22.4		Sum SFT# = 109.8 ± 19.8
Catalano et al. [146] [AGT]	Healthy lean women from Vermont, USA (*abnormal* glucose tolerance during pregnancy at baseline)	Sum SFT# = 88.7 ± 16.8 BMI = 20.6 ± 1.1 kg/m^2	Sum SFT# = 93.5 ± 18.3		Sum SFT# = 108.9 ± 16.3

Paxton et al. [42]	Ethnic diverse women from New York, USA (26 ± 4.8 years)	UW = 10.5% NW = 61.5% OW = 14.5% Ob = 13.5%	Bic SFT = 15,6 ± 8.4 Tri SFT = 23.5 ± 8.6 Sub SFT = 24.7 ± 11.8 Thigh SFT = 38.5 ± 14.7 Thorax SFT = 19.3 ± 8.1 UIliac SFT = 22.0 ± 9.0 Calf SFT = 23.4 ± 7.1 Chest SFT = 13.0 ± 7.1		Bic SFT = 16.0 ± 8.4 Tri SFT = 24.6 ± 8.5 Sub SFT = 27.7 ± 11.0 Thigh SFT = 43.6 ± 13.4 Thorax SFT = 17.3 ± 6.5 UIliac SFT = 25.7 ± 8.1 Calf SFT = 26.0 ± 7.0 Chest SFT = 13.9 ± 7.9
Soltani et al. [141]	Women from Sheffield, UK NW: 26.44 ± 5.32 years OW: 26.91 ± 4.50 years Ob: 27.68 ± 3.83 years	(NW) BMI = 22.7 ± 1.3 kg/m^2 (OW) BMI = 27.2 ± 1.4 kg/m^2 (Ob) BMI = 34.5 ± 3.54 kg/m^2	(NW) Sum SFT∂ = 84.30 ± 24–31 (OW) Sum SFT∂ = 125.02 ± 22.76 (Ob) Sum SFT∂ = 158 ± 21.52		

(continued)

Table 4.5 (continued)

References	Population	Prepregnancy	<16 weeks	16–28 weeks	>28 weeks
Presley et al. [140]	Two groups of healthy women from Cleveland, Ohio, USA Development group: 30.3 ± 4.4 years Validation group: 30.4 ± 4.5 years	Development group: BMI = 25.8 ± 4.2 kg/m² Validation group: BMI = 27.9 ± 6.2 kg/m²			Development group: Bic SFT = 8.6 ± 5.1 Tri SFT = 18.8 ± 4.7 Sub SFT = 16.2 ± 7.9 Costal SFT = 17.6 ± 7.1 Thigh SFT = 33.4 ± 12.6 SIliac SFT = 15.3 ± 6.8 SPatellar SFT = 10.6 ± 5.4 Validation group: Bic SFT = 8.7 ± 3.8 Tri SFT = 18.0 ± 6.3 Sub SFT = 14.7 ± 4.2 Costal SFT = 16.6 ± 5.5 Thigh SFT = 30.7 ± 11.1 SIliac SFT = 13.6 ± 5.3 SPatellar SFT = 8.7 ± 2.7
Stevens-Simon et al. [135]	Ethnic diverse adolescents from Denver, CO, USA (13–19 years)	BMI = 21.9 ± 5.1 (15.8–36.8) kg/m²	Bic SFT = 10.7 ± 8.0 Tri SFT = 16.2 ± 6.3 Sub SFT = 15.7 ± 7.1 Thigh SFT = 22.2 ± 8.1 Costal SFT = 11.4 ± 5.6 SIliac SFT = 12.3 ± 8.4		Bic SFT = 12.4 ± 6.4 Tri SFT = 20.5 ± 8.8 Sub SFT = 21.5 ± 8.8 Thigh SFT = 27.4 ± 8.3 Costal SFT = 15.7 ± 6.6 SIliac SFT = 17.4 ± 6.9
López et al. [147] [offspring <3 kg]	Urban women from Argentina (19–49 years), offspring birth weight < 3.0 kg	BMI = normal	Bic SFT = 8.3 (7.7–8.9) Tri SFT = 16.1 (15.0–17.3) Sub SFT = 16.9 (15.8–17.9)	Bic SFT = 10.1 (9.4–10-7) Tri SFT = 18.6 (17.5–19.8) Sub SFT = 19.9 (18.8–21.0)	Bic SFT = 11.3 (10.6–11.9) Tri SFT = 19.9 (18.8–20.9) Sub SFT = 21.9 (20.9–22.9)

López et al. [147] [offspring >3 kg]	Urban women from Argentina (19–49 years), offspring birth weight > 3.0 kg	BMI = normal	Bic SFT = 11.0 (10.5–11.5) Tri SFT = 20.6 (19.8–21.4) Sub SFT = 20.7 (19.9–21.5)	Bic SFT = 12.5 (11.9–12.1) Tri SFT = 22.8 (22.9–23.6) Sub SFT = 23.6 (22.7–24.4)	Bic SFT = 13.5 (12.9–14.1) Tri SFT = 24.4 (23.6–25.1) Sub SFT = 25.2 (24.3–26.1)
Kannieappan et al. [134]	Overweight and obese women form Australia (29,7 ± 5.2 years)	BMI = 29.2 (27.6–33.6) kg/m^2	Bic SFT = 13.21 (6.5–21.3) Tri SFT = 24.13 (11.1–38.8) Sub SFT = 25.37 (22.0–47.4)		
Branco et al. [148]	Healthy Caucasian women from Portugal (33.2 ± 1.6 years, range 32–37)	BMI = 22.5 ± 3.1	Bic SFT = 6.8 ± 2.6 Tri SFT = 16.2 ± 3.9 Sub SFT = 11.5 ± 4.4 Thigh SFT = 20.4 ± 7.5 Calf SFT = 13.4 ± 5.7 SIliac SFT = 19.1 ± 4.0 Sum SFT§ = 124.7 ± 24.5	Bic SFT = 6.7 ± 3.1 Tri SFT = 17.5 ± 4.2 Sub SFT = 12.6 ± 4.4 Thigh SFT = 23.4 ± 9.4 Calf SFT = 14,1 ± 6.5 SIliac SFT = 20.7 ± 4.9 Sum SFT§ = 131.5 ± 30.5	Bic SFT = 7.1 ± 2.9 Tri SFT = 16.3 ± 4.4 Sub SFT = 13.3 ± 4.1 Thigh SFT = 23.8 ± 8.1 Costal SFT = 14.3 ± 5.0 SIliac SFT = 19.0 ± 5.1 Sum SFT§ = 130.7 ± 27.7

Sd standard deviation, *Sum SFTβ* sum of four skinfold thickness (biceps, triceps, subscapular, suprailiac), *Sum SFT#* sum of seven skinfold thickness (biceps, triceps, subscapular, costal, suprailiac, mid- and lower-thigh), *BMI* body mass index, *Bic SFT* biceps skinfold thickness, *Tri SFT* triceps skinfold thickness, *Sub SFT* subscapular skinfold thickness, *Thigh SFT* thigh skinfold thickness, *Costal SFT* costal or subcostal skinfold thickness, *SIliac SFT* suprailiac, iliac, or iliac crest skinfold thickness, *UIliac SFT* upper-iliac skinfold thickness, *Calf SFT* calf skinfold thickness, *SPatellar SFT* supra-patellar skinfold thickness, *NO* normal weight, *OW* overweight, *Ob* obese, *(NW) Sum SFT∂* sum of five skinfold thickness (triceps, biceps, subscapular, suprailiac, and mid-thigh), *Sum SFT§* sum of six skinfold thickness (biceps, triceps, subscapular, thigh, calf, suprailiac) consistently higher skinfolds in prepregnancy and early pregnancy [146]. The steeper increase in skinfolds' size observed in late pregnancy, in women who without abnormal glucose tolerance, faded these differences between these two groups [146].

One highly constant of SFT assessment in pregnancy is the high individual variability that can be observed in the literature (see Table 4.5). It should also be acknowledged the terminological/methodological diversity found in the literature. For instance, we have found different names for the same SFT site (e.g., lower-thigh SFT [146] has also been called knee SFT [142] or supra-patellar SFT [140], despite using the same measurement protocol), and also different measurement protocols have been proposed for the same SFT (e.g., suprailiac crest has been measured using varying anatomical landmarks, including (1) at the midpoint between the anterior superior iliac spine and the lowest rib [140–142] and (2) just above the iliac crest in the midaxillary line [111, 114, 148]). This arbitrariness prohibits generalization of skinfold measurement for monitoring pregnancy in clinical settings and also prevents the determination of skinfold measurement reference cutoffs for the identification of abnormal body composition gestation-related changes and the prediction of hazardous health outcomes for both the mother and the fetus. Research and practice should follow standardized guidelines for anthropometric assessment, also in pregnancy.

Bottom line, SFT seem highly valuable for use in clinical practice and may be used to assess body composition of pregnant women in a 2-C model. The high individual variability of SFT throughout the course of pregnancy advises individualization in the follow-up of whole and depot-specific BF during pregnancy [139]. It has been suggested that the use of SFT measurements themselves can be preferred for the assessment and follow-up of adiposity during pregnancy, instead of using SFT to calculate BF and FFM [25]. We recommend the classical standardized protocols from Lohman and colleagues [149] for the assessment of skinfolds to avoid terminological/methodological randomness.

4.4.3.4 Body Circumferences

Body circumferences have been shown to be less skill dependent and have lower interobserver variation, as compared with overall skinfold measurement [150, 151], including in pregnancy [134]. Body circumferences, sometimes called body girths [152], have also been widely used and recommended [2, 18, 37, 153–156], for use in clinical settings. Waist circumference measurement has been extensively used in different settings and populations and is one of the most studied body circumferences [18, 153, 155, 156]; however, its usefulness may be compromised during pregnancy because of the wide morphological and body composition changes in this specific region of the body during pregnancy. Yet, abdominal circumference, as measured horizontally at the level of the navel [149], has been used during pregnancy [98, 129, 141]. Apparently the abdominal circumference is useful in the prediction of TBW, explaining 27% of TBW variation throughout pregnancy, and therefore it has been proposed to be included in a multivariate prediction model of TBW (Fig. 4.4) [129]. Accordingly, both high abdominal circumference and TBW have also been shown to be associated with hypertensive disorders of pregnancy [98, 128].

Table 4.6 Recommended mid-upper arm circumference cutoff values for the diagnosis of increased risk for low birth weight offspring

	16 weeks of gestation	28 weeks of gestation	36 weeks of gestation
Mid-upper arm circumference (cm)	24.5	25.5	26.5

Adapted from Lopez et al. [147]

The circumference of the upper arm, as measured using Lohman and colleagues' guidelines [149], has been recognized as the most relevant circumference measurement to be used in pregnancy [25, 122]. Upper arm circumference has been used for decades in the assessment of malnutrition in diverse populations, including children and overall population in underdeveloped countries, particularly in emergency settings [157–162], and it has been recommended that it should be used more often in nutritional studies [163, 164]. Upper arm circumference has been widely used during pregnancy [114, 134, 147]. It seems highly associated with gestational weight and may even be used as an alternative to weight in settings where a weight scale is not available [147]. Cutoff values for the diagnosis of increased risk for low offspring birth weight have been proposed for mid-upper arm circumference (Table 4.6) [147].

Paxton and colleagues [42] have proposed wrist circumference at the 39th week of gestation to be useful for the calculation of BF, based on a multivariate model (Fig. 4.4); however, the wrist circumference measurement protocol is not disclosed. In the absence of other protocol to be included in Paxton and colleagues' equation (Fig. 4.4), we recommend the measurement of wrist circumference perpendicular to the long axis of the forearm just distal to the styloid process of the radius and ulna, which are easily palpable, as proposed by Lohman and colleagues [149]. Neck circumference seems to be related to the risk of developing maternal hypertensive disorders [165] and gestational diabetes mellitus [166] and, accordingly, has recently been proposed as a promising clinical marker to monitor obesity throughout pregnancy [167]. Other body circumferences have been sparsely used during pregnancy [148] with no confirmed clinical usefulness to date.

4.5 Effect of Exercise on Body Composition in Pregnancy

Participation in physical activity and exercise has been recognized as an important part of a healthy lifestyle and has also been recommended during pregnancy (see Chap. 8). Lifestyle interventions that included exercise have been effective in reducing (excessive) GWG [168, 169]. Group interventions seem particularly valuable for GWG control, as compared to traditional individual approaches [170]. Behavior interventions using behavior change techniques for weight management seem effective to control GWG in obese pregnant women, but not in the overweight and morbidly obese [171]. Specific guidelines regarding exercise prescription to promote healthy GWG lack robust scientific support for the optimal dose/response for each exercise prescription component [169]. Behavioral intervention on physical activity and diet combined has been shown to reduce sum of skinfold thickness in one large RCT [172] but not in another [173]; however, one cannot say whether a possible effect is due to changes in physical activity or diet. Data on the effect of physical activity or exercise alone on specific body components of women during pregnancy is lacking.

Several electronically based (e-based) interventions are starting to be tested during pregnancy [174–176]. An e-based intervention reported that mobile text messaging was useful in controlling GWG in obese mothers [176], yet it has been reported that sending motivational mobile text messages (SMS) did not improve physical activity during pregnancy, regardless of frequency or time, and the use of wearable lifestyle monitors was suggested as preferable [174]. Data reporting the effects on body composition and related outcomes of e-based interventions taking advantage of constant technological development and availability to promote healthy lifestyles, including physical activity, during pregnancy, is not yet available and is expected to increase shortly.

Physical activity has been shown to slightly increase during midpregnancy and abruptly decrease during late pregnancy [177], which is nearly opposite to GWG trajectory. This may advise for trimester-specific physical activity strategies to be tested for enhancing mothers' lifestyles and GWG during pregnancy. Data is lacking to support optimal dose/response exercise prescription to enhance specific components of mothers' body composition during pregnancy [169].

4.6 Conclusion

This chapter reviews body composition rules and fundamentals to support why and how body composition should be assessed during pregnancy. Pregnancy is characterized by profound adaptations and alterations in body composition which must be taken into consideration in the assessment and interpretation of body composition data. Body composition is considered to be a relevant component of health-related fitness and is shown to be predictive of several pregnancy-related risks which underline the importance of carefully monitoring and follow-up fitness component during this exquisite phase of women and new being's life. Even though research regarding body composition during pregnancy is not as overwhelming as in the overall population, it was possible to find and report specific techniques and methods to use in pregnancy to assess body composition and to show specific cutoff values regarding some of these methods. A recent review [178] has highlighted the importance of pregnancy, as an opportunity to protect or enhance current and future health of the mother and the offspring. This was argued to be a cornerstone for the future sustainability of health-care systems, whose will have to increasingly focus on prevention to avoid collapse. From this point of view, exercise seems highly important to promote healthy pregnancies, including assuring a healthy body composition trajectory throughout the course of pregnancy, and is a strong candidate for a core component of pregnancy health care.

4.7 Further Research

Most often, validated methods for the assessment of body composition are proposed for specific gestational ages, and there is the need for finding tools that are simple to use in clinical practice and allow for the assessment of body composition throughout the course of all pregnancy. This topic warrants further research. To our knowledge research focusing on the effect of exercise on specific body components during pregnancy and resulting health outcomes during pregnancy and thereafter are lacking. Future research should consider collecting and reporting more detailed data on women's body composition and how this changes throughout pregnancy and postpartum. Only with such data can the relationship between maternal body composition and related outcomes in mother and child be studied in depth.

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Biomechanical Adaptations of Gait in Pregnancy: Implications for Physical Activity and Exercise

5

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Abstract

During pregnancy, women experience several changes in the body's physiology, morphology, and hormonal system. These changes may affect the balance and body stability and can cause discomfort and pain. The adaptations of the musculoskeletal system due to morphological changes during pregnancy are not fully understood. Few studies clarify the biomechanical changes of gait that occur during pregnancy and in postpartum. The purpose of this chapter is to analyze the available evidence on the biomechanical adaptations of gait that occur throughout pregnancy and in postpartum, specifically with regard to the temporal, spatial, kinematic, and kinetic parameters of gait and balance.

The highlights of this chapter are the following: (1) Pregnancy requires biomechanical adjustments as shown by several publications in the last 20 years. (2) Adaptations due to pregnancy are recognized to provide safety and stability. (3) Most studies performed a temporal, spatial, and kinematic analysis, and few studies performed a kinetic analysis. (4) There is lack of consistency in the results of biomechanical studies due to different methodological approaches. (5) The adaptation strategies to the anatomical and physiological changes throughout pregnancy are still unclear, particularly in a longitudinal perspective and regarding kinetic parameters. (6) The main biomechanical adaptations during pregnancy are gait speed reduction, longer double-support time, and increased step width, and ground reaction forces decrease. (7) There is lack of information regarding the effects of physical activity and exercise, risk of falls, and low back pain on the biomechanical adjustments. (8) Exercise adaptations can be provided in order to increase adherence, safety, and effectiveness.

Keywords

Pregnancy · Postpartum · Biomechanics · Loading · Gait · Balance · Exercise

5.1 Introduction

In the last two decades, the literature has been supporting the recommendation to initiate or continue exercise in most pregnancies [1, 2]. Several benefits of physical activity are evidence based [3], and pregnant women with absence of medical or obstetric complications are advised to accumulate 30 min or more of moderate-intensity activity per day on most, if not all, days of the week [2]. Moreover, an increase in sedentary behavior during pregnancy has been associated with adverse perinatal health outcomes [2, 4, 5].

Pregnancy represents a window of opportunity for the adoption of an active and healthy lifestyle since women are more focused on their own health [6]. However, it is also a risk period for sedentariness, musculoskeletal disorders, and other discomforts [7–16].

Pregnancy leads to several changes in the body's anatomy [17], physiology [18] (see Chap. 3), body composition and morphology (see Chap. 4), and hormonal [19] and musculoskeletal systems of women [17]. Over 38–42 weeks, women experience several changes which are especially visible in increased weight (10–15 kg) [20], an adaptation of the musculoskeletal system, and skeletal alignment. The maternal weight gain, the growth in size and weight of the fetus, and the increase in maternal abdominal and breasts weight and volume lead to an increase in lumbar lordosis, resulting in a shift in the woman's center of gravity [21].

One of the aspects that most influence the musculoskeletal system is the increase in maternal weight. The weight gain during pregnancy is related to several factors, such as the amount of blood, the increased volume of the breasts, and the increased fat mass and extracellular fluid [22]. The fetal tissues, the placenta, and the amniotic fluid are related to the weight gain of the fetus [20]. The variation in weight gain during pregnancy is related to the accretion of protein, fat, water, and minerals, not only in maternal components (blood, mammary and uterine tissues, body composition) but also in the fetal components (fetus, placenta, and amniotic fluid).

The ideal weight gain during pregnancy is related to the women's weight or body mass index (BMI) before pregnancy. The weight gain may range between 12.5 and 18 kg for women underweight ($BMI < 18.5$), between 11.5 and 16 kg for women with normal weight ($18.5 \leq BMI < 25$), between 7 and 11.5 kg for women who are overweight ($25 \leq BMI < 30$), and between 5 and 9 kg for obese women [20]. Further explanation on this topic can be found in Chap. 4.

Anatomical adaptations during pregnancy are related to the 10–15 kg increase in body mass, the enormous size augmentation of the uterus and breasts, and the rib cage expanding laterally [17]. Additionally, the alterations in the hormonal context will influence the musculoskeletal system [19] leading to ligament laxity.

Maternal morphological adaptations to pregnancy are more evident in the trunk, due to enlarged uterus and breasts. Ostgaard et al. [23] referred an increment of abdominal girth and anterior-posterior and transverse trunk breadths. These dimensional increases are also accompanied by adaptations in abdominal muscle structure with increased abdominal muscle length and diastasis recti abdominis [24].

The physical symptoms are common in pregnancy and are predominantly associated with normal physiological changes that occur during this time. However, most women experience some degree of musculoskeletal discomfort [6]. The enlarged uterus will anteriorly displace the center of mass which, in turn, lengthens the moment arm of the pelvic stabilizers, increasing stress in the stabilizers of the pelvic girdle and spine [17]. The changes in spinal curves and pelvic posture are related to increased lumbar lordosis and thoracic and cervical kyphosis. These adaptations will, in turn, stretch the abdominal muscles [17].

There are many anatomical changes during pregnancy that could potentially lead to gait alterations, and those alterations may contribute to musculoskeletal overuse conditions such as back and lower limb pain [25]. Low back pain is more prevalent in pregnant women (25%) than in the general population (6.3%); however, only the pelvic girdle pain (a subgroup of low back pain) is associated with pregnancy [26]. Low back pain is one of the most prevalent conditions during pregnancy [27]. Aldabe et al. [28] stated that the onset of low back pain suggests that there is more influence of biomechanical factors than hormonal adaptations. Further explanation of these topics (low back pain and pelvic girdle pain) can be found in Chap. 6.

Several authors [29, 30] suggested that body composition is associated with alterations of the gait pattern. Thus, it is important to characterize the changes in morphology and gait pattern, which will affect the functionality of the pregnant women.

The changes in human foot morphology and foot function occur throughout the whole life, and the foot has to bear loads during all kinds of bipedal locomotion. Furthermore, disease-dependent modifications can also have an influence on plantar loading, and it is reasonable to assume that foot function will undergo changes in life [31].

Other less visible changes are the increased joint laxity and change in the center of gravity. Altogether, these changes affect the balance and body stability and can cause discomfort and pain [32]. The hormonal and anatomic alterations lead to lower limb adaptations as a kinetic chain, in order to enhance postural stability [17].

Several authors focused on the possible alterations of gait during pregnancy. Such alterations may compromise the dynamic stability of walking and balance. On the other hand, a more variable gait pattern suggests poorer neuromuscular control, possibly leading to a fall [33].

Figure 5.1 shows the main anatomical, morphological, and musculoskeletal adaptations that occur during pregnancy.

Thus, the knowledge about the biomechanical adaptations during the pregnancy period and its consequences on women's gait and physical activity ability is of utmost importance.

The purpose of this chapter is to analyze the available evidence on the biomechanical adaptations of gait that occur throughout pregnancy and in postpartum, specifically with regard to the temporal, spatial, kinematic, and kinetic parameters of gait, as well as the potential implications for exercise prescription.

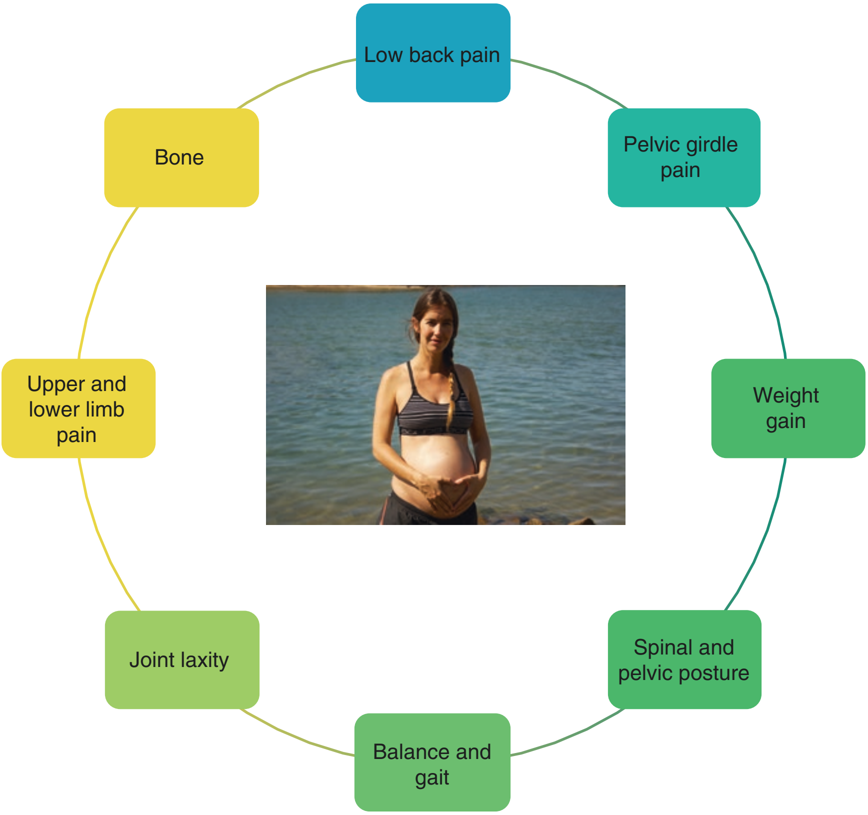

Fig. 5.1 Main anatomical, morphological, and musculoskeletal adaptations that occur during pregnancy

5.2 Understanding the Biomechanical Variables

Biomechanics is one of the disciplines in the field of human movement and exercise science and can be defined as the study of the motion and causes of motion of living things [34], or as the science that examines forces acting upon and within a biological structure and effects produced by such forces [35].

According to Elliott [36], biomechanics can be divided into three broad categories from a research perspective: (1) Clinical biomechanics involves research in the areas of gait, neuromuscular control, tissue mechanics, and movement evaluation during rehabilitation from either injury or disease; (2) occupational biomechanics typically involves research in the areas of ergonomics and human growth or morphology as they influence movement; and (3) research in sports biomechanics may take the form of describing movement from a performance enhancement (such as matching of impulse curves in rowing) or injury reduction perspective (such as the assessment of knee joint loading during downhill walking).

Occupational biomechanics may provide an understanding of the body adaptations occurring during pregnancy while working, actively commuting or walking, and exercising. According to Brüggemann et al. [37], two areas of research are of major interest: (1) the quantification or estimation of mechanical load acting on the biological structures and (2) the study of biological effects of locally acting forces on living tissue, effects such as growth and development or overload and injuries.

The strength of sports biomechanics research is the ability to establish an understanding of causal mechanisms for selected movements (such as the role of internal rotation of the upper arm in striking and the influence of elastic energy and muscle pre-stretch in stretch-shorten-cycle actions). Biomechanics research may also play an integral role in reducing the incidence and severity of sporting injuries, such as identification of the causes of knee joint injuries [36]. The growth of modeling and computer simulation has further enhanced the potential use of sports biomechanics research (such as quantification of the knee joint ligament forces from a dynamic model and, as an example, optimizing gymnastics performance through simulation of in-flight movements).

The morphological, physiological, biomechanical, and hormonal adaptations during pregnancy can influence physical activity and the daily task performance [38], as well as sporting activities and exercise. However, to our knowledge, the main applications of biomechanical studies with pregnant women which are depicted in Fig. 5.2 have been focusing limited motor tasks.

5.2.1 Why Gait Analysis?

Gait analysis or motion analysis of human gait, as one branch of biomechanics, has developed since early studies in the late 1900s of the twentieth century. Motion analysis has been extended during the past two decades to investigate many other activities in addition to gait analysis.

Nevertheless, one of the most studied human movements is gait, since it is the basic natural form of locomotion and it is used throughout the life. Thus, since childhood to elderly, walking is the functional way of moving from one place to another. With growing, the human body will change anatomically, going through different stages of growth, and in adulthood, there is a possible stabilization of its development.

The human body can percept and react in order to adapt to various kinds of environments like stairs, different surfaces, or obstacles. The lower limb segments optimize the energy conservation to exhibit a normal kinematical pattern. And this depends on muscle activation, which is responsible for producing a certain angular

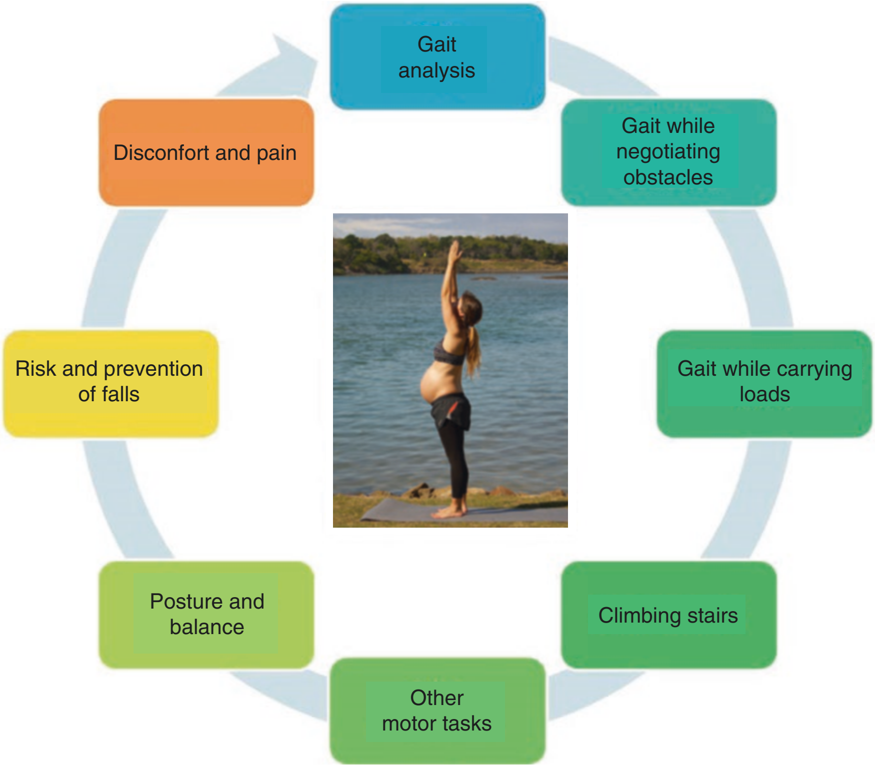

Fig. 5.2 Main applications of biomechanics studies with pregnant women

joint displacement in order to provide an accurate and necessary range of motion [39]. Biomechanical methods, such as the three-dimensional motion capture synchronized with the ground reaction forces platforms, can be used in order to obtain joint kinematic and kinetic data, which represent a pattern to be interpreted quantitatively or qualitatively. When pathologies occur, the human body muscular efficiency is compromised, and compensatory reactions of the adjacent segments can happen, resulting in a mixture of normal and abnormal motions, compromising the functional versatility and increasing energy costs [39]. These pathologies can be detected by analyzing curve patterns of certain biomechanical parameters such as the joint's range of motion or ground reaction forces produced by the impact between the feet and a surface. In biomechanics, populations with a specific characteristic have particular attention regarding gait analysis. The human body can suffer physical changes as consequences of a physiological process, which in turn may affect locomotion [40]. Pregnancy, as a natural and physiological process, produces in women changes involving the motor system. Walking is a common way of physical exercise during pregnancy, and daily physical activity during almost 40 weeks can cause injuries by overuse of certain specific muscles, joint overload, asymmetries, and uncomfortable or painful walking. There is very little literature on the biomechanics of gait during pregnancy and lack of consensus among scientists regarding body adaptation in this period [40]. Taking into account overload conditions is important to quantify biomechanical load and adaptations during gait, in order to prevent or detect pathologies that compromise functional locomotion.

5.2.2 Spatiotemporal and Kinematic Analysis

Several methods can be used to collect spatial, temporal, and kinematic variables. One method known for decades is the videography, and it still is used to collect and analyze kinematic data (e.g., [25, 41, 42]). Videography requires the use of video cameras, the amount of which will depend on the type of analysis: for a two-dimensional (2D) analysis, one video camera is only required; for a three-dimensional (3D) analysis, at least two cameras are needed. The biggest advantages of this method are the easiness in having the instruments and we can consider that it is probably the cheapest method to acquire kinematic data, even because there are several free analysis software. A relatively recent method is the optoelectronic system, used in several studies (e.g., [40, 43]). This system is based on the same principle of having several cameras to acquire images for 3D analysis, but with the particularity of receiving only infrared light. Both methods base its analysis on the estimation of the position of predefined anatomical bone landmarks, which are digitized from each image of the video from each camera. However, the capability to digitize the landmark with high precision in a regular video image or in an infrared image can be quite different. The standard error in videography is around 3 cm, while in optoelectronic systems, the error might stand below 1 mm. One factor that also contributes to the error is the calibration method. In videography, calibration is based in the digitalization of a structure with well-known dimensions, of at least four coplanar points for 2D analysis, or at least six noncoplanar points for 3D analysis, in order to associate the real coordinates to the digital coordinates in the video image. Then, the reconstruction of the trajectory is made through the direct linear transformation (DLT) algorithm [44]. In optoelectronic systems, the 3D space is calibrated by wand type, with a wand of an exact length which is moved randomly across the recorded field. A static trial enables segment reconstruction and allows defining the dimensions, joint centers, and the segment coordinate system.

Kinematic variables are divided into linear and angular and are based on time and position of collected markers. Many variables can be computed, including displacement, velocity, and acceleration, either linear or angular, for segments, joints, and center of mass. Each of these has its own pattern, which can be analyzed qualitatively, by observing the data curve, or quantitatively through a detailed selection of values that characterize the time series of values, namely, the mean, standard deviation, maximum and minimum peaks, amplitudes, and others. For more details about the kinematic methods and algorithms, further readings of Bartlett [45], Richards [46], Robertson et al. [47], and Winter [48] are suggested.

5.2.3 Kinetic Analysis and Biomechanical Loading

5.2.3.1 Ground Reaction Forces

Ground reaction forces (GRF) reflect the acceleration of the total body center of gravity (CG) and can be obtained using a force plate (Fig. 5.3). Force plates have been one of the most important measuring devices used in biomechanics for many years for quantifying external forces during human and animal locomotion [49]. GRF is most accurately measured with one of the proven force platforms available commercially, such as the Kistler force platform (Kistler AG, Winterthur, Switzerland) which utilizes piezoelectric transducers and the AMTI force platform (Advanced Mechanical Technology, Inc., Watertown, MA) which uses strain gauge technology [50].

Typically, the gait cycle is defined as the amount of time from the initial foot contact with the ground to the next instant when the same foot starts the following initial contact [51]. As a cyclical locomotor task, gait provides several impacts on the ground. Ground reaction forces produce joint reaction and moments of force and some internal forces like bone-on-bone, ligament, and muscle forces [48]. To analyze human gait, ground reaction forces and motion data are measured, synchronized in time. Both parameters are used to calculate other variables, as joint moments which are calculated by the inverse dynamics method and add more information about the stress imposed in the joints and the necessary muscle control [39]. When GRF are unobtainable, simulation models can predict these data and can add more information for the understanding of interactions of the musculoskeletal system with the physical environment, such as the foot floor contact. In a clinical context, applied to the pregnant population, this methodology can be important to provide

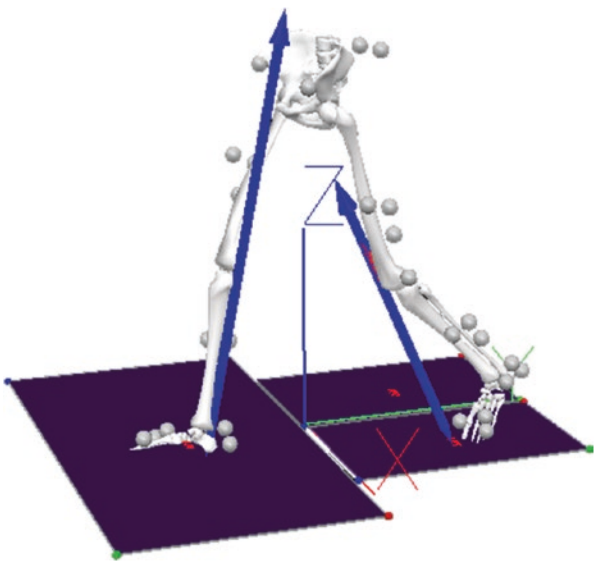

Fig. 5.3 Representation of the biomechanical model of the lower limb, in contact with the force platforms

more important biomechanical information that could not be collected in another way and to monitoring the foot contact during the pregnancy.

The GRF acts at a point usually called the center of pressure (CoP), under the area of the foot. Like the weight and most other contact forces, GRF is actually a distributed force that acts over the entire contact surface. As a force, the GRF is a vector quantity that can most conveniently be defined in terms of the magnitude, direction, and point of application of its resultant [50].

Most force platforms give a full three-dimensional description of the GRF vector. The sign convention is the one where the GRF is positive upward, forward, and to the right [50, 52]. It is important not to lose sight that the vertical, anterior-posterior, and mediolateral GRF are three components of a single force that changes in magnitude, direction, and point of application, during the course of support [50]. The description of these three components is useful in motion analysis.

The anterior-posterior (FX) GRF trace from the right foot shows "braking" during the first half of the stance phase and "propulsion" during the second half, concerning walking. The left foot shows the same pattern but with the direction of the lateral force reversed [52]. Thus, the anterior-posterior component is first a braking force to mid-stance, followed by propulsion, and usually represents a sine curve with an amplitude of 25% of the body weight (BW), as shown in Whittle [52].

The lateral or mediolateral GRF (FY) is of lower magnitude in most situations and relates to balance during walking. This component of force initially acts in the medial direction with a magnitude of 10% BW or less and then acts laterally during the balance of stance phase [53]. The mediolateral component has been studied to better understand ankle instability. This lateral component of force is generally very small. It is the smallest of the three components and falls in the neighborhood of 10–20% BW. As an example, if a runner is to maintain a straight-line running path, the resultant side-to-side GRF impulse elicited during right and left foot contacts will have to equal zero when averaged over several footfalls [50].

Considering each component of the GRF separately (Fig. 5.4), the largest is the vertical component (FZ) and accounts for the acceleration of the body's center of mass in the vertical direction during walking. The vertical force shows a characteristic double hump, which results from an upward acceleration of the center of gravity during early stance, a reduction in downward force as the body "flies" over the leg in mid-stance, and a second peak due to deceleration, as the downward motion

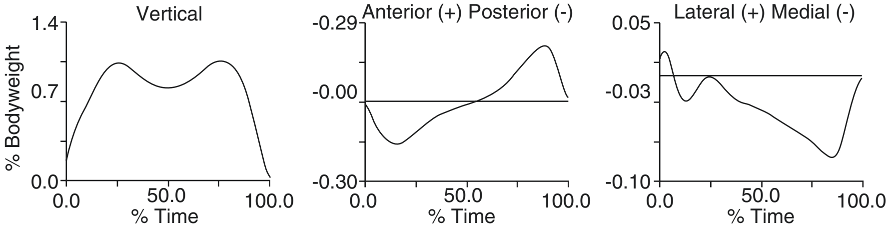

Fig. 5.4 Vertical, anterior-posterior, and medial-lateral ground reaction forces, during an entire gait cycle

is checked in late stance [52]. The vertical curve of the GRF is sometimes called the "M curve" because it resembles that letter. During the first 100 ms, the GRF goes to a maximum of 120% BW during the double stance phase. During single stance phase, the vertical GRF drops to about 80% BW or for the more dynamic walker to 60–70% BW. When the acceleration is positive, the GRF must be greater than BW. The positive acceleration occurs during double stance when the center of mass is at its lowest point. The vertical component has received the greatest attention from a research standpoint. Because of its magnitude, it dominates the resultant GRF and can barely be distinguished from that of the resultant if one is superimposed on the other [50].

The true value of the force platform is only appreciated when the GRF data are combined with kinematics data. This combination provides a much more complete description of the gait than either by itself and permits the calculation of joint moments of force and powers [52]. Image analysis can provide kinematics data. Although describing motion can be an end in itself, the most important reason for collecting kinematics data is to derive various kinetic quantities [47].

5.2.3.2 Biomechanical Loading

One particular source of loading on the body is the ground reaction force [47]; thus, GRFs are a common indicator of external biomechanical load. The major biological effects of forces include changes in the development of biological tissue and transportation of nutrients through the human body [54]. The major mechanical effects produced by forces include the ability to accelerate a mass and the ability to deform a material [54].

The effects of biomechanical loading applied to the musculoskeletal system can be either biopositives or bionegatives. Bionegative effects can result from situations of insufficient loading or from excessive loading. Before maturity, insufficient loading might result in cases of abnormal growing and development of the musculoskeletal system. In the adult, insufficient loading might result in a decrease of functional capacity. Excessive loading before maturity can also lead to abnormal growing and development and injuries, independently of age. The biopositive effects before maturity include the harmonious growing of the musculoskeletal system and the increase of functional capacity in all ages [55].

Despite not yet defined, it has been suggested that there is an optimal window of loading that healthy individuals should maintain and that loading above this window presents the risk of injury [35]. The information derived from GRF measures is also important in gait research for diagnosing lower limb problems and injury prevention [54]. The intensity of skeletal exercise has been suggested to be defined by the loads applied to the bone [56]. Based upon the literature and preliminary laboratory studies, high skeletal loading intensity has been defined as ground reaction forces of greater than four times body weight (BW), moderate intensity as 2–4 BW, and low intensity as GRF less than 2 BW [57]. Nevertheless, the result of the loading on the body depends on three factors: the magnitude of the force, the rate at which the force is applied, and the repetition of load application [47].

Biomechanical studies, although in small number, can contribute to improving knowledge about the effect of the anatomical and functional changes on the musculoskeletal system, which occurs during pregnancy and influence pregnant motor tasks and daily physical activity. The laboratory setting provides accurate data and more kinematical and kinetic data, necessary for biomechanical modeling. However, data collecting takes longer time, and the pregnant women are required to visit the laboratory several times.

5.2.3.3 Plantar Pressure

Plantar pressure is reflected by the ability to measure the force exerted by area of the foot, which allows detecting excessive pressures in each region of the foot and, in turn, allows preventing tissue damage [46]. Pressure is therefore a scalar quantity and as such is not dependent on direction but instead of magnitude [58]. Plantar pressure also shows the shape of the foot contact with the ground.

Pressure is commonly measured in gait analysis by either using force plates or in-shoe pressure monitor devices [59]. Pedography is an accurate and reliable pressure distribution measuring system for monitoring local loads between the foot (Fig. 5.5) and the shoe or the floor in the field context [60]. Pressure systems also allow calculating the vertical component of GRF.

The use of a pressure platform (e.g., Novel EMED-X system, Munich, Germany) placed on the floor is quite easy, allows obtaining several biomechanical parameters of barefoot gait, and enables its use in exercise and health centers. In-shoe plantar pressure measurement systems are capable of measuring pressures at the interface between the shoe and the foot. This equipment can be used in clinical, rehabilitation, and sports fields in order to assess patterns of forces between the agent and the ground [60, 61].

Compared to force platforms, pressure insoles have the advantage of measuring the plantar pressure directly applied to the foot during less constrained tasks and may be used to assess other parameters like force distribution along the plantar region or between right and left foot, including outside the laboratory, with relative ease.

The information derived from podobarometric measures is also important in gait and posture research for diagnosing lower limb problems and injury prevention [62–65]. Several factors have been associated with high levels of plantar pressure (i.e., peak pressure and pressure-time integral) generated during gait, such as increased body weight [66], foot structure (arch type) [67], foot pain and risk of falls [68], active diabetic foot ulcers [69], and walking strategy [70]. To our knowledge, only two studies investigated the effects of an exercise intervention on plantar pressure variables (in older adults) [29, 71].

Pregnant women's feet undergo morphological changes with the advancement of pregnancy and postpartum. Thus, it is important to understand the structural changes of the foot during pregnancy and postpartum because these changes may alter the foot biomechanics and the plantar pressure pattern. However, the current literature on plantar pressure in pregnancy is sparse.

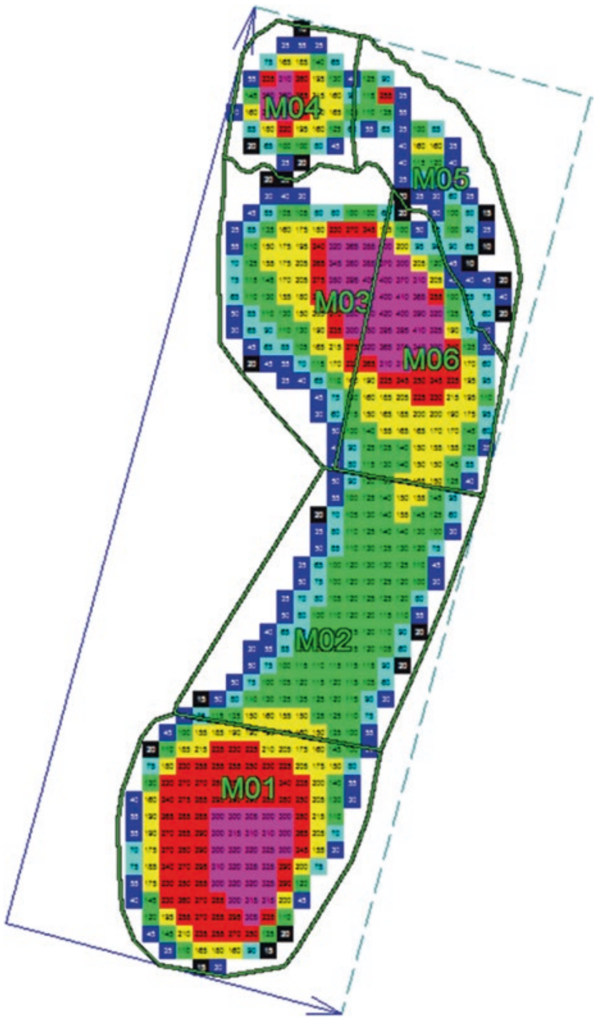

Fig. 5.5 Example of plantar pressure distribution by six foot regions: M01, hindfoot (heel); M02, midfoot; M03, medial forefoot; M04, hallux; M05, toes; M06, lateral forefoot

5.3 Biomechanical Gait and Balance Adaptations During Pregnancy

Until now, only two review studies can be found in the literature [72, 73]. Anselmo et al. [74] also reviewed the literature involving lower extremity changes experienced by pregnant women and their pathophysiologic causes. We have updated a previous review from Branco et al. [72] in order to analyze the experimental studies focused on gait analysis during pregnancy and postpartum.

We included in this review the published biomechanical studies found in literature, via PubMed and Scopus search, in October 2017, that match the following criteria: (1)

subjects were healthy pregnant and postpartum women; (2) studies were performed by means of optoelectronic systems, image analysis, force, and plantar pressure platforms; (3) outcome measures related to biomechanical variables of gait including spatial (stride length, step length, and stride width), temporal (single- and double-support time), kinematic (velocity and cadence), and kinetic (plantar pressure, ground reaction forces, joint moment, and joint power) parameters; (4) any observational and controlled trials that evaluated biomechanical variables of gait; and (5) papers published after 1997 in the English, Portuguese, Spanish, and French languages.

The following combination of terms was used: "pregnancy" and "gait," "walking," and "biomechanics" (restriction: humans). Papers were excluded if they were reviews, congress abstracts, or letters. Papers were first selected by reading the titles and abstracts, followed by reading the full text. The final analysis included 27 studies published between 1997 and 2017. Table 5.1 shows the biomechanical studies published in the last two decades, listed by chronological order of publication, regarding authors, sample size, data collection phases, sample mean age, outcome variables, and biomechanical instruments used.

5.3.1 General Characteristics of the Biomechanical Studies with Pregnant and Postpartum Women

Table 5.1 shows the information about the publications focused on the biomechanical analysis of gait in women during pregnancy and in the postpartum period. The first paper considered in this analysis was published in 1997. The sample sizes across the studies ranged from 2 to 70. All studies reported the mean age and standard deviation. Different periods of pregnancy were analyzed. Majority of the studies were designed to observe the walking pattern throughout two or three trimesters of pregnancy [42, 43, 76–79, 82–86, 88–95], and some of them also described the walking pattern after delivery [25, 40–43, 79, 80, 82, 88, 93, 94]. Almost all authors considered the third trimester of pregnancy. Control group was usually observed only once, except for the study by Sunaga et al. [96], where the group was registered twice within 16 weeks, and the analysis of Gilleard [42] where two studies of nonpregnant were carried out within 32 weeks.

Researchers performed different approaches in the selection of experimental groups: some of them focused on the observation of the same group of women throughout pregnancy [42, 43, 79, 82–86, 88–90, 92–94], some observed three nondependent groups of women in each trimester [77, 78, 91], some papers were designed to investigate the same group of women (self-controlled) before pregnancy [40, 82] or/and postpartum [25, 40–42, 79, 80, 82, 88, 92–94], and some articles involved nonpregnant women in the control group [77, 80, 81, 84–87, 89, 91, 92, 95]. The range of age groups of the participants varied from 20 to 40 years old. Some studies have follow-up design, and other studies were cross-sectional.

Regarding equipment, different studies used video-based systems for kinematic analysis, except for two studies that use optoelectronic systems [40, 86]. Only three studies report a kinetic analysis [40, 41, 82], and most studies provide an analysis of the kinematic, spatial, and temporal parameters, as follows.

Table 5.1 Biomechanical studies published in the last two decades, listed by chronological order of publication, including authors, sample size, data collection phases, sample mean age, outcome variables, and biomechanical instruments used

Authors	Sample, size (*N*) and groups	Data collection phase(s) of pregnancy and postpartum	Sample, mean age (years)	Biomechanical outcome variables	Biomechanical instruments
Nyska et al. [75]	28 pregnant 28 nonpregnant	–	28 years	–	EMED system
Foti et al. [25]	2—before pregnancy 15—third trimester 13—postpartum	Third trimester 1 year postpartum	32 years	Time and distance Kinematic Kinetic	60 Hz video cameras 1 AMTI force platform
Goldberg et al. [76]	13	First trimester Second trimester Third trimester	–	Plantar pressure	–
Huang et al. [77]	10 experimental group 10 control group	First trimester Second trimester Third trimester	–	Joint moments	EVA motion analysis system
Lymbery and Gilleard [41]	13	Third trimester 8 weeks postpartum	27.8 ± 1.2	Spatial Temporal Ground reaction forces	60 Hz EVA motion analysis system 1 Kistler force platform
Ribas and Guirro [78]	15—first trimester 15—second trimester 15—third trimester 15—nonpregnant	First trimester Second trimester Third trimester	23.3 ± 25.5	Peak contact pressure, width support distance, contact area	Plantar pressure analysis Matscan5.1 40 Hz

(continued)

Table 5.1 (continued)

Authors	Sample, size (*N*) and groups	Data collection phase(s) of pregnancy and postpartum	Sample, mean age (years)	Biomechanical outcome variables	Biomechanical instruments
Carpes et al. [79]	7	Second trimester Third trimester Until 4th month postpartum	23 to 35	Spatial Temporal 3D kinematics	60 Hz video cameras
Gaymer et al. [80]	22 pregnant 20 nonpregnant	38 weeks 4 months postnatal	–	Mean and maximum plantar pressures	Plantar pressure analysis (Fscan system) 500 Hz
Karadag-Saygi et al. [81]	35 pregnant 35 nonpregnant	Third trimester	Pregnant: 29.5 ± 4 years Nonpregnant: 30 ± 5 years	Static and dynamic pedobarographic parameters	Plantar pressure analysis (PMD-S System)
Hagan and Wong et al. [82]	2	Before pregnancy First trimester Second trimester Third trimester 12 to 16 weeks postpartum	21 and 39	Spatial Temporal 2D kinematics	30 Hz video cameras
Ribeiro et al. [83]	6	First trimester Second trimester Third trimester	32 ± 6.3 years	Plantar pressure (contact time, contact area, peak pressure, and maximum force)	Capacitive insoles from the pedar-X system
McCrory et al. [84]	41 pregnant 40 nonpregnant controls	29 weeks 35 weeks	Pregnant: 26.5 ± 6.4 Nonpregnant: 29.5 ± 4.9	GRF Fallers and non-fallers	Vicon 120 Hz BertecForce plate 1080 Hz
Forczek and Staszkiewicz [40]	13	Before Third trimester Half year postpartum	29.15 ± 3.5	Time and distance ROM Base of support	Vicon 250 3D system
Moccellin and Driusso [85]	13 pregnant 20 nonpregnant	First trimester Second trimester Third trimester	29.15 ± 5.64	Statokinesigram GRF	2 Bertec force platforms

Branco et al. [86]	22 pregnant 12 nonpregnant	Second and Third trimesters	32.5 ± 2.6	Spatial Temporal 3D kinematics	200 Hz Qualisys Oqus 300
Gilleard [42]	9	18, 24, 32, 38 weeks 8 weeks postpartum	32.6 ± 4.3	Spatial Temporal Trunk kinematics	60 Hz EVA motion analysis system 1 Kistler force platform
Aguiar et al. [87]	18 pregnant 18 nonpregnant	27 weeks	Pregnant 32.6 years Nonpregnant: 20.4 years	Spatial Temporal 3D kinematics	200 Hz Qualisys Oqus 300, Kistler and AMTI force platforms
Branco et al. [88]	11	First trimester Second trimester Third trimester Postpartum	33.20 ± 1.62 years	3D GRF, 3D joint moments, 3D joint power	200 Hz Qualisys Oqus 300, Kistler and AMTI force platforms
Yoo et al. [89]	19 pregnant women 15 nonpregnant	Second trimester Third trimester	29.54 ± 3.45 years	Posturography	GAITRite system
Gimunova et al. [90]	9 pregnant women	First trimester Second trimester Third trimester	30.90 ± 2.56 years	GRF	Pedar insole system
Bertuit et al. [91]	58 pregnant women 9 postpartum 23 control	6th, 7th,8th, 9th month pregnancy	29 ± 6 years	Plantar pressure	GAITRite electronic walkway
Branco et al. [43]	11	First trimester Second trimester Third trimester Postpartum	33.20 ± 1.62 years	Spatial and temporal parameters 3D joint kinematics	200 Hz Qualisys Oqus 300
Branco et al. [92]	24 pregnant 12 nonpregnant	Second trimester Third trimester	Pregnant: 32.4 ± 2.6 years Nonpregnant: 20.58 ± 1.73	GRF, joint moments, joint power	200 Hz Qualisys Oqus 300, Kistler and AMTI force platforms

Table 5.1 (continued)

Authors	Sample, size (*N*) and groups	Data collection phase(s) of pregnancy and postpartum	Sample, mean age (years)	Biomechanical outcome variables	Biomechanical instruments
Blaszczyk et al. [93]	28	First trimester Third trimester 2 and 6 months postpartum	28.2 ± 3.4 years	Spatiotemporal	Axotape v.2.0 1KHz
Ramachandra et al. [94]	70	First trimester Second trimester Third trimester 3 days after partum 6 months postpartum	27.98 ± 3.65 years	Static plantar pressure	Plantar pressure analysis
Elsayed et al. [95]	11 pregnant 11 nonpregnant	Second trimester Third trimester	Pregnant: 26.9 ± 5.2 years Nonpregnant: 26 ± 5.3 years	Plantar pressure	Global postural system (version4.7.16, Italy)

2D two-dimensional analysis, *3D* three-dimensional analysis, *ROM* range of motion, *GRF* ground reaction forces

There are also two studies focused in specific methodological issues when collecting and processing kinematic and kinetic data from pregnant women [97, 98].

5.3.2 Spatiotemporal and Kinematic Adaptations During Pregnancy and Postpartum

5.3.2.1 Center of Gravity and Balance

The displacement of the center of gravity (in the static position) has been discussed over the years with different statements. Some studies indicate that the center of gravity (CG) shifts upper and anteriorly (e.g., [25, 99]). Other studies state that the CG shifts on the upper and posterior direction (e.g., [100]). Whitcome et al. [22] evaluated the evolution of lumbar lordosis in bipedal hominids, and the results elucidate that the CG moves anteriorly until the fetus reaches 40% of the expected final weight. From that moment, the woman increases the lordotic adjustment which in turn enables the control of the CG but with greater biomechanical costs [25].

Hormonal changes in women are quite variable throughout pregnancy. However, the hormone relaxin may have a more decisive role in the mechanics of movement, as it provides greater ligament laxity in the pelvis and in the peripheral joints [32, 101, 102]. The concentration peak of relaxin occurs around the 12th week of gestation, which means that there is enough time to act on osteoarticular structures until the end of pregnancy.

Jang et al. [103] referred that pregnant women often remark that their balance degrades during pregnancy. They measured monthly the postural sway in 30 pregnant women and controls. They concluded that the perceived degradation in balance during pregnancy was strongly related to increasing postural sway instability in the anterior-posterior direction. Also, the lateral stability during pregnancy was maintained and likely accomplished by increasing stance width.

5.3.2.2 Spatial and Temporal Parameters During Gait

The variables of gait velocity, stride length, step length, stride width and base of support, and single- and double-support time are the spatial and temporal parameters analyzed by the papers reviewed. Table 5.2 summarizes the main spatial and temporal results and conclusions of the reviewed papers.

Most papers reviewed showed changes in spatial and temporal parameters in late pregnancy, specifically, a significant decrease in speed [40, 82], a significant reduction in the gait cadence [40], a significant decrease in the length of the gait cycle [42, 79, 82, 86, 93] and in step length [40, 79, 82, 86], and a significant increase in the double-support time [25, 79, 86, 87, 93]. Other studies showed a significant reduction in the single-support time [25, 79] and a significant increase in step width [41, 42, 87]. Forczek and Staszkiewicz [40] also found a significant increase in the base of support. Nevertheless, the remaining studies suggest that pregnant women have the need to increase the body stability and use the parameters listed above to meet those demands.

Table 5.2 Objectives, main results, and conclusions of studies with spatial and temporal analysis on gait, during pregnancy

Study	Main goals/objectives	Main results and conclusions
Foti et al. [25]	To objectively analyze gait during pregnancy	Decreased single-support time^{3T} Increased double-support time^{3T}
Lymbery and Gilleard [41]	To investigate selected temporospatial and GRF parameters in the stance phase of gait during late pregnancy	Increased step width^{3T}
Carpes et al. [79]	To describe the kinematic changes during pregnancy and in postpartum	Increased time in double-support and stance phase^{3T} Decreased time in single-support^{3T} Decreased mean stride length and step length^{3T}
Hagan and Wong [82]	To study pregnancy-related changes in women's gait	Decreased gait speed^{3T} Decreased stride length^{3T}
Forczek and Staszkiewicz [40]	To measure the selected gait parameters	Decreased velocity, frequency of steps, step length^{3T} Increased base of support width^{3T}
Branco et al. [86]	To describe spatial and temporal parameters and quantify the kinematic variables on the structures of the lower limb during gait	Decreased stride length, left and right step length^{3T} Increased double-support time$^{2T \text{ and } 3T}$
Gilleard [42]	To investigate the linear trends for change in the range of motion of the thoracic and pelvic segments and thoracolumbar spine, and the temporospatial characteristics for walking at a self-determined natural speed as the pregnancy progressed and in the early post-birth period using a longitudinal retest design	Decreased stride length^{3T} Increased step width^{3T}
Aguiar et al. [87]	To understand which gait adaptations may be related to an increased trunk mass or more associated with other factors such as the girth of the thigh during pregnancy	Increased stride width^{3T} Increased left step time^{3T} Increased right and left stance time^{3T} Increased double-support time^{3T}
Blaszczyk et al. [93]	To assess precisely spatiotemporal gait diagrams	Decreased gait velocity$^{1T \text{ and } 3T}$ Decreased stride length$^{1T \text{ and } 3T}$ Increased stance phase time$^{1T \text{ and } 3T}$ Increased double-support time$^{1T \text{ and } 3T}$ Increased swing phase^{3T}

1T = first trimester; 2T = second trimester; 3T = third trimester

5.3.2.3 Gait and Joint Kinematics

Based on reviewed studies (Table 5.3), the joint kinematics of the lower limb shows no changes during the first trimester and few changes in the second trimester, and the third trimester has most of the reported changes. Figures 5.6 and 5.7 show kinematic adaptations during walking reported in the studies found, respectively, for second and third trimesters.

Table 5.3 Objectives, main results, and conclusions of studies with kinematic analysis on gait during pregnancy and postpartum

Study	Main goals/objectives	Main results and conclusions
Foti et al. [25]	To objectively analyze gait during pregnancy	Increased maximum anterior pelvic tilt^{3T} Increased maximum hip flexion^{3T} Increased maximum hip adduction during stance^{3T} Decreased maximum hip extension^{3T}
Carpes et al. [79]	To describe the kinematic changes during pregnancy and in postpartum	Increased knee flexion^{3T}
Hagan and Wong [82]	To study pregnancy-related changes in women's gait	Decreased dorsiflexion$^{2T\text{ and }3T}$ Increased pelvic tilt^{3T}
Branco et al. [86]	To describe spatial and temporal parameters and quantify the kinematic variables on the structures of the lower limb during gait and compare it between the later stages of second and third trimesters of pregnancy and with a control group of nonpregnant women	Pregnancy influences the biomechanical changes^{3T} Decreased hip extension$^{2T\text{ and }3T}$ Increased knee flexion^{3T} Decreased plantar flexion^{3T} Decreased hip abduction$^{2T\text{ and }3T}$
Gilleard [42]	To investigate the linear trends for change in the range of motion of the thoracic and pelvic segments and thoracolumbar spine, and the temporospatial characteristics for walking at a self-determined natural speed as the pregnancy progressed and in the early post-birth period using a longitudinal retest design	Decreased range of motion in lateral rotations for pelvis and thoracolumbar spine[a] Decreased range of motion in pelvic lateral motion[a] Decreased range of motion in flexion/extension for pelvis and thoracolumbar spine^{3T}

(continued)

Table 5.3 (continued)

Study	Main goals/objectives	Main results and conclusions
Aguiar et al. [87]	To understand which gait adaptations may be related to an increased trunk mass or more associated with other factors such as the girth of the thigh during pregnancy	Increased peak eversion and peak inversion and therefore foot rotation ROM[3T] Decreased maximum knee extension and knee ROM during swig phase[3T] Increased knee extension during stance phase[3T] Increased maximum hip flexion[3T] Decreased hip extension peak[3T] Increased pelvis anterior tilt[3T] Decreased maximum pelvic lateral motion and lateral ROM[3T]
Branco et al. [43]	To describe the kinematic variables in the joints of the lower limb during gait at the end of the first, second, and third trimesters of pregnancy and in the postpartum period	Increased knee flexion[2T] Decreased knee extension[2T] Decreased hip extension[2T and 3T] Increased hip flexion[2T and 3T] Increased pelvis anterior tilt[2T and 3T] Increased ankle inversion[3T] Decreased hip adduction[3T] Decreased pelvis right elevation[2T] Increased pelvis right elevation[3T] Increased hip internal rotation[2T and 3T]

[a]Through pregnancy with no reversal in PP; 1T = first trimester; 2T = second trimester; 3T = third trimester

Considering the sagittal plane, the angular displacement of the pelvis increases in the anterior tilt of approximately 5° [25, 43, 82, 86, 87]. The joints of the lower limb show an increase in hip flexion during stance phase [25, 43, 82, 86, 87] and a decrease in hip extension at the end of stance phase [25, 43, 86], an increase of knee flexion during the terminal stance phase [43, 79, 86] and a decrease of knee extension at the end of swing phase [43, 87], and a decrease of ankle dorsiflexion and plantar flexion [82, 86].

In the frontal plane, Gilleard [42], Aguiar et al. [87], and Branco et al. [43] found a reduction in the amplitude of the unilateral elevation of the pelvis. The hip joint

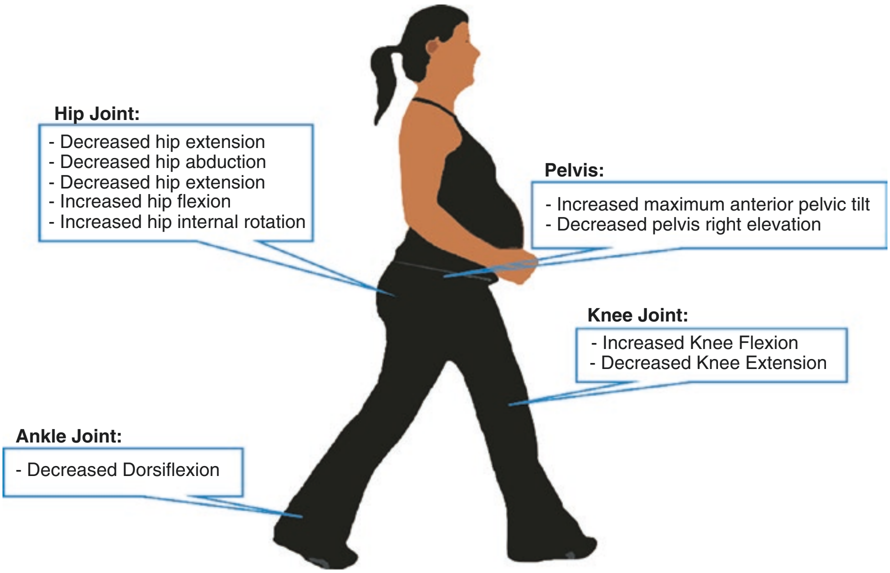

Fig. 5.6 Gait kinematic adaptations of pregnant women at the end of the second trimester

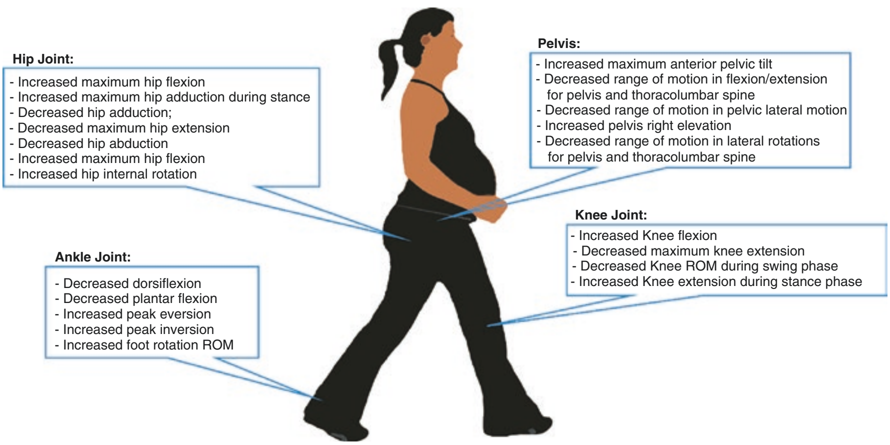

Fig. 5.7 Gait kinematic adaptations of pregnant women at the end of the third trimester

had different results considering the two studies performed: Foti et al. [25] found a peak with greater magnitude in the hip adduction, while Branco et al. [43, 86] found a decrease of this peak; the ankle joint only shows an increased peak inversion and peak eversion, respectively, in the pre-swing and initial swing phases [43, 87].

Few studies have done an analysis of the transverse plane. Gilleard [42] found a decrease in the range of motion of the pelvis, and Branco et al. [43] found an increase in the peak of hip internal rotation.

5.3.3 Biomechanical Loading During Pregnancy and Postpartum

5.3.3.1 Ground Reaction Forces

Changes in the different components of GRF were found during pregnancy. Table 5.4 summarizes the main results and conclusions of those studies. Significant decreases were found in the vertical component of the GRF [85, 88, 90, 92], and also showed lower magnitudes in the anterior and posterior component of GRF [85, 88, 92].

Lymbery and Gilleard [41] investigated the GRF variables in the stance phase of walking during late pregnancy, and they concluded that in late pregnancy, mediolateral GRF tended to be increased in medial and lateral directions. These results were corroborated in recent studies [88, 92]. They suggested that women may adapt their gait to maximize stability in the stance phase of walking and to control mediolateral motion. Similar results were found in CoP, where an increase in lateral displacement [41, 85] and a decrease in anterior displacement [41] were found.

Table 5.4 Objectives, main results, and conclusions of studies with ground reaction forces analysis during pregnancy and postpartum

Study	Main goals/objectives	Main results and conclusions
Lymbery and Gilleard [41]	To investigate selected temporospatial and GRF parameters in the stance phase of gait during late pregnancy	Increased mediolateral GRF^{3T} Increased lateral COP^{3T} Less anteriorly COP^{3T}
Moccellin and Driusso [85]	To evaluate static and dynamic postural control during the three trimesters of pregnancy and to check the quality of life in each trimester	Decreased magnitudes of vertical reaction force^{3T} Decreased magnitudes of anterior-posterior reaction forces^{3T} Increased lateral COP^{3T}
Branco et al. [88]	To assess the gait kinetics, in order to check if there are any changes in the dynamics of the load of women from the beginning of pregnancy until the postpartum period	Decreased magnitudes of posterior reaction forces^{1T} Decreased magnitudes of vertical reaction force^{3T} Decreased magnitudes of anterior reaction forces^{3T}
Branco et al. [92]	To quantify the lower limb kinetics of gait and draw a comparison between women in the second and third trimesters of pregnancy and a nonpregnant group	Decreased magnitudes of vertical reaction force^{3T} Decreased magnitudes of anterior reaction forces^{3T} Increased medial reaction forces^{3T}

1T = first trimester; 2T = second trimester; 3T = third trimester

5.3.3.2 Plantar Pressure

The plantar pressure allows determining how the pressure is distributed through the regions of the foot. In Table 5.5 are summarized the main plantar pressure results and conclusions of the reviewed studies. Regarding the forefoot, there are distinct results between studies, as some studies point to a decrease in peak pressures [75, 76, 91] and others point to an increase in peak pressure for that region of the foot [80, 81, 94, 95]. For midfoot region, the results are more consensual, whose peak

Table 5.5 Objectives, main results, and conclusions of studies with plantar pressure analysis during pregnancy and postpartum

Study	Main goals/objectives	Main results and conclusions
Nyska et al. [75]	To measure plantar foot pressure distribution statically and dynamically in pregnant women	Decreased maximal pressures in forefoot^{3T} Increased maximal pressures in hindfoot^{3T} Increased total contact area^{3T} Increased total maximal force^{3T} Decreased contact time in medial side of the forefoot^{3T} Increased peak pressures in midfoot for booth feet and in lateral side of the right forefoot^{3T} Decreased peak pressures in medial side of the forefoot^{3T}
Goldberg et al. [76]	To determine changes in foot use and foot pressure patterns during pregnancy	Decreased floor contact times, impulse and hindfoot peak pressure increases; forefoot peak pressure^{1T} Increased contact times, impulse and peak pressure in hindfoot^{3T} Decreased forefoot peak pressure^{3T}
Ribas and Guirro [78]	To analyze plantar pressure and postural balance during the three trimesters of pregnancy, and correlate these with anthropometric characteristics	Positive correlation between center of force and size of support base $^{1T\text{ and }3T}$
Gaymer et al. [80]	To quantify the plantar pressure of women in late pregnancy and assess the persistence of these changes after normalization of the patients' hormone profile postpartum	Increased peak plantar pressure for forefoot and midfoot^{3T} Decreased maximum peak plantar pressure in the hindfoot^{3T}
Karadag-Saygi et al. [81]	To evaluate plantar pressure changes and postural balance differences in pregnant women	Increased forefoot pressure on the right side for standing and walking^{3T} Increased contact times in the forefoot^{3T} Increased contact times^{3T}

(continued)

Table 5.5 (continued)

Study	Main goals/objectives	Main results and conclusions
Ribeiro et al. [83]	Describe longitudinally, and compare the plantar pressure distribution in orthostatic posture and gait throughout pregnancy	Decreased contact area of lateral rearfoot[2T] Decreased peak pressure of medial rearfoot Increased contact area of midfoot[3T] Increased contact time for midfoot and medial forefoot[3T] Decreased absolute maximum force for medial rearfoot[2T and 3T] Increased absolute maximum force for medial forefoot[2T]
Bertuit et al. [91]	To investigate plantar pressures during gait in the last 4 months of pregnancy and in the postpartum period. A comparison with nulliparous women was conducted to investigate plantar pressure modifications during pregnancy	Decreased peak pressure and contact area for the forefoot and rearfoot[3T] Increased peak pressure and contact area for the midfoot[3T]
Ramachandra et al. [94]	Study the structural changes of foot and static plantar pressure patterns in women across various trimesters of pregnancy and postpartum	Increased forefoot and hindfoot pressure for both feet[3T] Increased total contact area[3T] Increased average pressure[3T] Increased maximum pressure for right foot[3T]
Elsayed et al. [95]	To investigate the plantar pressure distribution during pregnancy	Asymmetry of weight bearing[3T] Increased pressure in 5th metatarsal for both feet[3T]

pressure is higher during pregnancy [75, 80, 91]. In posterior region of the pregnant women's foot (referred to in the various studies as hindfoot or rearfoot), dissimilar results were also found where Nyska et al. [75], Goldberg et al. [76], and Ramachandra et al. [94] report an increased peak pressure; however, Gaymer et al. [80] and Bertuit et al. [91] reported a decreased peak pressure in this foot region. Relatively to contact time of the different regions of the foot with floor, only Nyska et al. [75] report a decrease of this variable in the medial side of forefoot; however, in the other studies, an increased contact time for hindfoot [76], midfoot [83], and forefoot [81, 83] was found.

Other variables were studied based on plantar pressure data, namely, an increased contact force in the medial forefoot and a decrease for medial rearfoot [83] and a positive correlation between the center of force and the size of the base of support [78]. In general, authors refer that those changes may be responsible for the musculoskeletal complaints of lower limb [75] and foot pain in pregnant women; however, pressure distribution may be relieved by exercise and shoe wear modifications [81]. Also, those adjustments suggest that pregnant women keep the dynamic stability during walking gait [83, 91].

5.3.3.3 Joint Reaction Forces

In Table 5.6 are summarized the main findings and conclusions of joint reaction forces found in the studies, and Figs 5.8, 5.9, and 5.10 show kinetic adaptations reported in the reviewed studies, respectively, for first, second, and third trimesters.

Few studies have evaluated the kinetic parameters of gait during pregnancy. Foti et al. [25] analyzed the joint moments of force and joint powers with and without normalizing the weight of the women in late pregnancy. Although they found several changes in these parameters without normalization, the authors recommend the analysis with normalization [25]. The analyses performed with normalized data found a significant increase in the hip extensors moment [77] and a significant decrease in the knee extensors moment [77] and in the ankle plantar flexors moment

Table 5.6 Objectives, main results, and conclusions of studies with kinetic analysis on gait during pregnancy and postpartum

Study	Main goals/objectives	Main results and conclusions
Foti et al. [25]	To objectively analyze gait during pregnancy	Increased hip abduction moment^{3T} Decreased ankle plantar flexion moment^{3T}
Huang et al. [77]	To find a reasonable model to compensate the lack of the anthropometric data and compare the pregnant data with the normal data	Increased hip extension moment^{3T} Decreased knee extension moment^{3T} Increased knee adduction moment^{3T} Decreased ankle plantar flexion moment^{3T}
Branco et al. [88]	To assess the gait kinetics, in order to check if there are any changes in the dynamics of the load of women from the beginning of pregnancy until the postpartum period	Decreased hip extensors moment^{3T} Decreased hip flexors moment$^{2T\text{ and }3T}$ Increased hip external rotators moment$^{2T\text{ and }3T}$ Increased eccentric contraction of the hip external rotators$^{2T\text{ and }3T}$ Decreased eccentric contraction of hip flexors^{3T} Decreased concentric contraction of the knee extensors^{1T} Decreased ankle plantar flexors moment^{3T} Decreased eccentric contraction of ankle abductors^{3T}

(continued)

Table 5.6 (continued)

Study	Main goals/objectives	Main results and conclusions
Branco et al. [92]	To quantify the lower limb kinetics of gait and draw a comparison between women in the second and third trimesters of pregnancy and a nonpregnant group	Decreased participation of the hip flexors^{2T} Increased participation of hip external rotators^{2T} Decreased participation and asymmetry of hip flexors^{3T} Increased concentric contraction of hip extensors^{3T} Decreased eccentric contraction of hip flexors^{3T} Increased concentric contraction of hip abductors^{3T} Increased concentric contraction of hip external rotators^{3T} Decreased participation of the knee extensors^{2T} Increased participation of the knee flexors^{2T} Decreases participation of the ankle dorsiflexors^{2T} Decreased participation of the ankle evertors^{2T} Decreased participation of ankle dorsiflexors^{3T} Decreased concentric contraction and asymmetry in ankle dorsiflexors^{3T}

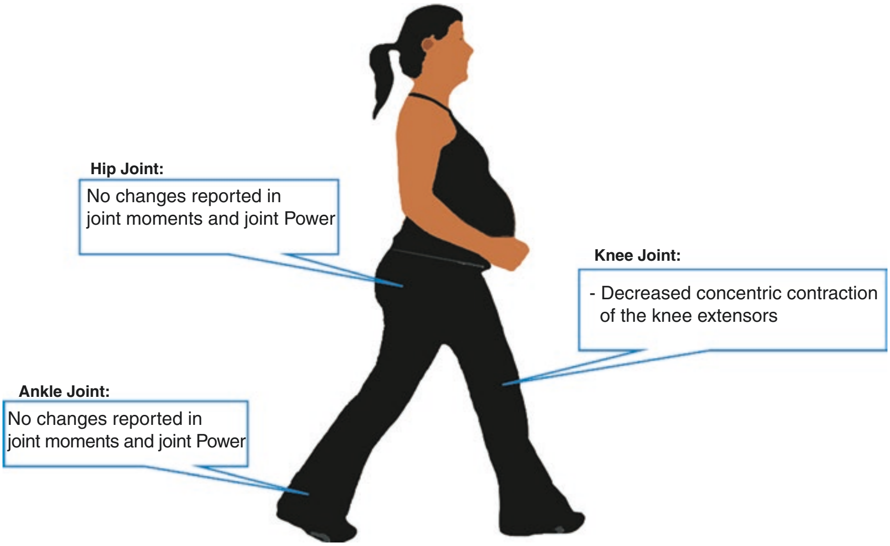

Fig. 5.8 Joint kinetic adaptations of pregnant women at the end of the first trimester, during gait

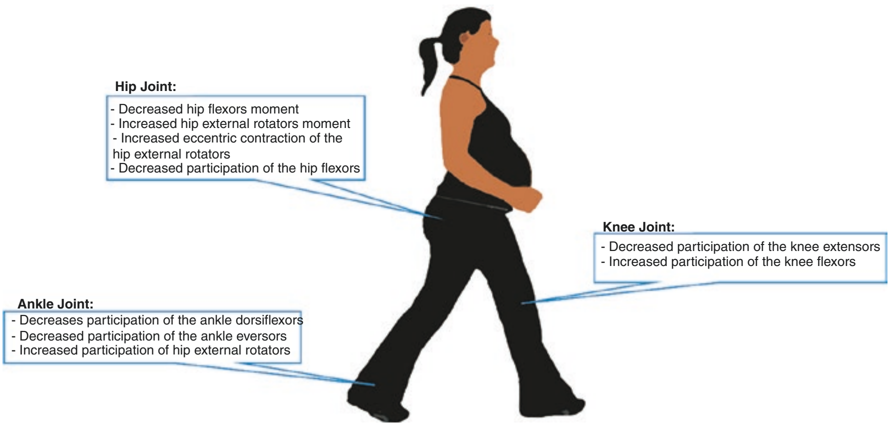

Fig. 5.9 Joint kinetic adaptations of pregnant women at the end of the second trimester, during gait

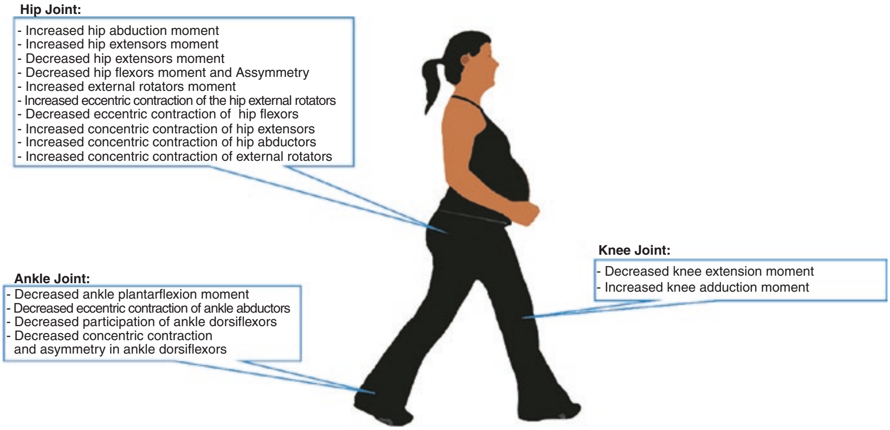

Fig. 5.10 Joint kinetic adaptations of pregnant women at the end of the third trimester, during gait

[25, 77] in the sagittal plane. In the frontal plane, there was an increase of the hip abductors moment [25] and in the knee adductors moment [77].

The body composition [29, 30], the increased loading in the trunk anterior area [104, 105], and the higher foot pressures in the pregnant women [75, 80] are associated with alterations of the gait pattern. The joint laxity increases, and consequently, there is an increase in the joints amplitude [101].

At the end of pregnancy, the adoption of strategies such as increasing the width of the base of support caused by the other body segments allows minimizing the increased weight and trunk girth effects. Indeed, such changes can substantially modify the gait pattern, contributing to an overload of the musculoskeletal system, causing lower limb, hip, and lower back pain [25, 81, 106].

5.4 Other Biomechanical Adaptations During Pregnancy

5.4.1 Balance and Fall Risk

Throughout pregnancy, women experience hormonal, anatomical, and physiological alterations that are often accompanied by increased weight and ankle edema [107] and decreased postural control which increase the risk of falling during this period [32, 107, 108]. Falls are the leading cause of nonfatal injury across all age groups and a common incident for pregnant women [109], with nearly 27% of pregnant women falling during pregnancy [110, 111].

Gottschall et al. [109] analyzed the adaptations in temporal-spatial parameters as well as muscle activity during hill walking transitions in pregnant women between gestational week 20 and 32. The authors concluded that pregnant women increased joint flexion as well as muscle activity at the ankle, knee, and hip during the transition between level and hill surfaces. The authors suggested that pregnant women exaggerate cautious gait patterns by walking slower and wider with greater joint flexion and muscle activity in order to safely transition between level and hill surfaces. Ersal et al. [111] characterized the postural responses of pregnant fallers, non-fallers, and controls to surface perturbations, concluding that increasing ankle stiffness could be an important strategy to prevent falling by pregnant women. Moreover, Inanir et al. [108] prospectively evaluated pregnant women regarding their dynamic postural stability, concluding that pregnancy has a negative effect on postural stability, especially in the third trimester. Moreover, these gait disorders occurring during pregnancy not only increase the risk of falls and musculoskeletal discomfort but may also affect the quality of life of pregnant women [107].

Approximately 40% of falls occur during staircase locomotion [112]. McCrory et al. [110] analyzed the biomechanics of stair locomotion in pregnant women compared to nonpregnant controls. The mediolateral excursion of the CoP during ascent was greater in the third trimester, and the anteroposterior braking impulse was greater in both ascent and descent during pregnancy. Moreover, the vertical GRF loading rate during descent was greater in pregnant women than in controls. The authors concluded that these alterations are likely related to increased instability during stairway walking and could contribute to increased fall risk during pregnancy [110]. Thus, these authors also analyzed the ground reaction forces in pregnant fallers, pregnant non-fallers, and nonpregnant controls to determine if pregnant fallers display alterations to ground reaction forces that increase their risk of falling on stairs [112]. The authors found that pregnant fallers increase stability during staircase locomotion. Pregnant fallers had an increased anterior-posterior braking impulse, medial impulse, and minimum between vertical peaks during ascent [112]. Moreover, during descent, pregnant fallers demonstrated a smaller anterior-posterior propulsive peak and propulsive impulse and a greater minimum between vertical peaks.

5.4.2 Trunk Motion and Load Transportation

Gilleard [42] investigated the systematic changes in the range of motion for the pelvic and thoracic segments of the spine, the motion between these segments (thoracolumbar spine), and temporospatial characteristics of step width, stride length, and velocity during walking as pregnancy progresses and post-birth. The author concluded that as pregnancy progresses, there were significant linear trends for an increase in step width and a decrease in stride length. Regarding trunk motion, there was a significant linear trend for a decrease in the range of motion of the pelvic segment and thoracolumbar spine about a vertical axis (side-to-side rotation) and the pelvic segment range of motion around an anterior-posterior axis (i.e., side tilt). Moreover, not all adaptations were resolved by 8 weeks post-birth [42]. Sawa et al. [113] also compared the gait characteristics and the functional ability of the trunk between women before and during the third trimester of pregnancy, suggesting that the functional ability of the trunk during gait declines in late pregnancy. Wu et al. [114] also suggest that pregnant women experience difficulties in realizing the more antiphase pelvis-thorax coordination that is required at higher walking velocities.

McCrory et al. [112] were the first to investigate the thoracic and pelvic kinematics of gait regarding the "waddle" way of walking during pregnancy. The authors concluded that pregnant women demonstrate a lateral shifting of the body during gait, which accompanied a greater step width. The increased thoracic extension and anterior pelvic tilt along with decreased sagittal plane ROM are likely adaptations to increased abdominal size [23].

Sunaga et al. [96] analyzed the changes in the pattern of rising from a chair and walking forward as pregnancy progresses. The authors found that the peak trunk-flexion angle during rising was smaller in pregnant women than in controls. Moreover, the hip extension angle during the stance phase was larger than in controls. Also, the peak horizontal and vertical velocities of the center of mass were lower, and appeared earlier, in pregnant women than in controls. The authors conclude that pregnant women should not initiate gait until reaching a stable standing position after rising, in order to ensure safety.

5.5 Implications for Exercise Prescription and Intervention

A strategy to promote health and control weight gain during pregnancy is by performing structured or recreational physical activity. The guidelines for exercise prescription of the American College of Obstetricians and Gynecologists recommend aerobic exercise consisting of activities that use large muscle groups in a continuous, rhythmic manner, as well as resistance exercise [115], as well as flexibility and neuromotor exercises [34]. Further discussion on this topic is addressed in Chap. 7. The adaptations of the exercise programs based on effectiveness and safety must take into consideration the morphological, biomechanical, physiological, and psychological alterations that occur during pregnancy. Moreover, in order to better develop safe and effective exercise programs, it is necessary to understand, among other variables, the physical activity patterns of pregnant women and the characteristics of proper exercise. These issues are addressed in Chaps. 1, 8, and 9. As an example, walking is one of the movements most commonly performed by people in the day-to-day tasks, easy to control exercise intensity, and emerges as a highly recommended physical activity for pregnant women (see Chaps. 1 and 7). Chapter 9 provides guidance on the specific adaptations of several recreational activities such as aerobics, step, strength training, stretching, and water exercise, among others, that might be adapted to healthy pregnant women.

The anatomic and biomechanical changes, together with hormonal changes, on the one hand, increase joint forces and, on the other hand, increase the laxity of joints. These factors may contribute to joint pain, reduced coordination, and increased injury risk [17]. Moreover, these consequences may vary from mild to severe discomfort that resolves postpartum, to clinically significant musculoskeletal disorders contributing to future health problems. During pregnancy and postpartum, these factors may prevent women from either being physically active or practicing exercise. Regarding musculoskeletal health, the importance of exercise prescription for both preventive and rehabilitation programs should be emphasized. Thus, exercise prescription during the different phases of pregnancy and in the postpartum period must include the forms of adaptation of the type of exercise, the intensity, duration, and frequency, but also take in consideration the biomechanical adaptations and its consequences.

Physical exercise should provide adequate levels of mechanical loading, fundamental for bone health, minimizing the adverse effects such as pain and injury. One important characteristic of most of the recreational physical activities is the repetition of movements that induce GRF of low magnitude (1–2 BW) and high frequency (around 3000–4000 times on a 30-min session). When performing motor tasks such as walking, the adaptations of the musculoskeletal system due to morphological changes during pregnancy are not fully known.

Mechanical loading is related to the magnitude of the external and internal forces, with the frequency of the forces applied to the body, with the repetition of the load application, and with the way musculoskeletal structures deal with the internal forces [55], and could be truly related to musculoskeletal injuries, reported in the back, hip, knee, and ankle. Thus, the assessment of biomechanical loading in the musculoskeletal system of pregnant women is of particular interest. Also, the quantification or estimation of the mechanical load is essential to understand how much we need to maintain and improve the morphological and functional quality of biological structures [37]. This might give a major contribution to exercise prescription (see Chap. 8) and injury prevention (see Chap. 10).

On the one hand, the level of discomfort or the diagnosed disorder may be a good indicator for a specific exercise program during pregnancy aiming to decrease back pain intensity and increase functional ability [116, 117] or a referral to a physiotherapeutic program (see Chaps. 6 and 10). On the other hand, promoting good posture and regular exercise can be recommended as a method to relieve back pain in pregnant women [117]. Thus, exercise prescription must be adapted to the morphological and biomechanical alterations that occur during pregnancy and contribute to pain relief and treatment. Nevertheless, it is not fully understood whether exercise programs can prevent pain, falls, or injury. The results of the present analysis may be useful to develop recommendations for pregnancy and postpartum specific exercise programs and eventually for foot, pelvic, and lumbar pain prevention.

The following questions are of major importance:

- How can exercise programs contribute to health, functional ability, pain relief, or treatment?
- How can the pregnant body be best protected while exercising?

Based on the data available, some practical recommendations for exercise prescription and intervention can be provided to health and exercise professionals, in order to improve the well-being of women throughout pregnancy by means of an active and healthy lifestyle:

- Musculoskeletal health adaptations should be further addressed in the national and international guidelines for physical activity and exercise during pregnancy and postpartum.
- The benefits of exercise on the musculoskeletal health of pregnant women should also be further developed in those guidelines.
- Neuromotor (balance[1] and coordination[2]) exercise and posture training should be included in any exercise intervention throughout pregnancy.
- Combined weight-bearing exercise with several types of weight-supported exercise (water or cycling) may be included in any exercise intervention throughout pregnancy.
- Exercise planning should avoid very fast movements and quick changes of position in group exercise with music, walking classes, or dynamic strength training, in order to avoid falls and stress to the joints.
- All pregnant women should be advised to be careful with wearing proper sports shoes regarding cushioning and impact attenuation, especially in what is concerned with the type of floor (indoor and outdoor).
- All pregnant women should be advised to be careful with the type and the conditions of the floor when exercising outdoor in order to avoid falls.
- All pregnant women should enhance visibility around the feet during exercise (e.g., exercising close to a mirror).

[1] Coordination is defined by the ability to use the senses, such as sight and hearing, together with body parts in performing tasks smoothly and accurately. In American College of Sports Medicine, Riebe D, Ehrman JK, Liguori G, Magal M. ACSM's guidelines for exercise testing and prescription. Tenth edition. ed. Philadelphia: Wolters Kluwer; 2018.

[2] Balance is defined by the maintenance of equilibrium while stationary or moving. 34. Ibid.

5.6 Further Research

Further research is required using common outcome measures and standard follow-up periods of data collection (weeks of gestation and postpartum period). Most of the results presented in this review are consistent between studies. However, there is a great scarcity of studies addressing the gait biomechanics of pregnant women in a longitudinal perspective.

Very few studies analyzed the kinetics of gait of pregnant women. Nevertheless, these data are seen as essential to understand the magnitude and implications of changes in the welfare of women. In future research, there must be a special focus on the analysis of moments of force and joint powers to understand the changes in muscle participation and type of contraction, regarding the direction of angular motion of the joints.

It is not possible to understand the influence of morphological changes, if body composition and anthropometric variables are not quantified throughout pregnancy. Further research is required to understand to which extent these variables influence the biomechanical parameters.

No studies were found addressing the effects of physical activity, low back and pelvic pain, or maternal weight gain on the gait biomechanical adaptations of gait throughout pregnancy and postpartum. It would be of particular interest to understand either the impact of an active lifestyle or the effect of different types of exercise on the biomechanical adaptations occurring during pregnancy.

Gait analysis is a useful tool for understanding movement impairments or discomfort, which may impact on pregnant women's well-being. The use of gait analysis in pregnant women, especially those with gestational diabetes and lower limb pain, may lead to improvements in healthcare including the treatment and prevention, as well as to the development of targeted exercise interventions. On the one hand, there is a critical demand for research to evaluate if walking strategies in pregnant women change throughout pregnancy in order to effectively intervene and minimize the incidence rate [109]. On the other hand, it is also of particular importance to understand whether exercise intervention would have an effect on those walking strategies. Moreover, postural stability tests may detect pregnant women with a high fall risk [108].

Future research could address the influence of specific exercise interventions and footwear on the plantar pressure pattern in pregnant women, especially in the increased plantar pressures in hindfoot with the advancement of pregnancy.

There is sparse evidence on the effects of targeted exercise interventions on plantar pressure and ground reaction force variables, especially in pregnant women. Thus, it would be interesting to understand how active women deal with increased mechanical loading from physical activity and in comparison with sedentary women. Moreover, there is a lack of evidence on the effect of exercise on quality of life and musculoskeletal health.

More specific questions could assess whether there are any significant imbalances between the right and left sides of the pregnant women's body; how long does it take to recover in the postpartum period; what are the adaptations in other locomotion-related tasks such as negotiating obstacles and stairs, and carrying loads; and what is the real impact of weight gain.

Overall, future research should be focused on strengthening evidence by increasing the number of participants and better explain the characteristics of recruitment and of the women. Other focus should be the development of prospective studies to minimize bias in estimating the prevalence of falls and back and lower limb pain, regarding the biomechanical adaptations and the effects of an active lifestyle.

5.7 Conclusion

In this chapter, we have reviewed the musculoskeletal and biomechanical changes of gait during pregnancy and in the postpartum period. Although the dedicated literature is limited, the available evidence suggests biomechanical adaptations of gait throughout pregnancy and the postpartum period. However, no studies were found addressing the effects of physical activity, low back and pelvic pain, or maternal weight gain on the gait biomechanical adaptations of gait throughout pregnancy and postpartum.

In order to better develop safe and effective exercise programs, it is necessary to understand the physical activity patterns of pregnant women, the characteristics of proper exercise in terms of mechanical loading, and also its effects in the pregnant women in terms of gait, functionality, morphology, and treatment of low back pain. Thus, the assessment of biomechanical loading in the musculoskeletal system of pregnant women is of particular interest. This information becomes very important to implement exercise programs for pregnant women and to develop strategies to increase adherence.

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Specific Musculoskeletal Adaptations in Pregnancy: Pelvic Floor, Pelvic Girdle, and Low Back Pain: Implications for Physical Activity and Exercise

6

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Abstract

Pregnancy and childbirth bring along several changes to a woman's body, especially to the musculoskeletal system. Pregnancy represents a window of opportunity for the adoption of an active and healthy lifestyle, but it is also a risk period for musculoskeletal disorders, impairments, and other discomforts. This chapter addresses the evidence-based knowledge on the most prevalent pelvic floor muscle dysfunction (urinary incontinence), diastasis recti abdominis, pregnancy-related low back pain, and/or pelvic girdle pain, since these factors are reported to have a negative effect on daily activities. The chapter also provides recommendations for treatment of such disorders and guidance on how to recover functional capacity.

Keywords

Pregnancy · Postpartum · Pelvic floor · Low back pain · Pelvic girdle pain Physical activity · Exercise

6.1 Introduction

Pregnancy and childbirth bring along several changes to a woman's body, especially to the musculoskeletal system. Pregnancy represents a window of opportunity for the adoption of an active and healthy lifestyle, but it is also a risk period for musculoskeletal disorders, impairments, and other discomforts. This chapter addresses the evidence-based knowledge on the most prevalent pelvic floor muscle dysfunction (urinary incontinence), diastasis recti abdominis, pregnancy-related low back pain and/or pelvic girdle pain, since these factors are reported to have a negative effect on daily activities. The chapter also provides recommendations for treatment of such disorders and guidance on how to recover functional capacity.

6.2 The Pelvic Floor

The urethra, bladder, vagina, uterus, and bowel situated within the pelvis are given structural support by pelvic floor structures arranged into a superficial and a deep layer of muscles and connective tissue (ligaments and fascia) [1]. In addition to pelvic organ support, the pelvic floor maintains continence, permitting urination, defecation, intercourse, and vaginal birth [1].

The superficial layer of the pelvic floor includes the perineal muscles (ischiocavernosus, bulbospongiosus, and transversus perinei superficialis), and the deep layer includes the levator ani (LA) muscle [1]. These pelvic floor layers in addition to the urethral and anal sphincter system (external and internal sphincter muscles and vascular elements within the submucosa) play a significant role in maintaining pelvic organ support and continence [1–3].

The pelvic floor muscles (PFM) interact with the supportive ligaments and fasciae in order to maintain support of the pelvic organs and protect the pelvic floor connective tissue from excessive loads [3–5]. The function of this supportive system is illustrated by the "boat in dry dock theory" by Norton [5], where the PFM act as water in the dock floating the boat (pelvic organs) unloading the mooring (ligaments and fasciae) holding the boat in place. If the water is removed (loss of pelvic floor muscle tone), the moorings (pelvic ligaments and fasciae) are placed under excessive strain.

A voluntary PFM contraction can best be described as an inward lift and squeeze around the urethra, vagina, and rectum [6, 7]. During a voluntary PFM contraction, the medial portion of the LA muscle interacts with the endopelvic fasciae and compresses the urethra against adjacent tissues, which creates increased urethral pressure and stabilization of the urethra and bladder neck [2, 3].

The normal baseline activity of the PFM keeps the pelvic openings closed and keeps the pelvic floor elevated in a cranial direction [4, 8]. In situations where abdominal pressure increases, during physical exertions such as coughing, laughing, high-impact activities, etc., a simultaneous well-timed PFM contraction will counteract the increased abdominal pressure by increased structural support and compression of the urethra [2–4, 9]. The PFM is supposed to react automatically when the abdominal pressure increases. The pelvic floor works like a "firm trampoline" giving a quick response when loads are put onto it [10].

Together with the urethral sphincter muscles, the PFM play an important role for maintaining urinary continence [2–4, 9]. The mechanical supportive potential of the PFM is demonstrated by Miller et al. [11]. By perineal ultrasound assessment, they found that a voluntary contraction of the PFM prior to and during a cough (a maneuver called the "Knack") resulted in a significant reduced displacement of the bladder neck [11]. Use of the "Knack" maneuver has also shown to significantly reduce urine loss among women with SUI [12, 13].

6.2.1 Pelvic Floor Dysfunction and Risk Factors

The understanding of the development of pelvic floor muscle dysfunction is far from complete. Rather than a single factor, the most common types of pelvic floor dysfunction (UI, fecal incontinence, and pelvic organ prolapse) probably have a complex list of risk factors [14–16]. Factors that may lead to the development of pelvic floor impairment and dysfunction in women can according to Bump and Norton [14] be classified into the following four categories:

- *Predisposing factors*: e.g., gender, racial, neurologic, anatomic, collagen, muscular, cultural, and environmental.
- *Inciting factors*: e.g., childbirth, nerve damage, muscle damage, radiation, tissue disruption, and radical surgery.
- *Promoting factors*: e.g., constipation, occupation, recreation, obesity, surgery, lung disease, smoking, menstrual cycle, infection, medication, and menopause.
- *Decompensating factors*: e.g., aging, dementia, debility, disease, environment, and medication.

DeLancey et al. [16] integrate factors affecting pelvic floor dysfunction into an "Integrated Lifespan Model," in which pelvic floor function is plotted into three major life phases: (1) development of functional reserve during growth, influenced by predisposing factors, e.g., genetic constitution; (2) amount of injury and potential recovery occurring during and after childbirth; and (3) deterioration occurring with advancing age. Throughout the lifespan a decline of the functional reserve of the pelvic floor may be accelerated by other factors, e.g., obesity and chronic coughing, medications, and dementia.

Knowledge about the various risk factors and their relative importance in relation to type of pelvic floor dysfunction is essential for primary and secondary prevention strategies [14, 16].

6.2.2 Urinary Incontinence

UI has been defined by the International Continence Society as "the complaint of any involuntary leakage of urine" and can further be classified into subtypes with the following definitions [17]:

- Stress urinary incontinence (SUI): "the complaint of involuntary leakage on effort or exertion, or on sneezing or coughing."
- Urge urinary incontinence (UUI): "the complaint of involuntary leakage accompanied by or immediately proceeded by urgency."
- Mixed urinary incontinence (MUI): "the complaint of involuntary leakage associated with urgency and also with exertion, effort, sneezing, or coughing."

6.2.2.1 Prevalence

A systematic literature review by Hunskaar et al. [18], including 36 epidemiological studies from 17 countries, showed a prevalence of any UI within the range 5–69% among the general female population. However, most of these studies showed a UI prevalence within the range 25–45% [18]. A wide range in UI prevalence might be explained by differences in the population studied, definition of UI, type of UI, and assessment of UI [19–21]. According to an updated review on UI prevalence by Milsom et al. [22], recent epidemiological studies report estimates on UI prevalence that are within the prevalence range reported by Hunskaar et al. [18]. The most common type of UI reported by young and middle-aged women is SUI, while older women are more likely to report MUI and UUI [18, 22].

6.2.2.2 Prevalence During Pregnancy

Studies of prevalence of UI during pregnancy have shown period prevalence within the range 32–64% for any type of UI and 40–59% for the combination SUI/MUI [18, 22]. Higher period prevalence has been reported in parous than in nulliparous women [23–27]. The largest prospective population-based study included in the review by Milsom et al. [22] is the study published by Wesnes et al. [27]. This study was part of the Norwegian Mother and Child Cohort Study. Results showed that prevalence of UI increased from 15% before pregnancy to 48% at gestational week 30 for nulliparous women and from 35% before pregnancy to 67% at gestational week 30 for parous women. SUI was the most common type of UI with figures showing an increase from 9% before pregnancy to 31% at gestational week 30 for nulliparous women and from 24% to 42% for parous women.

6.2.2.3 Prevalence After Childbirth

The estimation of postpartum UI is, according to Milsom et al. [22], challenged by study heterogeneity (study design and method, definition of UI, and sample studied). In their review they therefore chose to summarize data from 22 studies on primiparous women enrolled at larger hospitals serving a defined population. The range of UI prevalence (any type) in primiparous women during the first year postpartum, regardless of delivery mode, was 15–30%. According to Milsom et al. [22], the included studies showed consistently higher UI prevalence in women who delivered vaginally than in women who delivered by caesarean section, with the exception of one study [28].

6.2.3 Etiology and Pathophysiology of Urinary Incontinence

UI also occurs in women who never have gone through pregnancy and childbirth. However, pregnancy and childbirth are considered main etiological factors for the development of UI [29]. Connective tissue, peripheral nerves, and muscular structures are already during pregnancy subjected to hormonal, anatomical, and morphological changes. During vaginal delivery, the abovementioned structures are forcibly stretched and compressed. This may initiate changed tissue properties, which may contribute to altered pelvic floor function and increased risk of UI [29]. The picture of possible causative factors and the pathophysiology of UI are complex, some factors are studied more than others, and the importance of factors associated by the pregnancy itself versus factors associated childbirth is still under discussion [29].

6.2.3.1 Pregnancy

Prospective observational studies have shown increased prevalence of UI from the first trimester to the second and further into the third trimester [26, 30, 31]. One hypothesis of increased prevalence during pregnancy is linked to increased bladder pressure due to the growing uterus and weight of the fetus, and another is linked to hormonal changes altering the viscoelastic properties [26]. In the observational study by Hvidman et al. [26], the authors suggest that UI may not be provoked by the onset of pregnancy but by its progressive concentration of pregnancy hormones which may lead to local tissue changes. They found no association between UI and the birth weight of the child and state less support for the theory linking UI to increased pressure on the bladder caused by weight of the fetus. Studies have shown an association between UI and maternal obesity both during pregnancy [27] and after childbirth [32–34], which could be caused by increased intra-abdominal pressure and increased bladder pressure [35].

The PFM is considered to play a significant role in the continence control system [2–4, 9], and urine loss may be linked to impaired PFM function, e.g., weak PFM. Several observational studies have demonstrated significantly higher PFM strength in continent women than in women having UI [36–43], while some studies did not find such difference [44, 45]. Two of the abovementioned studies were on pregnant women [36, 40, 43]. In addition to significantly higher PFM strength, Mørkved et al. [40] also report a significantly thicker PFM among the continent pregnant women.

UI during pregnancy is transient in some women but may become long-lasting in others. Prospective observational studies have shown that antenatal UI may increase the risk of postpartum UI [34, 46–48].

6.2.3.2 Childbirth

Parity seems to be an increased risk factor for UI [15, 24, 31, 49–51]. In a cross-sectional study of 27,900 women, Rortveit et al. [50] report a relative risk (RR) of UI of 2.2 (95% CI, 1.8–2.6) for primiparous women and 3.3 (95% CI, 2.4–4.4) for grand multiparous women. Altman et al. [48] included 304 primiparous women and followed them 10 years prospectively. They found vaginal delivery to be independently associated with a significant long-term increase in SUI and UUI, regardless of maternal age and number of deliveries. This is supported by Viktrup et al. [34] following 241 primiparous women 12 years after their first delivery.

The protective effects of caesarean section have been and still are much debated. In a systematic review by Press et al. [52], the prevalence of postpartum SUI after caesarean section was compared with vaginal delivery. Based on data from six cross-sectional studies, caesarean section reduced the risk of postpartum SUI from 16% to 10% (OR 0.56; 95% CI, 0.45–0.68), while data from 12 cohort studies gave a reduction from 22% to 10% (OR 0.48; 95% CI, 0.39–0.58). However, risk of severe SUI and UUI did not differ by mode of birth.

6.2.3.3 Bladder Neck and Urethral Hypermobility

Impaired structural support of the urethra may cause increased bladder neck mobility and reduced compression of the urethra which again may lead to UI [3]. Peschers et al. [53] investigated change in bladder neck mobility, during the Valsalva maneuver, from late pregnancy to 6–10 weeks postpartum. They found increased mobility in women who delivered vaginally ($p < 0.001$) but found no such change in women with elective caesarean section ($p = 0.28$). Their findings are supported by Meyer et al. [54] and Dietz et al. [55].

Meyer et al. [56] found significantly higher bladder mobility, during the Valsalva maneuver, in women with SUI (mean parity 2.4, SD 0.8) when compared to nulliparous continent women. However, the association between increased bladder neck mobility and SUI may not solely be explained by vaginal childbirth. King and Freeman [57] followed nulliparous pregnant women with no preexisting UI from gestational week 15–17 to 10–14 weeks postpartum. They found that primiparous women with SUI postpartum had significantly greater antenatal bladder neck mobility than continent counterparts, which could be explained by a predisposed weak connective tissue, aggravated by pregnancy hormones and collagen remodeling [57, 58].

A study on bladder neck mobility and tissue stiffness was performed by Howard et al. [59]. Results from their study showed that primiparous women with SUI displayed similar bladder neck mobility during a cough and during a Valsalva maneuver ($p = 0.49$), while significantly less mobility was displayed during a cough than during the Valsalva both for continent nulliparous women ($p = 0.001$) and for continent primiparous women (0.002). When controlling for abdominal pressures, their calculations showed that nulliparous women displayed a significantly greater pelvic floor stiffness during a cough than the continent and incontinent primiparous women ($p = 0.001$).

6.2.3.4 Neural Denervation

Neuromuscular impairment is associated with the development of incontinence. Smith et al. [60] found that terminal branches of the pudendal nerve had a delayed conduction both to the striated urethral muscle and to the PFM in women with SUI when compared to continent women. Such denervation seems to be related to parity and vaginal childbirth [61–64]. In a biomechanical study by Lien et al. [65], lengthening of pudendal nerve branches was simulated by using a 3D computer model. The results from this study showed that the inferior rectal branch of the pudendal nerve may exhibit a strain of 35%. Pudendal nerve neuropathy appears to be associated with both a long second stage and high birth weight [63, 66, 67]. Such neural impairment may alter the muscle morphology. In a study by Gilpin et al. [68], biopsy samples from women with SUI showed a significant higher number of muscle fibers with pathological damage when compared to biopsy samples from continent women.

6.2.3.5 Weakening of the Pelvic Floor Muscles

Vaginal delivery is considered as a main risk factor for weakening of the PFM [63, 66, 69–74]. Due to the extensive stretching of muscle fibers and the likelihood of muscle denervation, it is not surprising that vaginal delivery may lead to reduced vaginal resting pressure and impaired PFM strength and endurance and that caesarean section may protect the PFM. A PubMed search gave seven studies [36, 54, 75–79] investigating change in PFM strength from pregnancy to shortly after childbirth in relation to mode of delivery. Except from one study [77], the other six studies showed a significant reduction in PFM strength after vaginal delivery, but no significant decline after caesarean section.

6.2.4 Levator Ani Muscle Defects

Vaginal delivery may stretch and load beyond the physiological properties of the PFM, which may lead to muscle fiber tearing and reduced contractile force. The biomechanical study by Lien et al. [80] showed that muscle fibers, of the most medial part of the LA muscle, might be stretched up to three times their resting length as the fetal head is crowning. Their findings showing a pronounced stretch and deformation of the medial part of the LA muscle are confirmed by Hoyte et al. [81] and Parente et al. [82].

During recent years, technical advancement within magnetic resonance and ultrasound imaging has enabled diagnosis of defects of the LA muscle [83]. Major defects of the LA muscle are often defined as an abnormal insertion of this muscle toward the pubic bone, visually seen as a complete loss of visible muscle attachment at this specific site either unilaterally or bilaterally [69, 72, 83]. Imaging studies have shown that major LA muscle defects among primiparous women delivering vaginally could appear in 20–36% of the women [69, 84]. The use of forceps [70] and length of the second stage [70, 85] are associated with major LA muscle defects, whereas the importance of fetal head circumference and high fetal birth weight seems to be less clear [84–86].

Decreased strength is one of the most common symptoms following muscle tears within sport injuries [87]. Hence, decreased PFM strength in women with major LA muscle defects is expected but has been sparsely investigated. A PubMed search revealed five observational studies [88–92] in which PFM strength in women with and without LA muscle defects was assessed. Results from all five studies showed significantly reduced PFM strength in women with LA muscle defects when compared to women without such defects. Dynamometer was used for assessment of PFM strength in two of these five studies [88, 91], digital palpation in one study [89], transperineal ultrasound in one [90], and manometer in one [92]. These studies did also differ in age and parity of the women included.

Major LA muscle defects have shown a marked effect on hiatal dimensions [93–95] and pelvic organ support [95] which in turn could be explanatory factors for pelvic floor dysfunction. Major defect of the LA muscle has been linked to pelvic organ prolapse in particular [83, 88, 96, 97], while the link between LA muscle defects and UI is debated. Two studies [69, 84] report a significant association between LA muscle defects and SUI in the postpartum period. However, contradictory findings are reported for the link between LA muscle defects and SUI in studies on women with mixed parity and mean age >50 years [86, 98, 99].

6.2.5 Muscle Injury Regeneration

The healing process of a torn muscle has three phases: (1) the destruction phase, (2) the repair phase, and (3) the remodeling phase [87, 100, 101]. In the destruction phase, the rupture is followed by necrosis and formation of a hematoma. In the repair phase, a phagocytosis of necrotized tissue takes place, followed by proliferation of skeletal muscle satellite cells which induce regeneration of myofibrils. Along with this is formation of scar tissue and revascularization of the injured area initiated. During the remodeling phase, a further maturation of the regenerated myofibrils is implemented together with remodeling of the scar tissue, followed by recovery to functional capacity [87, 100, 101].

6.2.5.1 Treatment Principles for Skeletal Muscle Injuries

Recommendations for treatment of muscle injuries and how to recover functional capacity are most often based on theoretical framework from epidemiological studies, clinical practice, and findings from experimental research [102]. Early mobilization is a standard treatment after muscle injury within sports medicine, and training is believed to be important in speeding up tissue healing (repair and remodeling). This approach is supported by experimental studies showing that early mobilization after a muscle injury may facilitate the following: more rapid capillary ingrowths, improved parallel orientation of the regenerating myofibrils, and improved tensile properties [87, 100, 101, 103].

6.3 Diastasis Recti Abdominis

Pregnancy and childbirth bring along several changes to a woman's body, especially to the musculoskeletal system [104]. The most obvious change is related to the growth of the fetus and the stretching of the abdominal muscles, which may influence the mother's posture and balance [104]. Today there is a strong focus on the pregnant woman's appearance, especially through social media. Webpages and apps recommend how women should stay thin and get back into shape and "a flat tummy" at an early stage of the postpartum period. Using the search terms "diastasis recti" and "exercise," 278,000 hits were obtained on Google. In addition, there are easily available advices on how to get rid of what is named "the mum's belly" (e.g., www.mammamage.se, www.breakingmuscle.com, www.befitmom.com, www.babybellybelt.com, tummyzip.com). A systematic review of the scientific literature has found none or very weak evidence behind any of these advices [105].

A strong focus on an area of the body that is naturally changed during pregnancy and after childbirth and that may recover by itself over time maybe a risk factor for development of an unhealthy attitude toward exercise, appearance, body shape, and image, and new mothers may become dissatisfied with their bodies and especially their abdomen. On the other hand, pregnancy and childbirth *are* risk periods for the development of obesity and musculoskeletal complaints such as low back and pelvic girdle pain [106] and pelvic floor dysfunctions including urinary and anal incontinence and pelvic organ prolapse [107]. A possible link between these conditions and injuries and weakness of the abdominal muscles has been postulated [108].

Diastasis recti abdominis (DRA) is defined as an impairment with midline separation of the two rectus abdominis muscles along the linea alba. The condition affects a significant number of women during the antenatal and postnatal period [109]. Prevalence rates (with and without protrusion/hernia) during pregnancy vary between 27% and 100% in the second and third trimesters [110, 111]. Postpartum, the prevalence rates of DRA vary between 30% and 68% [112, 113]. In a longitudinal study of 300 first-time pregnant women at Akershus University Hospital in Norway, Sperstad et al. [114] found that prevalence rates changed from 33% at gestational week 21 to 60%, 45.4%, and 32.6% at 6 weeks, 6 months, and 12 months postpartum, respectively. However, DRA has been found to be common in middle-aged women [115] and may also be present in men [116]. Whether strong abdominal muscles can prevent or are a risk factor for development of the condition is not known. To date there are no prevalence studies or assessments of this condition among recreational exercisers and elite athletes [104].

DRA is diagnosed by measuring the distance between the median borders of the two rectus abdominis, inter-rectus distance (IRD), and measurement methods in use are palpation with fingerbreadths, caliper, or ultrasound [117]. Palpation is the most commonly used method in clinical practice [118] and has an intra- and inter-tester ICC of 0.7 and 0.5, respectively [119]. However, ultrasound has been found to have the best intra- and inter-tester reliability with ICC > 0.9 [120]. To date there is no consensus on where to measure IRD along the linea alba (frequently used locations are 4.5 cm above the umbilicus, at the umbilicus, and 4.5 cm below the umbilicus) or the cutoff point for diagnosing the condition [117]. A commonly used cutoff point is two fingerbreadths on palpation [117]. Candido et al. [121] have classified severity of the diastasis as mild (2.5–3.5 cm or visible protrusion with diastasis less than 2.5 cm), moderate (3.5–5 cm), and substantial (>5 cm).

The etiology and risk factors for DRA are not clear [122]. Fernandes da Mota et al. [123] found that neither age, BMI, weight gain during pregnancy, hypermobility, birth weight, abdominal circumference at gestational week 35, nor exercise level before and during pregnancy was a risk factor for diastasis 6 months postpartum. This was in agreement with results of Sperstad et al. [114] comparing women with and without diastasis 12 months postpartum. Spitznagle et al. [115] found higher prevalence of DRA in older multiparous women, while Candido et al. [121] did not find any relationship with parity. None of the abovementioned studies found any relationship with mode of delivery (vaginal versus caesarean section) and diastasis.

6.3.1 Consequences of Diastasis Recti Abdominis

It has been postulated that DRA, in addition to being a cosmetic concern for many women, may reduce low back and pelvic stability, cause low back and pelvic girdle pain and be related to pelvic floor dysfunctions such as urinary incontinence, anal incontinence, and pelvic organ prolapse [115, 124]. However, to date there is scant scientific knowledge on this topic. An association between DRA and abdominal muscle strength has not yet been substantiated with strong evidence. In a longitudinal small study following six women from gestational week 14 to 8 weeks postpartum, Gilleard and Brown [125] found that women with IRD >3.5 cm measured with palpation had reduced curl-up "capacity." This was supported by a study following 40 women postpartum, which found that postpartum women had weaker abdominal muscles than a control group [126]. However, at 6 months postpartum, there was no correlation between IRD and reduced abdominal muscle strength.

No strong link between DRA and low back pain has been found. Parker et al. [127] found that women at least 3 months postpartum with DRA had more abdominal and pelvic pain than women without. However, two other studies did not find any difference in prevalence of low back or pelvic girdle pain in primiparous women 6–12 months postpartum between women with and without DRA [111, 114]. Most of these studies included women with light and moderate diastasis. Hence, it is important to investigate the association between severe diastasis and low back and pelvic girdle pain.

6.4 Pregnancy-Related Low Back Pain and Pelvic Girdle Pain

Pregnancy-related low back pain (LBP) and/or pelvic girdle pain (PGP) is common across many countries, irrespective of socioeconomic factors [128–131], and is reported to have a negative effect on daily activities such as walking, lifting, climbing stairs, lying flat on the back, turning in bed, housework, exercise, employment, leisure, sexual life, hobbies, and personal relationships [132]. Women with LBP and PGP report a significantly lower health-related quality of life than that reported by healthy women, and a major factor affecting their quality of life is found to be lack of physical ability [133, 134]. PGP during pregnancy greatly affects a woman's experience of her pregnancy, her roles in relationships, and her social context [135, 136]. These women are struggling with enduring pain that disturbs most aspects of their lives [135, 137], and the pain is perceived as an unpredictable and potentially disabling condition [138]. Whereas most women recover after delivery, a number of women continue living with disabling PGP. Postpartum PGP may influence women's lives for months and years after delivery. Discouragement, isolation and loneliness may be part of a daily life with pain and limited physical activity [139].

The prevalence rates of pregnancy-related LBP and PGP vary depending on the criteria used and mode of reporting, but are estimated to be about 50% during pregnancy [140]. Whereas LBP is usually defined as pain between the 12th rib and the gluteal fold, PGP is defined as pain experienced between the posterior iliac crest and the gluteal fold, particularly in the vicinity of the sacroiliac joints [106]. PGP generally arises in relation to pregnancy and is defined as pain in the pelvic musculoskeletal system that does not derive from gynecological and urological disorders. A diagnosis of PGP can be reached after the exclusion of lumbar causes, and the pain or functional impairments in relation to PGP must be reproducible by specific clinical tests [106]. Although similar and overlapping features may be ascribed to LBP and to PGP, it is argued that a distinction should be made [106, 140]. PGP has more impact on pain intensity and disability than LBP [141, 142]. Whereas the normal progression of LBP during pregnancy peaks between 12 and 30 weeks [143, 144], PGP increases progressively with advancing pregnancy [145]. Most probably about 20–25% of all pregnant women who suffer from PGP sufficiently seriously require medical help [106, 146]. Though the majority of women with PGP recover spontaneously soon after delivery, 3–7% report having serious problems from persistent PGP years after delivery [140, 147]. In the only study among elite athletes, 12.6% reported retrospectively that they experienced PGP 6 weeks postpartum and 9.7%

experienced LBP. The prevalence increased to 19.4% for PGP and 29% for LBP at the time of completing the questionnaire 0–17 years after delivery [148].

The etiology and pathogenesis of PGP are unclear and probably multifactorial. Possible underlying causes include hormonal and biomechanical aspects, inadequate motor control, and stress on ligament structures [149]. PGP often occurs during the early stages of pregnancy [151], and the symptoms typically regress shortly after delivery [147]. A possible association between serum relaxin levels and PGP is debated [147, 150, 151]. The exact movements that occur in the pelvic joints have been traced [152, 153]. Recently, it was shown that the movement in the sacroiliac joints is small and almost undetectable by precise radiostereometric analysis [154]. Even though small, any increased motion in the pelvic joints may diminish the efficiency of load transfer and increase the shear forces across the joints. Increased shear forces has been suggested to be one factor for pain in women with PGP [106]. The self-locking mechanism of the sacroiliac joints with the principles of form and force closure, based on a theoretical model from anatomical and biomechanical studies, was introduced in 1997 by Snijders and co-workers [155]. Failure of the self-locking mechanism and load transfer through the pelvis has been suspected in patients with sacroiliac pain [156, 157], and asymmetric laxity of the sacroiliac joints has been shown to correlate with moderate to severe levels of symptoms in subjects with postpartum PGP [158].

The sacrospinous ligament and superficial sacroiliac joint structures, such as the long dorsal sacroiliac ligament, are a potential source of pain in PGP [159–162]. An impaired load transfer during activities may result in overload of the ligaments of the pelvis and hence have an influence on PGP [163, 164]. Frequent or sustained pain-provoking postures might influence the pelvic ligaments and in turn link to other symptoms. Changes in spinal curvature and posture may be caused by pregnancy. Both increased lumbar lordosis [165] and a tendency for lumbar kyphosis or a flattening of the lumbar spine is reported to be prevalent during pregnancy [166, 167].

There is some evidence that PGP is related to an altered pelvic mechanism and/or motor control [168]. PGP disorders have been associated with an alteration in the strategy for lumbopelvic stabilization with excessive as well as insufficient motor activation of the lumbopelvic and surrounding musculature [169]. Impaired motor control patterns may be a possible mechanism for ongoing pain and disability in patients with persistent PGP [170]. Attention has been paid to motor control of local muscles, especially the transverse abdominals [170, 171]. Also the pelvic floor muscles are considered to be an important part of the local muscle system, and Stuge and co-workers found significantly smaller levator hiatus area in women with PGP than in controls both at rest, during voluntary contraction, and during automatic contraction [172, 173].

Whereas the role of muscle function in LBP in the general population is debated, an association between reduced muscle function and the development of LBP and/or PGP in pregnant women is reported [174]. Indications exist that pregnant women with gluteus medius weakness are more likely to have LBP than those without this weakness [175]. In pregnant women with LBP and/or PGP, both lower levels of trunk muscle endurance and hip extension muscle strength [176] and increased muscle activity during the active straight leg raise test are reported [177]. Consequently, an association between muscle dysfunction and LBP and/or PGP during and after pregnancy may exist.

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Further Reading

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Evidence-Based and Practice-Oriented Guidelines for Exercising During Pregnancy

7

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Abstract
Physical activity is associated with many health benefits during pregnancy, delivery, and the postpartum period. The last two decades produced an increasing amount of scientific evidence on the positive effects of the prenatal physical activity on the maternal and fetal health, as well as in pregnancy outcomes. However, authors from different countries observe insufficient level of physical activity in pregnant women. The lack of information among women on the exercises during pregnancy and lack of social support are two of the reasons hindering engagement in a prenatal exercise program. According to other studies, the knowledge of health benefits can lead to more favorable attitudes toward exercise during pregnancy, among women, exercise professionals, and healthcare providers. The purpose of this chapter is to review the information provided in the current guidelines for exercise during pregnancy in different countries, regarding the contents related to prenatal exercise programs.

Keywords
Guidelines · Exercise · Physical activity · Pregnancy · Postpartum

7.1 Introduction

Physical activity is associated with many health benefits during pregnancy, during delivery, and in the postpartum period. Research over the past 30 years has shown that regular physical activity during pregnancy has a positive effect on the physical and psychological condition of the pregnant woman, pregnancy and fetal development, parturition, and the postpartum period [1–5]. Physical activity started in pregnancy may be the first step to a lifelong change to a health-promoting lifestyle [6]. Research has also proved that prenatal physical activity of mothers has a long-term effect on the health of the children, including a reduction in the risk of obesity in later life [7]. This fact was taken into account, inter alia, in European documents, assuming that the popularization of physical activity in pregnant women is one of the strategic actions in the “EU Action Plan on Childhood Obesity 2014–2020” [8].

With the increasing amount of scientific evidence on the positive effects of the prenatal physical activity, the authors from different countries observe its insufficient level in pregnant women [4, 9–18]. As the reasons for this phenomenon, the authors list, among other things, lack of information among women on the exercises during pregnancy [4, 17] and lack of social support [19, 20]. For some women, pregnancy itself is a sufficient reason for not exercising [18, 19].

There have been few studies regarding the level of pregnant women’s knowledge and their attitudes toward prenatal physical activity [21–24]. Gouveia et al. [24] noted that although most mothers in Portugal understand the benefits of physical activity in pregnancy, that doesn’t seem to increase their participation. However, according to other studies, the knowledge of health benefits can lead to more favorable attitudes toward exercise during pregnancy among women from different countries [22, 23, 25]. Cannella et al. [22] showed that women who were informed about the benefits and risks of physical activity, risks of inactivity, and also the exercise techniques displayed more favorable attitudes toward prenatal physical activity. Many of the women surveyed in their study reported that they had received information about the benefits of prenatal physical activity, but fewer answered that they had received information about how to exercise safely.

The importance of healthcare professionals in promoting the benefits of physical activity and exercise, advising women on a healthy and active lifestyle during pregnancy, and referring them to a prenatal exercise specialist is highlighted in Chap. 1 [26]. Official guidelines for exercise in pregnancy could be an effective tool in fulfilling this task. Tanha et al. [25] have proved that dissemination of such documents among pregnant women contributes significantly to the increase in their participation in prenatal exercise. Official guidelines published by national and international obstetrics, gynecology, or sports medicine institutions should be a trustworthy and comprehensive source of information on the safe and beneficial exercise program during pregnancy. They should be accessible to all interested in prenatal physical activity, pregnant women and their families, obstetric care providers, and exercise professionals, to enable an effective cooperation in the exercise program design.

Pregnancy causes many changes in the woman's body: morphological, physiological, biomechanical, and psychological [27]. They should be taken into account in the planning of the intensity, frequency, and duration of the exercise sessions and also of their content—through a proper selection of the type of exercises and their technique [28–30]. Evenson et al. [31] have shown that nine out of ten guidelines on exercise in pregnancy from different countries contained information on the intensity and duration of exercise. Eight of these documents contained recommendations on the exercise frequency. In this chapter we aimed to answer the question on what information on the contents of prenatal exercises is provided in the current guidelines for exercise during pregnancy in different countries. We have updated a review study published in 2015 [32] that was focused on detailed information on the contents of prenatal exercises presented in reliable guidelines. The methodological issues are fully described in the original paper.

In this chapter we included other recent documents that were the official position of national obstetrics, gynecology, or sports medicine institutions on prenatal physical activity. In the following part of this work, we call these documents "guidelines on exercise in pregnancy." We have narrowed the documents to those published in English, which ensures their wide usage. The first stage of the update began with a search of documents in the scientific database MEDLINE with Full Text. Bearing in mind that the guidelines do not need to have the character of scientific work, and only represent the official position of credible national institutions, in the second stage, we completed the search of documents in public search engines. We used the keywords "exercise" or "physical activity" and "pregnancy" and "guidelines" or "statement." The 30th of December 2017 was the last date searched. In the first stage of the analysis, we looked for the general recommendation on the type of exercise and information on the recommended and not recommended forms of exercise and sports activities for pregnant women and if it is advised to consult with the healthcare provider on the exercise program. In the second stage of the analysis, we looked for detailed information that might be useful for designing the contents of targeted exercise classes for pregnant women.

7.2 General Features of the Guidelines on Physical Activity in Pregnancy

We have analyzed 13 documents from seven countries, Australia [33, 34], Canada [35, 36], Denmark [37], Norway [38], South Africa [39], the United Kingdom [40], and the United States [41–44], and an international document supported by the International Olympic Committee [2, 3, 45] (Table 7.1). Three of those (from Denmark and ACNM and ACSM in the United States) contain no information on references and the quality of scientific evidence. They are layman oriented, although they met our criteria for inclusion in the analysis (were published in English and were the most recent country-specific, official position of national obstetrics, gynecology, or sports medicine institutions).

The year of publication is a striking feature in the analysis of the guidelines on exercise during pregnancy (Table 7.1). Only five of the 13 documents have been published in the last 5 years. For obvious reasons they are based on scientific works that were frequently 15 or more years old. The American College of Obstetricians and Gynecologists (ACOG) recommendations were reaffirmed in 2009 with no changes compared to the first edition in 2002. Finally, in 2015 the ACOG recommendations were updated emphasizing that physical activity in pregnancy has minimal risk and highlighting that women who exercised regularly prior to pregnancy, in absence of contraindications, can continue and engage in moderate to strenuous activities [41]. Also in this update, several activities were introduced as recommended activities if pregnant women practiced them prior to pregnancy (i.e., aerobics, jogging, running, or stationary cycling). It is the first document where physical inactivity has been treated as a risky behavior leading among others to maternal obesity and related pregnancy complications, including gestational diabetes mellitus.

The Sports Medicine Australia recommendations were updated in 2016 [46], increasing the specification of the recommended physical activities during pregnancy (i.e., resistance training, swimming, or jogging) and introducing pelvic floor exercises as a recommended activity to include in exercise programs during pregnancy. More recently, Bø et al. and the Medical and Scientific Commission of the International Olympic Committee (IOC) drove a discussion about the management of pregnancy for elite athletes and produced comprehensive evidence summary on exercise during pregnancy [2, 3] and postpartum [45], as well as recommendations for future research [47]. The statements endorsed by IOC include scientific evidence about endurance and strength training on elite athlete during pregnancy. In addition the IOC pointed that future research should focus on the effects and obstetric risks of specific types of exercise, training place, or strenuous exercise. There is also a need to improve the knowledge on the influence of physiological and

Table 7.1 Characteristics of analyzed guidelines on exercise in pregnancy

Country	Organization	Title	Year of publication
Australia	Sports Medicine Australia (SMA) [33]	SMA statement: the benefits and risks of exercise during pregnancy	2002 Updated 2016 [33]
Australia	Fitness Australia. The Health & Fitness Industry Association [34]	Pre- and postnatal exercise guidelines	2013
Canada	Society of Obstetricians and Gynaecologists of Canada; Canadian Society for Exercise Physiology (SOGC/CSEP) [35]	Exercise in pregnancy and the postpartum period	2003
Canada	Canadian Academy of Sport and Exercise Medicine (CASEM) [36]	Position statement: exercise and pregnancy	2007; Updated 2008
Denmark	National Board of Health [37]	Healthy habits before, during, and after pregnancy. 1st English edition	2010
Norway	Directorate for Health and Social Affairs [38]	A National Clinical Guideline for Antenatal Care. Short Version—recommendations	2005
South Africa	South African Sports Medicine Association (SASMA) [39]	South African Sports Medicine Association Position Statement on Exercise in Pregnancy	2012
United Kingdom	Royal College of Obstetricians and Gynaecologists (RCOG) [40]	Exercise in pregnancy	2006
United States	American College of Obstetricians and Gynecologists (ACOG) [41]	Committee opinion: exercise during pregnancy and the postpartum period	2002; Reaffirmed in 2009 updated in 2015 [41]
United States	US Department of Health and Human Services (US DHHS) [42]	Physical Activity for Women During Pregnancy and the Postpartum Period Chapter in: 2008 Physical Activity Guidelines for Americans	2008
United States	American College of Nurse-Midwives (ACNM) [43]	Exercise in pregnancy	2014
United States	American College of Sports Medicine (ACSM) [44]	Current comment: exercise during pregnancy	Not reported
International	International Olympic Committee (IOC); three parts [2, 3, 45]	Exercise and pregnancy in recreational and elite athletes: 2016 evidence summary from the IOC expert group meeting, Lausanne	2016

anatomical changes related to pregnancy on the training development or influence of training during pregnancy on the return to the competitive level in the postpartum period.

Both in the scientific research on prenatal physical activity [25, 48, 49], and in educational standards [50], as well as in exercise programs [29], the authors refer to the official guidelines for exercise in pregnancy. Although it is difficult to estimate the extent of their impact, the contribution of these documents to change the perception of prenatal physical activity in the past decade is indisputable.

The breakthrough was the recommendation published in Canadian guidelines in 2003 that "All women without contraindications should be encouraged to participate in aerobic and strength-conditioning exercises as part of a healthy lifestyle during their pregnancy" [35]. ACOG [51] and SMA [52] issued similar recommendations in 2002 and in their latest updates [33, 41]. In contrast to this position, the guidelines issued 30 years ago suggested that exercising women reduce their habitual levels of exertion in pregnancy and that non-exercising women refrain from initiating strenuous exercise program [53]. Such conservative recommendations were based, among others, on the results of scientific studies demonstrating the negative effects of hard physical work, combined with undernutrition, on the development of pregnancy in laboratory animals [54, 55]. However, the results of research conducted on pregnant women have proved that those assumptions do not apply to people [1–5]. With the current evidence about the positive impact of prenatal exercise on maternal and child health, increasingly, the question is not "if" but "how" pregnant woman should exercise [53]. Our analysis of documents shows that the official guidelines on exercise in pregnancy from different countries barely respond to this question. The documents analyzed contain very general recommendations on exercise during pregnancy and very little information that exercise professionals could use when programming the contents of targeted exercise classes for pregnant women.

For an exercise program to be effective, it must take into account four training components: intensity, frequency, duration, and proper type of exercise [28]. The work by Evenson et al. [31] shows that the guidelines for exercise in pregnancy contain much more information on the intensity, frequency, and duration than on the contents of exercise programs. Meanwhile, the contents of prenatal exercise seem to be particularly important for pregnant women, because during this period, through physical activity, they should pursue both their overall objectives of promoting their own health and maternity.

7.3 Exercise Prescription Considering Prepregnancy Habits Related to Physical Activity or Exercise

The latest updates of the American College of Obstetricians and Gynecologists recommendations [41] and the Sports Medicine Australia [33] guidelines highlight the importance of considering the habits of pregnant women related to physical activity and exercise prior to pregnancy in order to individualize the prescription of exercise during pregnancy. The previous habits of physical activity or exercise of pregnant women determine the levels of their training components during pregnancy.

7.3.1 Previously Inactive Pregnant Women

The prescription of an exercise program in previously inactive pregnant women should commence with low-intensity activities such as walking or swimming, initially accumulated in short bouts, and follow a gradual progression up to the minimum level of the physical activity and exercise recommendations [41]. A walking program may be a good option for previously inactive pregnant women to become physically active [56], because it has been demonstrated that even mild walking (30% of peak aerobic capacity) improves fitness levels in sedentary women during pregnancy [57].

7.3.2 Previously Active Pregnant Women

Pregnant women with habits of physical activity or exercise prior to pregnancy and without obstetrics complications can continue their physical activity or exercise habits throughout pregnancy or until it causes any discomfort [33, 41].

Pregnant women who were regular exercisers before pregnancy and do not present obstetrics complications are able to engage in high-intensity exercise programs. When high-intensity or prolonged exercise exceeds 45 min, they should take into account a proper caloric intake and hydration before, during, and after exercise to minimize the risk of hypoglycemia [41].

7.3.3 Elite or Competitive Athletes

Pregnant women who are elite or competitive athletes need to maintain a more strenuous training schedule throughout pregnancy and resume high-intensity postpartum training sooner as compared to non-athlete pregnant women [41]. Their training program should be managed by experts that ensure the safety and well-being of the mother and the child [33]. Although an upper level of safe exercise intensity has not been established, women who were regular exercisers before pregnancy and who have uncomplicated, healthy pregnancies should be able to engage in high-intensity exercise programs. Particular attention should be paid to avoid weight loss and hyperthermia through a proper caloric intake and hydration before, during, and after exercise [41].

Studies show transient fetal bradycardia when the pregnant elite athlete exercises at above 90% of maximal maternal HR, but whether these transient fetal HR changes influence neonatal outcomes is unknown. However, to be appropriately cautious, IOC does not recommend maximum rate of oxygen consumption ($VO_{2\,max}$) testing and exercise above 90% of $VO_{2\,max}$, except in highly supervised (research) settings. Until more data are available in respect of strength training, athletes who prior to pregnancy developed heavy strength training should avoid Valsalva maneuver and large increases in intra-abdominal pressure which may temporarily decrease uteroplacental blood flow [2]. The repercussions to the fetus of these temporary changes remain unknown. Avoiding Valsalva maneuver by exhaling with an open airway also seems prudent [58]. In the absence of studies in elite athletes, IOC agreed that female athletes may consider refraining from repetitive heavy lifting efforts in the first trimester of pregnancy to avoid the potential risk of miscarriage. However, as IOC emphasized, these recommendations are based on low-quality evidence. Available studies were retrospective and based on participant's self-reports, conducted to assess the influence of lifting loads in occupational tasks, not in sport training. Indeed, Juhl et al. [59] observed that women with occupational lifting were more likely to have a first trimester miscarriage than women with no lifting. Nevertheless, they also noted that women with occupational lifting were more likely to smoke and less likely to engage in physical exercise. Undoubtedly, there is a need for well-designed research on the course of pregnancy, labor and delivery, and fetus development in heavy lifting athletes to support them with reliable information in terms of the safety of their training process.

7.4 Recommended Types of Exercise and Forms of Sports Activities for Pregnant Women

In Tables 7.2 and 7.3, we presented the results regarding the general recommendation on the type of exercise, information on the recommended and not recommended forms of exercise and sports activities for pregnant women, and an advice to consult with healthcare providers.

All guidelines contained general recommendations to perform aerobic exercises, 12 of them to perform resistance exercises and two of them flexibility exercises (Table 7.2). The forms of physical activity recommended for pregnancy were listed in 11 documents. The most frequently mentioned were walking and swimming (in nine out of 13). Other recommendations included inter alia aerobics, water exercise, jogging, cycling (especially stationary), running, and cross-country skiing. Certainly, in terms of biomechanical analysis, these forms of exercise are very beneficial for pregnancy, but it can be expected that they would not meet the interests and needs of all pregnant women of different countries. And here comes the controversial question related to sports activities, which generally are classified as hazardous for pregnant women.

All guidelines contained information on the forms of exercise to avoid in pregnancy. It was suggested that women should avoid sports activities with high risks of falling or loss of balance or with high risk of abdominal trauma. Those 14 documents provided specific examples of forms of sports to avoid. For example, in ACOG guidelines [41], we found gymnastics, horseback riding, and downhill skiing or sports with a high potential for contact, such as ice hockey, soccer, and

Table 7.2 Guidelines on the type of exercise and forms of sports activities recommended in pregnancy

	Australia (SMA) 2016	Australia (FA) 2013	Canada (SOGC/CSEP)	Canada (CASEM)	Denmark	Norway	South Africa (SASMA)	United Kingdom (RCOG)	United States (ACOG) 2015	United States (ACNM)	United States (ACSM)	United States (US DHHS)	International (IOC) 2016
General recommendation on the type[a] of exercise													
Aerobic exercise[b]	+	+	+	+	+	+	+	+	+	+[c]	+[c]	+	+
Strengthening exercise[d]	+	+	+	+	+	+	+	+	+	+[c]		+	+
Flexibility exercise		+											+
Recommended forms[e] of exercise and sports activities													
Aerobics[f]	+	+				+	+	+	+	+	+		
Cross-country skiing			+	+			+						
Cycling	+				+	+	+			+			
Dancing						+	+						
Exercise in water	+	+	+		+			+	+		+		
Gymnastics						+							
Hiking							+						
Jogging	+					+	+	+	+[g]		+		
Pilates									Modified				
Racket sports									+[h]				
Rowing							+						
Running	+						+		+[g]				
Stationary cycling	+		+	+			+		+		+		
Strengthening training	+	+			+				+[g]	+			

(continued)

Table 7.2 (continued)

	Australia (SMA) 2016	Australia (FA) 2013	Canada (SOGC/CSEP)	Canada (CASEM)	Denmark	Norway	South Africa (SASMA)	United Kingdom (RCOG)	United States (ACOG) 2015	United States (ACNM)	United States (ACSM)	United States (US DHHS)	International (IOC) 2016
Swimming	+		+	+	+	+	+		+	+	+		
Targeted prenatal classes	+	+						Aqua natal					
Walking	+		+	+	+	+	+		+	+	+		
Yoga									Modified	+			
An advice to consult healthcare provider on the type of exercise	+	+	+		+				+	+	+	+	

[a]Based on the provided health benefits
[b]Also called an endurance exercise or cardio exercise; in this kind of exercise, the body's large muscles move in a rhythmic manner for a sustained period of time. Brisk walking, running, bicycling, jumping rope, and swimming are all examples
[c]Based on the recommended forms of sports activities
[d]We searched for the information on muscle-strengthening exercise (this kind of exercise causes the body's muscles to work or hold against an applied force or weight)
[e]Based on the specific nature of the movements, skills, equipment, the environment, and the rules that determine participation in it
[f]Is a form of exercise that combines rhythmic aerobic exercise with stretching and strength training routines with the goal of improving all elements of fitness (flexibility, muscular strength, and cardiovascular fitness). It is usually performed to music and may be practiced in a group setting
[g]Recommended if a pregnant woman developed this activity prior to pregnancy
[h]Racket sports wherein a pregnant woman's changing balance may affect rapid movements and increase the risk of falling should be avoided as much as possible

Table 7.3 Guidelines on the type of exercise and forms of sports activities not recommended in pregnancy

	Australia (SMA) 2016	Australia (FA) 2013	Canada (SOGC/CSEP)	Canada (CASEM)	Denmark	Norway	South Africa (SASMA)	United Kingdom (RCOG)	United States (ACOG) 2015	United States (ACNM)	United States (ACSM)	United States (US DHHS)	International (IOC) 2016
Sports mentioned as risky in pregnancy													
"Hot yoga" or "hot Pilates"									+				
Basketball						+			+	+		+	
Bobsledding													+
Cricket	+												
Cycling											+		
Diving/scuba diving	+		+		+	+	+	+	+	+	+		+
Downhill skiing	+			+		+	+		+	+		+	+[a]
Generally contact sports	+	+						+	+				
Gymnastics	+			+			+		+	+	+		
Handball						+							
Hang gliding							+						
Heavy weight lifting	+				+				+[b]	+			+[b]
Horseback riding	+			+		+	+		+	+		+	
Ice hockey	+					+			+	+			+
Luge													+
Martial arts	+												
Off-road cycling									+				
Pole vaulting													+

(continued)

Table 7.3 (continued)

	Australia (SMA) 2016	Australia (FA) 2013	Canada (SOGC/ CSEP)	Canada (CASEM)	Denmark	Norway	South Africa (SASMA)	United Kingdom (RCOG)	United States (ACOG) 2015	United States (ACNM)	United States (ACSM)	United States (US DHHS)	International (IOC) 2016
Skating	+						+						
Skydiving	+								+				
Soccer	+						+		+	+		+	
Softball	+												
Surfing									+				
Vigorous racket games							+		+	+			
Water skiing	+						+		+				

[a]Downhill ski racing

[b]Referring to low to moderate level of evidence for a negative effect of occupational lifting, female athletes may consider refraining from repetitive heavy lifting efforts in the first trimester to avoid the potential risk of miscarriage

basketball (Table 7.3). It should be noted that there is no scientific evidence that some sports activities are indeed dangerous for pregnancy and fetal development. The classification of the forms of movement as "not recommended for pregnant women" is rather due to the cautious attitude of the authors of the guidelines. For example, in RCOG document, we found that: "Prudence dictates that activities such as contact sports should be avoided" ([40] p. 2). There are more and more studies that change the view of the so-called risky sports in pregnancy. For instance, research has casted doubts on the earlier assumptions that women should not scuba dive in pregnancy, as the fetus is not protected for decompression sickness and gas embolism [35, 40]. Results by Conger and Magann [60] prove that if the woman dived when she did not know she was pregnant, there was usually a normal outcome. It seems reasonable to classify forms of movement, as safe for pregnancy or not, on the basis of multidimensional research analysis.

Information to be included in official guidelines for exercise in pregnancy should be treated with extreme caution. Based on the studies of Tanha et al. [25], it can be assumed that these documents significantly influence the choice of the form of exercise by pregnant women. Listing certain forms of activity as potentially dangerous may result in women giving them up. In the case where they decide to continue participation in such sports, they may have to overcome the pressure of society. In the study by Fieril et al. [19], "Social reproach was cited as a barrier to exercise. Some women recounted that relatives, friends or colleagues demonstrated their lack of understanding about exercising during pregnancy or questioned a particular type of exercise, such as resistance training" (p. 1140). The research by Krans and Chang also corresponds to this observation [61]. They concluded that healthcare providers should be aware of cultural myths that prevent many African American women from performing certain activities during pregnancy. Changing social perceptions of various forms of prenatal physical activity can be of key importance for its development.

In the analyzed guidelines, we have noted certain inconsistency in classifying sport activities as recommended to perform or to avoid. Both cross-country skiing and cycling that have been proposed to pregnant women (Table 7.2) may be associated with a high risk of fall for a complete novice. Nevertheless, it will depend on the cultural and social aspects of the country, as well as on the woman' skills to perform a particular sport. In this vein, a more reasonable position in relation to all forms of activity is presented in the guidelines from South Africa that "the type of exercise needs to be individualized in accordance with the woman's skills, abilities and preference" ([39]; p. 70). The latest update of US guidelines includes some activities (i.e., racket sports or running) as safe if pregnant women usually practiced this activities prior to pregnancy [41]. The need to adapt the exercises for pregnancy was also mentioned in two other documents [40, 44]. However, there appeared to be no specific guidance on how to implement this task. We found only very brief advice like "Exercise should be safe – there should be minimum injury risk to both mother and fetus" and that "Exercise should be comfortable – especially as the pregnancy progresses" ([39]; p. 70). From a practical point of view, it would be valuable to develop guidelines on adaptation of exercises to different needs of pregnant women and action to minimize the risk of participating in various sports activities during pregnancy. This would allow women to self-assess the benefits and risks of a particular physical activity, so that they can make informed decisions about participation. Fieril et al. [19] report that modifying the type of exercise, altering exercise goals, and being extra attentive during performance are recommended strategies to overcome exercise barriers in pregnancy.

7.5 Targeted Exercise Classes for Pregnant Women

In Table 7.4, we presented the detailed information that might be useful for designing the contents of targeted exercise classes for pregnant women. Selecting variables for this analysis, we took into account that they should pursue goals specific to health-related physical activity, as well as specific targets for pregnant women, i.e., positive impact on pregnancy and child development and psychophysical preparation for childbirth and postpartum and to the tasks of motherhood [28–30, 62–66]. For this reason, our analysis of the documents focused on the specific content related to aerobic exercises (cardio part of the exercise classes), resistance (strengthening) exercises, stretching exercises, specific exercises for pregnancy (abdominal, pelvic floor, and body posture exercises),[1] and exercises preparing to childbirth (breathing exercises, birth positions, relaxation, pregnancy and birth visualization). Additionally, we searched for any tips on how to exercise when the common pregnancy complaints appear (i.e., diastasis recti abdominis, stress urinary incontinence, lumbopelvic or back pain). We also analyzed the organizational instructions useful in the implementation of the targeted exercise classes for pregnant women. Two independent persons reviewed the selected guidelines, according to the same criteria and using the same extraction form.

The main assumption of the targeted exercise classes for pregnant women should be such a selection of exercises, that they are not only safe for the mother and fetus but also bring women the most health benefits, among others, by alleviating common complaints of pregnancy [48, 67–69]. To be able to respond to the needs of all participants of the course, it is necessary to propose various versions of the exercises, considering trimester of pregnancy and its progress, the level of skills, and abilities of women. Pregnant women should be informed, both what is the correct technique of each exercise and also how to modify it in case of discomfort during its execution. Fieril et al. [19] recorded that in the opinion of pregnant women participating in resistance training "(…), besides length and intensity, a focus on the quality of the exercise performance was of paramount importance" (p. 1140).

The guidelines analyzed contained surprisingly little information on the exercise technique and other tips that might be useful for designing the contents of the targeted exercise classes for pregnant women (Table 7.3). Both Australian

[1] Abdominal, pelvic floor exercises and body posture are especially important in pregnancy, so for the purposes of this work, we have included them in exercises specific to pregnancy. However, differently oriented, they should be performed in all programs of physical activity.

Table 7.4 Guidelines useful for designing the contents of targeted prenatal exercise classes

	Australia (SMA) 2016	Australia (FA) 2013	Canada (SOGC/CSEP)	Canada (CASEM)	Denmark	Norway	South Africa (SASMA)	United Kingdom (RCOG)	United States (ACOG) 2015	United States (ACNM)	United States (ACSM)	United States (US DHHS)	International (IOC) 2016
Aerobic exercises (cardio part)													
General recommendations[a]	+	+				+	+	+	+	+	+		+
Detailed instructions[b]		+				+							+
Muscle-strengthening exercises													
General recommendations	+	+	+	+	+	+	+	+		+		+	+
Detailed instructions	+	+		+	+	+	+						+
Stretching exercises													
General recommendations		+											+
Detailed instructions	+	+											
Abdominal, pelvic floor, and body posture exercises													
General recommendations	+	+			+	+	+		+				+
Detailed instructions	+	+											
Exercises preparing to childbirth													
General recommendations		+											
Detailed instructions													
Exercises with common pregnancy complaints													
General recommendations	+		+	+	+	+			+				+
Detailed instructions	+				+	+							
Organizational recommendations													
Structure of the exercise class	+	+	+					+		+			
Exercise positions	+	+	+		+		+	+	+	+	+	+	
Other	+	+						+			+		+

[a]Related to the particular element of the targeted exercise classes for pregnant women
[b]Any tips related to the quality of exercise execution

documents [33, 34] mentioned pregnancy-specific exercise classes and RCOG [40] recommended aqua natal classes. Only the guidelines of Fitness Australia suggested what such classes should include [34], e.g., gradual warm-ups and cooldowns for prenatal circulation and avoidance of blood pooling; general strengthening plus particular focus on pregnancy-specific muscles such as pelvic floor core and postural muscle strengthening; modified strength training according to the Fitness Australia Safety Guidelines for Strength Training; modifications for standing and supine positions such as four-point kneeling, sitting on a fitball, and side lying; and flexibility training limited to a comfortable range of movement, relaxation, and labor preparation.

7.5.1 Aerobic, Resistance, and Stretching Exercises

In eight documents we found only general recommendation to perform aerobics [33, 34, 38–41, 43, 44], in six documents specified to low impact [34, 38, 39, 41, 43, 44], which is one of the basic modes of aerobic exercise in prenatal exercise classes. There were no tips on the selection and the technique of the aerobics moves and their usage.

In relation to the strengthening exercises, 12 documents contained only general advice to perform them [2, 33–43]. More detailed tips were inter alia to pay attention to correct technique [39], to consider that exercises requiring balance and agility may become more difficult while the pregnancy progresses [33, 41, 44], and to work with an instructor or use equipment to reduce the risk of overexertion [37]. It was also recommended to avoid breath holding [34, 36] and the Valsalva maneuver during resistance exercises [34, 39]. For safe and effective training, the guidelines from South Africa [39] and Australia [33] advised pregnant women to use relatively low weights. Other documents also discouraged to use heavy weights in pregnancy [28, 37, 43].

According to SMA pregnant women should avoid wide squats, lunges, or any unilateral leg exercises that place excessive shearing forces on the pubic symphysis [33]. Fitness Australia excluded some exercises that significantly involved abdominal muscles [34]. However, so far there was no study published which could indicate negative influences of such exercises on pregnant woman's body. Detailed guidance more often related to the number of sets and repetitions of exercises than their execution.

Only Australian guidelines [33, 34] provide short practical instructions on stretching exercises. We found recommendation that flexibility training should be limited to a comfortable range of movement [34] and also that it should be controlled and not "overextended" as joints and ligaments are already loose due to the release of the hormone relaxin in preparation for birth [33]. The Canadian guidelines from 2003 stated that "stretching and strength training exercises such as yoga and Pilates have not been studied in a pregnant population" ([35], p. 4). Nevertheless, in recent years, there have been several scientific publications on yoga [70–72] and Pilates classes [73, 74] for pregnant women. The outcomes of those studies should be disseminated in public sources of information by credible institutions.

7.5.2 Specific Exercises for Pregnancy and in Selected Pregnancy Complaints

In the older guidelines (published more than 5 years ago), we found very limited guidance on how to perform abdominal exercises. The only information available was that “the ability to perform abdominal strengthening exercises may be impeded by the development of diastasis recti and associated abdominal muscle weakness” ([35]; p. 4) and that “abdominal exercises are not recommended if diastasis recti develops” ([36]; p. 3). In Norwegian guidelines it was only generally stated that strong stomach muscles can prevent pain in the lower back and bad posture [38]. Newer documents contain some more information in this topic. Fitness Australia suggests that any exercise that places significant load on the abdominals or pelvic floor including abdominal curls, sit-ups, planks, and hovers should be avoided [34]. Nevertheless, this is not an evidence-based recommendation. ACOG guidelines propose strengthening of abdominal and back muscles to minimize the risk of low back pain [41]. IOC expert group presented available scientific data on the diastasis recti abdominis, concluding that the etiology and possible preventive and treatment strategies of this condition were not clear [2].

As regards the pelvic floor exercises, they were mentioned only in two older documents from Denmark [37] and Norway [38]. They were generally recommended for the prevention of stress urinary incontinence [37] and presented as particularly important during pregnancy and after the birth [38]. In the newer documents, we could see more emphasis on the pelvic floor muscle training. Australia Fitness underlines its meaning for pregnant women. The latest update of Sports Medicine Australia guidelines includes instruction to design pelvic floor exercise program for pregnant women. The exercise technique recommended in this document is to contract pelvic floor muscles maximally with an inward and upward squeezing movement, mixing slow and fast controlled contraction in a sitting, kneeling, standing, lying down, or standing with leg astride position [33]. The prevalence of pelvic floor dysfunctions and suggestions for their prevention and treatment, e.g., through supervised training in combination with home exercise, were discussed in the IOC summary [2].

In the analyzed documents, very little attention has been devoted to the body posture, except the note that strengthening exercises will help to maintain it [38, 39]. Pregnant women with pelvic or back problems were advised to cycle [37] or to exercise in the water [37, 38]. Fitness Australia generally recommended postural muscle strengthening [34]. According to IOC, “changes in spinal curvature during pregnancy as well as frequent or sustained pain-provoking postures might influence the pelvic ligaments, causing pain” ([2]; p. 582). The experts suggested that women should be aware of their body positions while pregnant to avoid unnecessary load and stress on joint, ligaments, and muscles, during exercise and daily activities. They also showed the relationship between pregnancy, exercise, and the low back pain or pelvic girdle pain. Other common conditions, illnesses, and complaints typical for pregnancy and the chances of their treatment through prenatal exercise were summarized in the IOC document, as well. The Part 5 of the IOC work will contain detailed recommendations for health professionals and active women in this subject.

Fitness Australia was the only one organization which presented labor preparation as an important part of activities for pregnant women [34]. The breathing exercises, birth positions, relaxation, pregnancy, and birth visualization were not even mentioned in any analyzed document.

7.5.3 Exercise Positions, Structure of the Exercise Class, and Other Organizational Recommendations

Eleven guidelines [2, 33–36, 39–41, 43, 44] recommended avoiding or limiting the supine position after the first trimester, or after 16 weeks of gestation, or after the fourth month of gestation. As an alternative solution, it was proposed to change the exercises [39] or to put a pillow or towel underneath one hip [43]. ACSM also suggested avoiding prone position until more information becomes available [44], and IOC suggests the necessity of research focus on the effect of exercise in the supine position during pregnancy in elite athletes [2].

With regard to the structure of the exercise classes in five documents, we found the advice to include a warm-up and cooldown in any exercise regimen [33–35, 40, 43] and in two documents to avoid motionless standing [39–41]. Other organizational tips were, e.g., to use properly adjusted exercise equipment and a smooth floor surface [44] and to use pelvic support belts for the weight-bearing exercise in women affected by joint laxity changes [40].

7.6 Exercise Professionals and Obstetrics Care Providers

Exercise professionals are supposed to play the most important role in providing information on exercise selection and techniques. However, in our previous work, we have proved [75] that although the future exercise professionals are generally aware of the positive impact of prenatal physical activity, they lack detailed knowledge, allowing the implementation of exercise sessions with pregnant clients. Those results demonstrate that there is a need to educate them on the exercise in pregnancy. An attempt at international discussion on how to prepare professionals to conduct exercises for pregnant women was undertaken during the 5th International Standards Meeting in Amsterdam in 2014, organized by the EuropeActive (former European Health and Fitness Association). Representatives from 12 European countries interested in the development of an international educational standard for the Pregnancy and Postnatal Exercise Specialists participated in this work. It is the first document of this type specifying the learning outcomes necessary for design and delivery of a prenatal exercise program, and set within the concept of the European Qualifications Framework [50]. The educational standard should correspond to the official and up-to-date guidelines for exercise in pregnancy. Thanks to this, professional tasks performed by Pregnancy and Postnatal Exercise Specialists would have a better chance to meet with the approval of pregnant women and medical staff.

Only the guidelines from Denmark state that the exercise during pregnancy should be supervised by an "instructor" [37], especially for the beginners [52]. The analyzed documents do not pay much attention to the exercise professionals' skills and competencies necessary to promote and implement exercise programs, foster women's adherence to exercise, evaluate their training progress, and, if needed, cooperate with a health professional. Only guidelines from the Health & Fitness Industry Association indicated that exercise professionals who offer specific services to pregnant or postpartum women are required to complete a Fitness Australia Continuing Education program [34]. This fact contrasts with often underlined role of health professionals in the implementation of prenatal exercises.

In eight analyzed guidelines, women in pregnancy were advised to consult the healthcare providers regarding their exercise program [33–35, 37, 41–44]. Such a recommendation seems justified only under the condition that the obstetricians and midwives would be well educated in this area. However, research shows that medical staff often remain at the former conservative position and do not support exercises during pregnancy. Only 1% of doctors in Poland recommend physical activity to pregnant women. What is more, 11% of them recommend that pregnant women limit their physical activity without any medical reason [14]. In the research by Hagen Haakstad et al. [6], only 36% of Norwegian pregnant women surveyed reported that they had received advice about physical activity at least once during their pregnancy from a physician or midwife. Similarly, Schmidt et al. [76] showed that only 48% of pregnant women surveyed had received information on the subject of physical exercise in pregnancy from their general practitioner or gynecologist.

As noted by Evenson and Bradley [21], more work is needed to understand what advice is being given to pregnant women by their healthcare providers. In another study Jukic et al. [77] observed that health professional advice was associated with prenatal physical activity. Because healthcare providers have great influence on patients' health behavior, it is critical that they give pregnant women accurate and sufficient information [22]. In the study by Padmanabhan et al. [78], women felt that their midwives provided detailed information on what they should not do during pregnancy but were rarely given information about what they should do in relation to diet and physical activity for weight management. Consequently, women often used information from a variety of sources which they filtered using "common sense." According to Watson [79], the majority of South African medical practitioners (98%) believe that exercise during pregnancy is beneficial and were knowledgeable on most of the expected benefits, but at the same time, most of them (83%) were unaware of the recommended exercise guidelines. These results highlight the need to educate healthcare professionals in this topic. Malta et al. [80] proved that after an educational intervention healthcare professionals were more likely to give their pregnant patients proper guidance regarding leisure-time walking (PR = 2.65; 95% CI = 1.82–3.83) and healthy eating (PR = 1.76; 95% CI = 1.34–2.31) compared to the control group. In order to prepare obstetricians and midwives to answer pregnant women's questions regarding exercise in pregnancy, they must be given reliable and comprehensive sources of information. The current guidelines certainly do not meet those requirements, especially in relation to the contents of the exercises.

The Canadian guidelines by SOGC/CSEP [35], Australian by Fitness Australia [34], and Sports Medicine Australia [33] proposed PARmed-X for pregnancy as a tool for collaboration between a pregnant woman, her obstetric care provider, and an exercise professional in terms of the exercise program design [81]. Watson et al. [79] observed that only 24% of health practitioners referred pregnant women to exercise specialists. In the area of prenatal physical activity, there is dynamically growing reliable information, both from research and practical experience, in the implementation of various programs of exercise for pregnant women. Documents recommending exercise during pregnancy should be based on it. Our analysis shows that the current guidelines in different countries should be updated, as also suggested by other authors [14, 22, 82, 83]. Much more practical guidance on exercise during pregnancy is contained in other publications, both in the form of scientific articles [84–86] and popular publications [29, 30, 87]. However, owing to the fact that they do not represent the official position of national or international obstetrics, gynecology, or sports medicine institutions, the scope and prevalence of their use may be limited.

7.7 Limitations

One of the limitations of the work is the selection of documents for analysis. Owing to the fact that the guidelines for exercise in pregnancy do not always have the character of scientific work and only represent the official position of credible national institutions, sometimes it was impossible to find them in the scientific databases. Nevertheless, we have tried to adopt such a procedure in seeking material for analysis to ensure its effectiveness and repeatability. We realize that we might have missed some of the documents that meet the inclusion criteria.

The procedure adopted for qualifying documents for the analysis excludes material published in other languages and not available on the Internet. Because of that the presented picture of the current guidelines on exercise during pregnancy is incomplete and is not global. It seems justified to continue and expand the international cooperation started by Evenson et al. [31] in order to collect the material published in other languages, understanding their contents, as well as their historical and cultural context. It is necessary to follow the analysis of official guidelines with international implementation activities, promoting exercise in pregnancy. One of them seems to be the development and dissemination of international educational standards for personnel involved in the implementation of programs of prenatal exercise. This task has already been started by EuropeActive in 2014 and published in 2015 [50].

Notwithstanding these limitations, the presented review can be a starting material for discussion in the work on updating the existing and creation of new documents in this area. We realize that the specific content that we propose for inclusion in a new version of the guidelines for exercise in pregnancy would significantly increase their volume. However, they would become a much more useful tool, supporting prenatal physical activity.

7.8 Conclusions

The analyzed guidelines provide little information on the contents of targeted prenatal exercise classes and on the adaptation of sports activities to pregnancy. The guidelines should be supplemented by more detailed guidance on which exercise professionals could rely in designing of exercise programs for pregnant women. The guidelines for exercise in pregnancy should be updated on the basis of high-quality research and in collaboration with practitioners in the field of prenatal physical activity, which could increase the chances of their implementation.

Few guidelines on physical activity and exercise in pregnancy are available and have been developed for healthcare providers only. The relevant stakeholders are also exercise specialists and pregnant women themselves.

Trustworthy and comprehensive guidelines created on the basis of international and interdisciplinary initiatives should be disseminated among all interested in prenatal physical activity, pregnant women and their families, obstetric care providers, and exercise professionals, to enable an effective cooperation and to globally promote exercise in pregnancy.

There is a need for transdisciplinary European guidelines on physical activity and exercise in pregnancy across the whole range of physical activity behavior and conditions (pregnant women with clinical conditions, inactive women, active women, and elite athletes).

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Exercise Testing and Prescription for Pregnant Women

8

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Abstract

Physical exercise should be part of an active lifestyle during pregnancy and the puerperium, as shown by growing evidence on its benefits for the health of pregnant women and newborns. Appropriate exercise testing and exercise prescription are needed to tailor effective and safe exercise programs. Exercise testing and prescription in pregnancy is the plan of exercise and fitness-related activities designed to meet the health and fitness goals and motivations of the pregnant woman. It should address the health-related fitness components and the pregnancy-specific conditions, based on previous health and exercise assessments, and take into account the body adaptations and the pregnancy-related symptoms of each stage of pregnancy and postpartum, in order to provide safe and effective exercise. This chapter reviews the guidelines for exercise testing and prescription of pregnant and postpartum women to be developed by exercise professionals, following the health screening and medical clearance for exercise by healthcare providers.

Keywords

Pregnancy · Postpartum · Physical activity · Exercise · Exercise prescription · Exercise testing · Health screening

8.1 Introduction

The purpose of this chapter is to provide exercise and healthcare professionals an understanding about the planning of the several steps of health screening, pre-exercise evaluation, exercise testing, and exercise prescription during pregnancy.

Exercise prescription commonly refers to the specific plan of fitness-related activities that are designed for a specified purpose, which is often developed by a fitness or rehabilitation specialist for the client or patient [1]. An exercise training program ideally is designed to meet individual health and physical fitness goals [2] independently of the fact that the client is in the group of the apparently healthy adult population, in a special stage of life (such as pregnancy), or has a determined clinical condition. An optimal exercise prescription should address the health-related physical fitness components and also the neuromotor fitness[1] [2] in order to provide effective and safe training.

Physical fitness is defined as a set of attributes or characteristics individuals have or achieve that relates to their ability to perform physical activity, and these characteristics are usually separated into the health-related and skill-related components of physical fitness [3]. According to the ACSM-American College of Sports Medicine [2], the *health-related* physical fitness components include the cardiorespiratory endurance, the body composition, the muscular strength and endurance, and the flexibility, while the *skill-related* components of physical fitness include agility, coordination, balance, power, reaction time, and speed.

Appropriate exercise testing and prescription are needed to tailor effective and safe exercise programs. This chapter reviews the guidelines and scientific papers for exercise testing and prescription of pregnant and postpartum women to be developed by exercise professionals, following the health screening and medical clearance for exercise by healthcare providers.

8.1.1 Previous Considerations Before Starting Exercise

Being a special stage of life, pregnancy includes several phases that have specific needs, and, although there are recommendations and guidelines for the exercise prescription during pregnancy, these should always be adapted to each case, and common sense should prevail. It should also be noted that pregnancy is a natural process, although complex, and occurs differently from woman to woman and even among the potential pregnancies of the same woman. That is, every pregnancy is a unique and special case! Thus, when a pregnant woman intends to become involved in an exercise program or to give continuity to it, it becomes essential to distinguish between two situations in the first place:

- Pregnancy occurs normally, without problems or clinical complications.
- Pregnancy is at risk or there is a certain clinical condition.

One frequent question is: When should a pregnant woman start exercising? The answer is that in the absence of clinical contraindications, every pregnant woman should start or continue exercising. Healthcare providers (i.e., gynecologists, general practitioners, or midwives) are in charge of assessing women's health and their pregnancies and answer the question, bearing in mind the benefits of an active lifestyle. According to Artal [4], pregnant women tend to be highly motivated to improve unhealthy behaviors and have frequent visits with their healthcare

[1] *Neuromotor exercise* training involves motor skills such as balance, coordination, gait, and agility, and proprioceptive training is sometimes called *functional fitness* training [2].

providers, which facilitates counseling, support, and supervision. The probability of a woman exercising during pregnancy is increased if her gynecologist/obstetrician encourages her to exercise [5]. Thus, after making sure that there are no contraindications for exercising, healthcare providers should provide counseling on an active lifestyle and refer pregnant women to an exercise physiologist with background and experience on pregnancy and postnatal exercise.

The pregnancy and postnatal exercise specialist role is to build exercise participation for beginners and already active women at all stages of pregnancy and during the postpartum period. In addition, this exercise professional will be expected to assess overall physical fitness, to develop proper exercise programs, to review participants' progress, and to be able to report on adherence and outcomes to relevant stakeholders [6]. Thus, following medical clearance for exercising during pregnancy, it is very important to understand the motivations, facilitators, and barriers for exercising [7] and the type of exercise on which she is interested in, as well as the level of experience she has.

In summary, there are three types of pregnant women in terms of practicing exercise:

- Those who do not practice any kind of exercise or physical activity prior to pregnancy: In them, we would advise to start with a light intensity physical activity or exercise program.
- Those who perform exercise regularly: In them, we would advise to maintain this regularity and control intensity and safety.
- Those who are athletes: In them, we would advise to continue with their training routine, possibly with some adaptations regarding exercise selection and safety.

On the other hand, a woman with any risk pregnancy or obstetric or clinical complications, with contraindications to exercise, is out of the scope of practice of the exercise professional, unless with medical supervision, prescription, and guidance. Nevertheless, a specific exercise program may be beneficial as an adjunct therapy or primary prevention of determined conditions [2]. ACSM recommends that a pregnant woman that is severely obese or has gestational diabetes mellitus or hypertension should consult her physician before beginning an exercise program, and the exercise program must be adjusted to her medical condition, symptoms, and fitness level [2].

8.1.2 Contraindications for Exercising While Pregnant

Summarizing, pregnant women who performed exercise or physical activity regularly before pregnancy may continue with it, and previously sedentary women may start exercising during pregnancy [4, 8–16]. However, although this practice is safe and recommendable for them, in certain situations, it should be inadvisable. There are medical circumstances in which the sudden appearance of complications due to their pregnancy or a bad maternal health status contraindicates the practice in an absolute or in a relative way. These absolute or relative contraindications for exercising during pregnancy are included in Box 8.1. The appearance of any of these relative contraindications may lead to stop performing the physical activity in order to avoid future complications and risks.

Box 8.1 Relative and Absolute Contraindications for Exercising During Pregnancy, According to ACOG, Adapted from ACOG, 2015 [16]

Relative contraindications

- Severe anemia
- Unevaluated maternal cardiac dysrhythmia
- Chronic bronchitis
- Poorly controlled type 1 diabetes mellitus
- Extreme morbid obesity
- Extreme underweight
- History of extremely sedentary lifestyle
- Intrauterine growth restriction in current pregnancy
- Poorly controlled hypertension
- Orthopedic limitations
- Poorly controlled seizure disorder
- Poorly controlled hyperthyroidism
- Heavy smoker

Absolute contraindications

- Hemodynamically significant heart disease
- Restrictive lung disease
- Incompetent cervix/cerclage
- Multiple gestation at risk for premature labor
- Persistent second or third trimester bleeding
- Placenta previa after 26 weeks of gestation
- Premature labor during the current pregnancy
- Ruptured membranes
- Preeclampsia/pregnancy-induced hypertension

Once established these limitations, an algorithm has been created to act accordingly with every pregnant woman (see Fig. 8.1). The utilization of the questionnaire PARmed-X for Pregnancy is explained in Sect. 8.3.

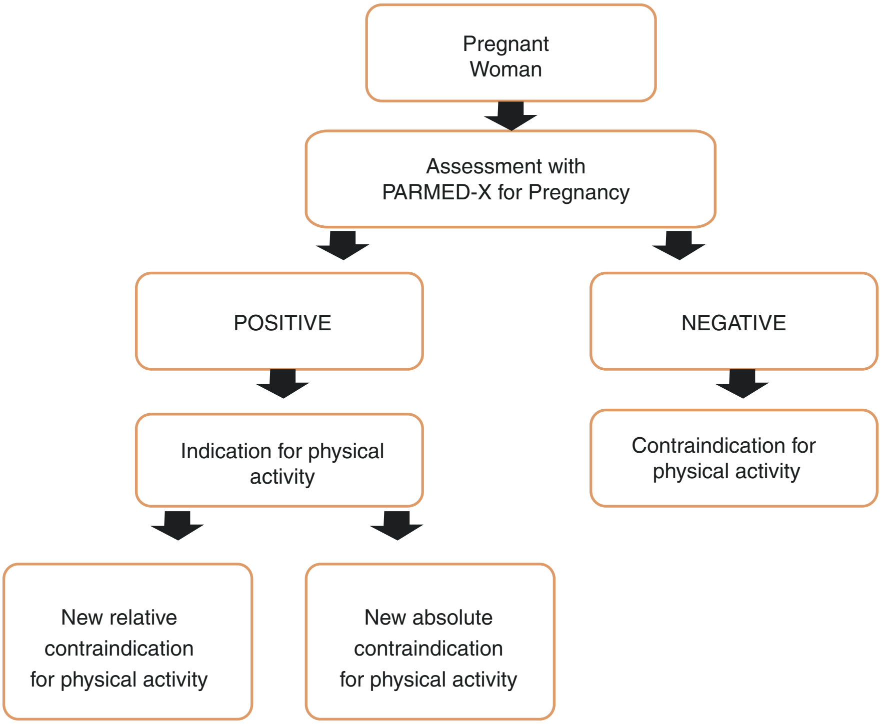


Fig. 8.1 Pre-exercise health screening regarding possible contraindications for exercising during pregnancy

8.2 Available Guidelines on Exercise During Pregnancy and Useful Sources of Information

When promoting physical activity and exercise during pregnancy and developing exercise prescription plans, either health professionals or exercise professionals are supposed to follow specific guidelines for physical activity and exercise during pregnancy. These guidelines may be published by national or international organizations. The main international organizations supporting and publishing guidelines for physical activity and exercise during pregnancy are listed in Box 8.2.

The American College of Obstetricians and Gynecologists was the organization that published in 1985, the first guidelines for pregnant and postpartum women [17], subsequently improved in 1994 [18]. In 2002, the ACOG published recommendations for physical exercise during pregnancy, promoting its benefits to the health and safety of exercise, both for active and inactive women prior to pregnancy, assuming the existence of medical authorization and the absence of contraindications [19, 20]. These ACOG recommendations from 2002 stated that pregnant women should accumulate 30 min or more of moderate-intensity exercise on most, if not all, days of the week if no medical or obstetric complications are present, i.e., a minimum of

Box 8.2 International Organizations Supporting and Publishing Guidelines for Physical Activity and Exercise During Pregnancy

ACNM—American College of Nurse-Midwives—http://www.midwife.org

ACOG—American Congress of Obstetricians and Gynecologists—https://www.acog.org/ (https://www.acog.org/Resources-And-Publications/Committee-Opinions?Keyword=exercise).

ACSM—American College of Sports Medicine—http://www.acsm.org/ (http://www.acsm.org/public-information/roundtables).

APA—American Pregnancy Association—http://americanpregnancy.org/(http://americanpregnancy.org/pregnancy-health/exercise-guidelines/).

CASEM—Canadian Academy of Sport and Exercise Medicine—http://casem-acmse.org/

CSEP—Canadian Society for Exercise Physiology—http://www.csep.ca/home (http://www.csep.ca/view.asp?ccid=519).

Department of Health—UK Government—https://www.gov.uk/ (https://www.gov.uk/government/publications).

DHSA—Norwegian Directorate for Health and Social Affairs—https://www.regjeringen.no/en/id4/

ESSA—Exercise and Sports Science Australia—https://www.essa.org.au

EuropeActive—http://www.europeactive.eu (http://www.ehfa-standards.eu/es-standards).

IOC—International Olympic Committee—https://www.olympic.org/ (https://www.olympic.org/news/ioc-drives-discussions-on-pregnancy-and-elite-athletes).

NBH—National Board of Health—http://sundhedsstyrelsen.dk

RCOG—Royal College of Obstetricians and Gynaecologists—https://www.rcog.org.uk/

SASMA—South African Sports Medicine Association—https://www.sasma.org.za/

SMA—Sports Medicine Australia—http://sma.org.au/ (http://sma.org.au/publications-media/sma-position-statements/).

SOGC—Society of Obstetricians and Gynaecologists of Canada—https://sogc.org/

US-DHHS—US Department of Health and Human Services—https://www.hrsa.gov/

WHO—World Health Organization—http://www.who.int/about/en/ (http://www.who.int/nutrition/publications/guidelines/antenatalcare-pregnancy-positive-experience/en/).

three exercise sessions of at least 15 min each, gradually increasing to 30 min per day, preferably on all days of the week [19, 20]. The recommendations were highlighted again in 2009, including the practice of 30 min or more of moderate exercise, mostly, if not every day of the week, in the absence of medical or obstetrical complications. In 2011, the recommendations for exercise in pregnancy were updated by Zavorsky and Longo [21, 22], particularly regarding the intensity of physical activity and strength training. According to the review paper on the available guidelines for exercising during pregnancy provided by Evenson et al. in 2013 [23], nine out of ten guidelines on exercise in pregnancy from different countries contained information on the intensity and duration of exercise, and eight of these documents contained recommendations on the exercise frequency. Evenson et al. [23] state that the program should consist of moderate-intensity exercise (including moderate-intensity aerobic exercise, light-intensity resistance training, Pilates and balance exercises, pelvic-floor training, and stretching), performed three times per week, under the supervision of an exercise specialist. In a previous review by Szumilewicz et al. [24], we analyzed existing guidelines worldwide from the Sport Medicine Australia (SMA) [8], Society of Obstetricians and Gynaecologists of Canada (SOGC)/Canadian Society for Exercise Physiology (CSEP) [9], American College of Obstetricians and Gynecologists (ACOG) [20] updated in 2015 [16], Directorate for Health and Social Affairs [25], Royal College of Obstetricians and Gynaecologists (RCOG) [11], Canadian Academy of Sport and Exercise Medicine (CASEM) [26], US Department of Health and Human Services (US-DHHS) [27], National Board of Health [28], South African Sports Medicine Association [29], American College of Nurse-Midwives (ACNM) [12], and American College of Sports Medicine (ACSM) [13]. Nevertheless, we verify that the documents analyzed contain very general recommendations on exercise during pregnancy and little information that exercise professionals could use when programming the contents of targeted exercise classes for pregnant women.

In December 2015, the ACOG republished its recommendations on “Physical Activity and Exercise During Pregnancy and the Postpartum Period” [16], which are summarized in Box 8.3. It is to be noted that this was the first document stating officially that moderate exercise during pregnancy does not cause miscarriage, fetal growth restriction, premature delivery, or musculoskeletal injury. More recently, Bø et al. and the Medical and Scientific Commission of the International Olympic Committee (IOC) drove a discussion about the management of pregnancy for an elite athlete and produced comprehensive guidelines and recommendations on exercise during pregnancy and postpartum [14, 30, 31], as well as for future research [32]. Further discussion and update are provided in another chapter of the present publication, by Szumilewicz et al. [33].

Box 8.3 Summary of ACOG Recommendations on “Physical Activity and Exercise During Pregnancy and the Postpartum Period” [16]

1. Physical activity in pregnancy has minimal risks and has been shown to benefit most women, although some modification to exercise routines may be necessary because of normal anatomic and physiologic changes and fetal requirements.
2. A thorough clinical evaluation should be conducted before recommending an exercise program to ensure that a patient does not have a medical reason to avoid exercise.

3. Women with uncomplicated pregnancies should be encouraged to engage in aerobic and strength conditioning exercises before, during, and after pregnancy.
4. Obstetrician–gynecologists and other obstetric care providers should carefully evaluate women with medical or obstetric complications before making recommendations on physical activity participation during pregnancy.
5. Regular physical activity during pregnancy improves or maintains physical fitness, helps with weight management, reduces the risk of gestational diabetes in obese women, and enhances psychologic well-being.
6. Additional research is needed to study the effects of exercise on pregnancy-specific outcomes, and to clarify the most effective behavioral counseling methods and the optimal intensity and frequency of exercise.
7. Similar work is needed to create an improved evidence base concerning the effects of occupational physical activity on maternal–fetal health.

8.3 Health Screening of Pregnant Women Before Starting Exercise

The first step before planning to start or continuing an exercise program during pregnancy is the health screening of the woman by a healthcare provider, i.e., overall health and medical and obstetric risks should be reviewed [9, 11, 15, 16]. The American College of Obstetricians and Gynecologists' Antepartum Records and Postpartum form [34] can assist healthcare providers in health screening.

To establish a prenatal fitness class for pregnant women, we have to know if she is going to be capable of following it in terms of prenatal fitness and health, intensity, type of pregnancy, and exercise. In a normal healthy pregnancy, no study has found any negative effect of moderate-intensity aerobic training on the development of the fetus or the outcome of pregnancy. In fact, it appears that the benefits of exercise during pregnancy clearly outweigh the potential risks. Current research suggests that healthy pregnant women can begin or maintain moderate-intensity aerobic exercise programs with little fear of adverse effects on their unborn fetus [35]. Moreover, recent systematic reviews show strong evidence on the effectiveness of physical activity on maternal cardiorespiratory fitness [36, 37], reduced risk of gestational hypertensive disorders overall and gestational hypertension [38], prevention and treatment of gestational diabetes mellitus [38–40], prevention of urinary incontinence [37], reduced cesarean delivery [38], and prevention of antenatal depression [41], as well as positive impact on offspring health in adulthood [42]. The maternal-fetal physiological reserve is going to be the limiting factor for prescribing a safe prenatal exercise program; thus, before performing the fitness activities, there is the need to evaluate pregnant women with a convenient checklist. In this regard, after medical clearance regarding a regular healthcare protocol, healthcare providers should encourage pregnant women to start or continue with a fitness program suitable for their needs and gestational status.

A convenient and worldwide used checklist is the Physical Activity Readiness Medical Examination (PARmed-X) for Pregnancy, updated recently, which aims to facilitate the communication between the healthcare provider, the fitness professional, and the pregnant woman [43]. The PARmed-X for Pregnancy is a guideline for health screening prior to participation in a prenatal exercise program but also includes guidance on exercise prescription, healthy lifestyle during pregnancy, and exercise safety. This questionnaire is available from CSEP website (http://www.csep.ca/en/publications/view-publications) in the English and French languages, and it can also be found in other languages, such as Portuguese from Brazil and from Portugal [44–46] and Spanish [47].

Three steps are required to fill in the four-page form (Fig. 8.2):

1. Pregnant women should provide all the information about their general health status, their status of current pregnancy, and provide the information about the daily activity habits during the past month.
2. The healthcare provider must remark the absolute and relative contraindications based on the current medical information provided by the pregnant women.
3. Once the health evaluation form has been signed by the healthcare provider, and in the absence of contraindications, pregnant women should give it to their prenatal fitness professional.

If necessary, the PARmed-X for Pregnancy may be used together with other preliminary screening tools, such as the latest version of the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) available at the official website [48] (http://eparmedx.com/) and in the main ACSM's publications [2, 49, 50]. This questionnaire helps on the decision of whether it is necessary to seek further advice before becoming more physically active or engaging in a fitness appraisal and can be fulfilled by a doctor, another healthcare practitioner, or a qualified exercise professional [50]. Another widely used tool is the ACSM Health Status and Health History Questionnaire [49, 51] to assess safety or possible contraindications to exercise. According to ACSM, these tools can be used in the two basic approaches to preparticipation physical activity screening: the self-guided screening and the professionally supervised screening [50]. In addition, ACSM provides the Exercise Preparticipation Health Screening Questionnaire for Exercise Professionals, which is a simple tool asking for symptoms, current activity, and medical conditions of the participants [51].

It is to be noted that health screening is of particular importance when these pregnant women are obese and have gestational diabetes mellitus or hypertension. These women should consult the healthcare provider before beginning an exercise program, which, in turn, must be adjusted to her medical condition, symptoms, and physical fitness level [2].

Thus, in the absence of pregnancy complications and contraindications for exercise, and regardless of previous physical activity and fitness levels, all women should participate in an exercise program, in accordance with main international organizations such as ACOG, SOGC, ACSM, CSEP, RCOG, IOC, and WHO.

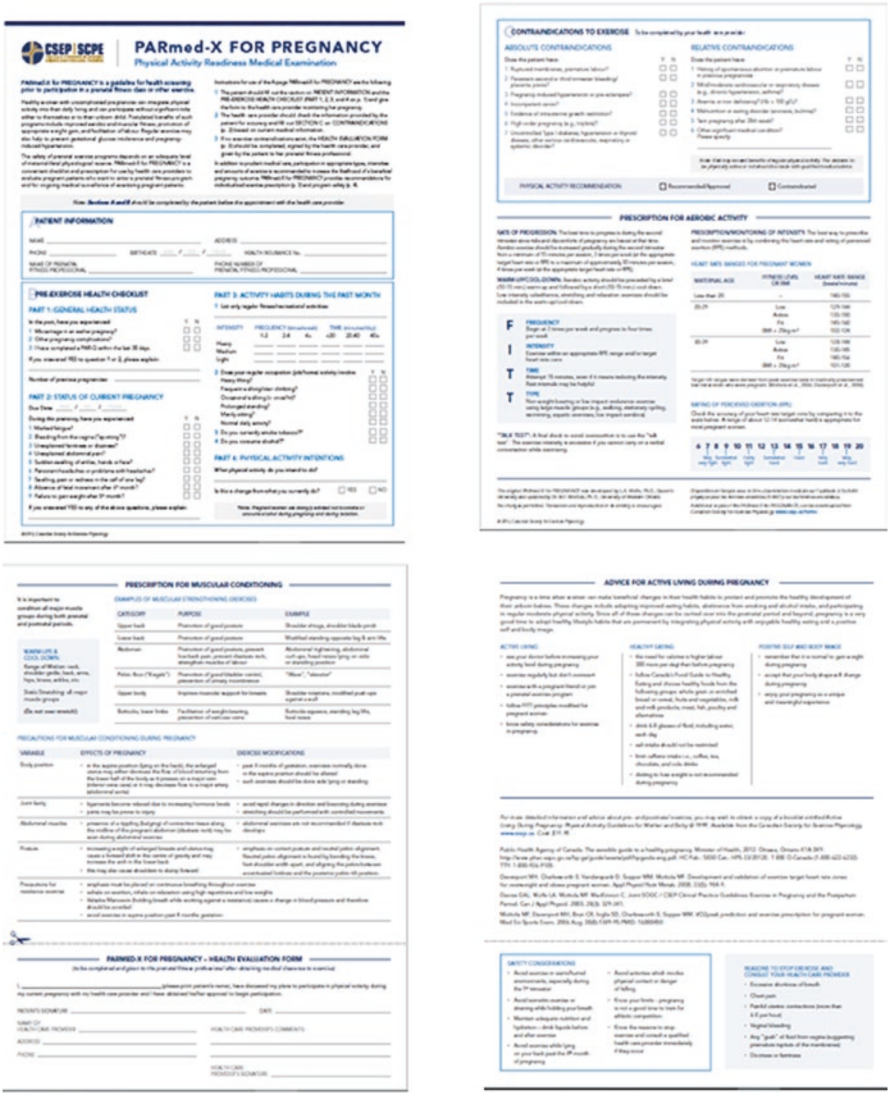


Fig. 8.2 The four-page form PARmed-X for Pregnancy by CSEP [43]

8.4 Pre-exercise Evaluation with Pregnant Exercisers and Athletes

Following the medical clearance provided by the healthcare provider, the exercise professional develops the pre-exercise evaluation of the pregnant women. It is important to understand some personal factors regarding her health and fitness level that will affect the exercise program plan, namely, the intensity, the complexity, and the adaptation of exercises. The fact that pregnant women are either sedentary or experienced in some exercise modes will affect the exercise prescription significantly. Thus, the second step is to know her pattern, level, and experience with physical activity and exercise:

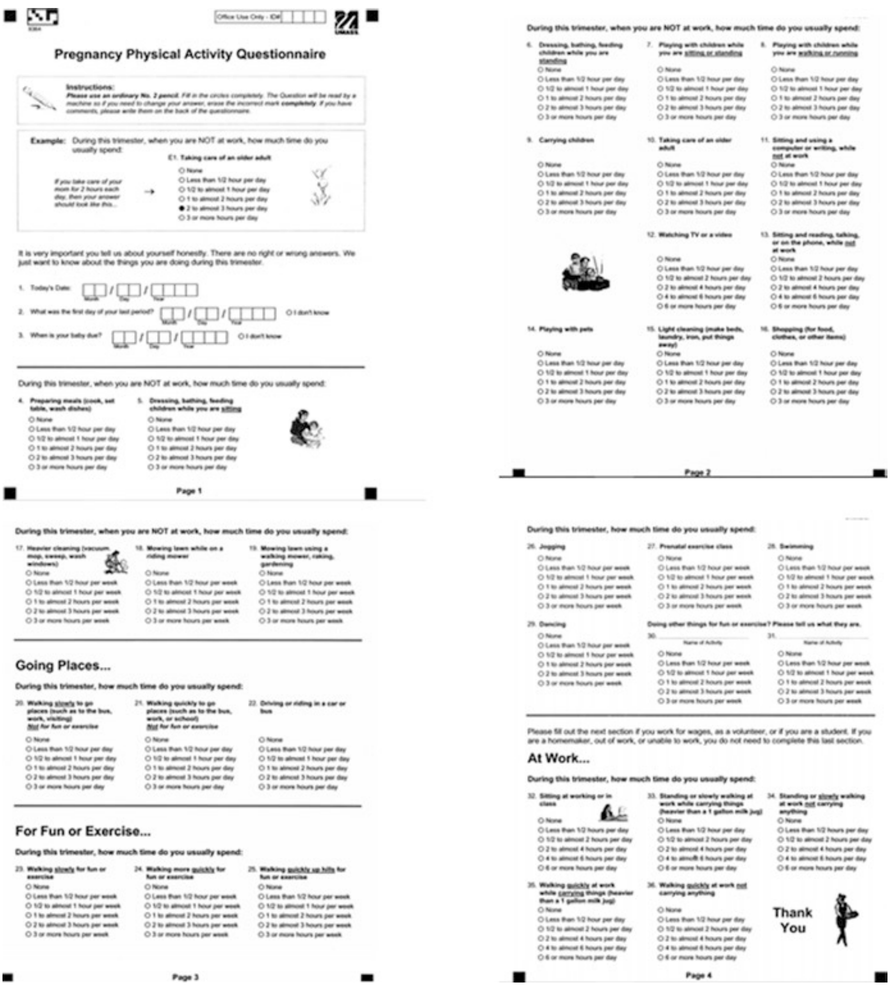
- For those who were sedentary prior to pregnancy, we need to plan a more simple exercise program, regarding the intensity (light) and complexity (low) of the exercises.
- For those who were active and perform exercise regularly, we need to plan an exercise program in order to maintain the intensity and complexity of the exercises she is motivated to do, or evaluate other options, regarding the safety of the program.
- For those who are athletes, we also need to plan an exercise program in order to maintain the intensity and complexity of the exercises she is motivated to do, or evaluate other options, regarding the safety of the program for her to continue with the training routine, possibly with some adaptations regarding exercise selection.

An objective form of better understanding the physical activity pattern and/or volume is using basic equipment, such as pedometers or accelerometers. The advantages of using accelerometers compared to other techniques of gait analysis include low-cost methods; testing is not restricted to a laboratory environment; accelerometers are small and not restricting walking [52].

Questionnaires such as the 7-day PAR (7-day Physical Activity Recall) interview [53, 54] (available from Professor James F. Sallis website: http://sallis.ucsd.edu/measures.html), and the PPAQ (Pregnancy Physical Activity Questionnaire) developed by Chasan-Taber et al. in 2004 [55], can also be used to recall physical activity pattern and volume. The PPAQ is a self-administered questionnaire regarding the current trimester of pregnancy. It assesses sedentary, light, moderate, and vigorous activity regarding household/caregiving, occupational, and sports/exercise activities. Pregnant women are asked to select the category that best approximates the amount of time spent in 32 activities and in inactivity during the current trimester. At the end of the questionnaire, an open-ended section allows the respondent to add activities not already listed (Fig. 8.3).

Other questions regarding maternal health and pregnancy itself that will affect exercise prescription includes the following:

- What is the woman's age?
- Is it the first pregnancy?
- On which stage of pregnancy is she?
- How were previous pregnancies?
- How is her self-perception of health?
- Is she aware of relative and absolute contraindications for exercising?
- Which are the main sign and symptoms related to pregnancy she is experiencing?
- What are her occupation and other leisure activities?
- When to start exercise during pregnancy?


Pregnancy Physical Activity Questionnaire

Going Places...

For Fun or Exercise...

At Work...

Thank You

Fig. 8.3 The four-page form PPAQ (Pregnancy Physical Activity Questionnaire) by Chasan-Taber et al. [55]

In brief, age may be related to fatigue, as well as her perception of health, and the existence of any disability or discomfort when performing the exercises. The type of occupation, regarding stress and physical activity, and other leisure activities will influence the global level of physical activity. A first pregnancy will promote physiological and psychological changes that she is experiencing for the first time. If it is the second or third pregnancy, the tendency will be to compare it with the previous ones (which may not have any comparison!). It means that, in practice, we must not assume that different pregnancies in the same client will progress in the same way. The stage of pregnancy is of particular importance regarding exercise selection and adaptation, as well as the main body adaptations and the signs and symptoms that can be more common and prevalent at each stage.

Regarding signs and symptoms related to pregnancy, exercise professionals and healthcare providers may objectively monitor them using a validated inventory available from Foxcroft et al. [56]. The authors developed a comprehensive inventory of pregnancy-related symptoms, with a mechanism for assessing their effect on function, providing a validated tool for assessing the impact of interventions in pregnancy [56]. There is a Spanish version of this tool as well [57]. Exercise professionals must be aware of the possible relative and absolute contraindications for exercising, as well as the signs for stopping exercise [16] in order to refer the client for a healthcare provider, as necessary.

After medical clearance, pregnant women can begin or continue an exercise program, preferably, supervised by a qualified exercise professional. However, both participants and exercise professionals should familiarize themselves with the absolute and relative contraindications to exercise during pregnancy, as well as with the signs and symptoms to terminate exercise [16], reproduced in Box 8.4.

Box 8.4 Summary of ACOG Recommendations Regarding the Signs and Symptoms to Terminate Exercise [16]

- Vaginal bleeding
- Regular painful contractions
- Leakage of amniotic fluid
- New dyspnea before exertion
- Dizziness
- Headache
- Chest pain
- Muscle weakness affecting balance
- Calf pain or swelling

Nonetheless, many women and healthcare providers do not know the most appropriate time to start exercising. Previous sedentary women can begin light activity anytime and progressively increase it. Previous active women can continue the exercise routine. Sometimes, the normal pregnancy-related symptoms, such as low back pain, tiredness, or nauseousness, may interfere with the adoption of an active lifestyle, but pregnant women should start exercising anytime they feel comfortable.

Other important questions, regarding the exercise prescription plan, as well as establishing realistic objectives and promoting adherence to exercise, are the following:

- What are the main motivations for exercising during pregnancy?
- Which are the women's preferences regarding exercise?
- What can be the main barriers and facilitators?
- Which strategies should but put in practice regarding adherence to exercise?

Assessing motivations and preferences of pregnant women, as well as identifying barriers and facilitators toward exercise, is a very important stage in the prescription process to avoid failure and behavioral relapse. More development on these topics can be found in Chap. 3 [7]. Finally, it is important to explain to a pregnant woman that physical activity and exercise, if tailored to her health and fitness level, will not bring any harmful effects neither for her nor for the baby. On the contrary, the participation in an exercise program may increase her perception of health [58], and there are several trustable sources of information from where she can learn about the general and specific benefits of exercise during pregnancy. An interesting source of information is the infographic with new advice on "physical activity for pregnant women" published by the UK's chief medical officers (CMOs), aiming at providing health and exercise professionals with the latest evidence on physical activity during pregnancy [59, 60].

In summary, addressing a pregnant woman at the beginning of an exercise program and developing a pre-exercise evaluation process is a key element to plan a tailored exercise prescription for an effective and safe exercise program. Exercise professionals must bear in mind that some of the above-described questions may be openly placed (or can be included in validated questionnaires) not only at the beginning of the exercise program, but whenever there is an alteration or adaptation regarding her health or fitness status. Moreover, it is important to bear in mind the psychological [7], physiological [61], musculoskeletal [62, 63], and biomechanical [64] adaptations occurring during this period of life.

8.5 Exercise Testing with Pregnant Women

Although not harmful, and unless the pregnant woman desires and requires it, extensive exercise testing during pregnancy should only be performed for medical reasons or for research purposes [2]. An extensive assessment protocol will take long time, and may be boring or without significance in a (monthly) changing body and mind, unless the testing is useful for motivation and education purposes, as well as requested by the pregnant participant or athlete in order to evaluate aerobic fitness.

In practice, there are several maximal and submaximal tests to evaluate the health-related physical fitness components (cardiorespiratory endurance, body composition, muscular strength and endurance, and flexibility), as well as the skill-related components of physical fitness (agility, coordination, balance, power, reaction time, and speed) [2]. Most tests were built for the apparently healthy adult population, and there are specific tests or adapted tests for the special populations. These tests can be used to objectively understand the effectiveness of an exercise intervention and to know the fitness status of the client. Nevertheless, simple tests could be used for motivation purposes and to quantify the effects of physical activity and exercise programs for pregnant women.

Regarding ethical and legal considerations, before any exercise testing, adequate informed consent should be obtained from participants. An example of form can be found in ACSM [2] (p. 46) or from the website https://certification.acsm.org/files/file/B_ExPrescripReferral_pdf.pdf. However, this form may vary according to the objectives and methods of the exercise testing. The consent form, along with a

Fig. 8.4 Treadmill walking and upright leg cycling are the most useful testing modalities during pregnancy

verbal explanation, should include the following information: (1) purpose (either exercise prescription or research) and explanation on the test (equipment, procedures, etc.), (2) potential participant's risks and discomforts, (3) responsibilities of the participant (e.g., information about health status), (4) benefits to be expected (e.g., diagnosis of illness, fitness evaluation, or exercise progression), (5) inquiries (e.g., any concerns or questions about the test), (6) state of the privacy of personal and health information (to be kept confidential), and (7) freedom of consent [2].

A comprehensive fitness testing includes in the first place, the measurements of heart rate (HR) and blood pressure (BP). Usually, in a fitness setting, HR can be determined using pulse palpation (for 30 or 60 s) or a heart rate monitor. Both methods can be used during the exercise session or to assess resting HR. Assessing resting heart rate requires allowing the participant some time to relax at least 5 min in order to stabilize HR. The same principle applies to resting BP measurement. Further description of heart rate and blood pressure measurements and procedures can be found in ACSM [2] (pp. 69 and 53, respectively).

According to the ACSM [2, 49], ACOG [16], and CSEP [9], maximal exercise testing should not be performed on pregnant women unless medically necessary and with medical supervision. Submaximal exercise testing is more appropriate for this special population [2] in order to assess the maximum rate of oxygen utilization of muscles during exercise (VO_{2max}). We can find guidance on clinical exercise testing during pregnancy and in the post-partum period in other publications provided by O'Toole and Artal [65], and Wolfe [66], regarding cycle ergometer or graded treadmill exercise.

According to Wolfe [66], treadmill walking and upright leg cycling are the most useful testing modalities during pregnancy (Fig. 8.4), since the injury risk is low, the physiologic monitoring is easy (not much vertical movement), and the exercises require basic movements. On the contrary, both treadmill running and bench stepping tests are less convenient in these respects, as well as arm cranking ergometry because a relatively small muscle mass is employed [66].

A peak maximal oxygen consumption[2] predicted equation determined for pregnant women can be found in Mottola et al. [67]. This equation was developed using a treadmill modified Balke protocol:

$$VO_{2\text{peak}} = (0.055 \times \text{peak HR in bpm}) + (0.381 \times \text{incline in percent}) + (5.541 \times \text{speed in mph}) + (-0.090 \times \text{BMI in kg/m}^2) - 6.846 \quad (8.1)$$

Other recommended treadmill protocols include, e.g., the modified Bruce and the Naughton protocols, because most sedentary pregnant women have low capacity for non-weight-supported exercise [66].

Typically, a submaximal test (i.e., <75% of heart rate reserve) is used in place of a maximal test, and most research studies have selected cycle ergometry, due to changes in posture and center of gravity of the pregnant women [49]. Cycling tests may involve one or more steady-state submaximal power outputs or progressive increases in power output, while the pedaling frequency should be 60–80 rpm to avoid lower limb fatigue [66].

Another option may be a field test consisting of walking for a predetermined time or distance, such as the Rockport One-Mile Fitness Walking Test and the 6-min walk test. They are easy to administer and require little equipment. In the well-recognized Rockport One-Mile Fitness Walking Test, the pregnant woman walks 1.6 km (1 mi) as fast as possible on a level surface, and HR is obtained in the final minute of completion of the walk. Then, the VO_{2max} of the woman is estimated using the following regression equation ([2], p. 86):

$$VO_{2\max}(\text{mL/kg/min}) = 132.853 - (0.1692 \times \text{body mass in kg}) - (0.3877 \times \text{age in years}) - (3.2649 \times \text{time in min}) - (0.1565 \times \text{HR}) \quad (8.2)$$

The 6-min walk test has been used with older and clinical populations, and its results have been related to morbidity and mortality. In this test the pregnant woman is assessed by the longer distance she can walk during a 6-min time interval. Then, one of the equations used to estimate the VO_{2max} is the following ([2], p. 86–87):

$$VO_{2\max}(\text{mL/kg/min}) = (0.02 \times \text{distance in } m) - (0.191 \times \text{age in years}) - (0.07 \times \text{body mass in kg}) + (0.09 \times \text{height in cm}) + (0.26 \times \text{RPP} \times 10^{-3}) + 2.45; \text{ where RPP = rate pressure product: HR} \times \text{SBP in mm Hg; SEE} = 2.68\ \text{mL/kg/min} \quad (8.3)$$

Further description of the procedures can be found in chap. 4 of ACSM [2].

After understanding the most appropriate tests for pregnant women, procedures should be selected according to the facilities and equipment available, the existence

[2] Measure of the highest rate of oxygen consumption during an exercise test regardless of whether or not a VO_2 plateau is reached.

of appropriate environment, and the qualifications of the exercise professional performing the tests [49]. The exercise professional must ensure the proper conditions of the facility and thermal environment where the testing takes place and must be aware of the proper conditions of the testing equipment, the full testing protocol (e.g., regarding the duration and the work rate of each stage, the monitoring of HR at least two times during each stage, the use of additional effort rating scales, etc.), as well as the subject appearance and symptoms and the test termination criteria. All exercise test protocols should incorporate a 3–5-min low-intensity warm-up to acquaint the pregnant woman with the equipment, as well as a gradual cooldown to avoid venous pooling of maternal blood, arterial hypotension, and reduced uterine blood flow [2, 66]. Moreover, the total length of a progressive treadmill or cycling exercise test should not exceed 10–12 min in order to minimize the reduction of uterine blood flow [66]. However, due to the fact that the acute physiologic responses to exercise are increased during pregnancy compared to nonpregnancy [2, 65], the prediction of maximal aerobic capacity may be compromised, although results can be used to determine the effectiveness of training [68].

There are no specific tests for proper assessment of musculoskeletal function—muscular strength and resistance and flexibility—although these components of health-related physical fitness are addressed in the recommended guidelines for exercise during pregnancy. The same situation occurs regarding the skill-related fitness components, namely, agility, coordination, and balance. Nevertheless, the main purpose of a prenatal exercise program is to promote maternal-fetal health, rather than to maximize physical performance [66].

To our knowledge, there is no published literature for the safety and validity of maximal muscle strength assessment for pregnant women. In addition, commonly used tests for the strength evaluation of the upper and lower body, or abdominal muscles, such as the bench press, leg press, curl-ups and the push-ups tests, are not practically justified in this stage of life due to anatomical and musculoskeletal changes. Isometric and isotonic strength involves a pressure response, which is undesirable during pregnancy [66]. Further explanation of the musculoskeletal health adaptations during pregnancy can be found in Fitzgerald and Segal [63].

A good option may be static handgrip strength test. The static handgrip strength test is measured with a dynamometer and has predicted mortality and functional status in older populations [2, 50]. After adjusting the grip, the participant holds the dynamometer in line with the forearm at the level of the thigh, away from the body, without touching the body or any other object. Then, the participant squeezes the handgrip as hard as possible, twice with each hand. The score is the highest of two readings with each hand (e.g., 58–62 would be a good score for women of 20–39 years). Further explanation of the procedures and fitness categories can be found in ACSM ([2], p. 97, Box 4.6 and Table 4.8).

Regarding flexibility, test procedures and fitness categories are provided in ACSM ([2], pp. 104–105, Box 4.9 and Table 4.13, respectively). Test procedures for goniometry assessment of joints commonly of concern to health and fitness professionals and static stretches for the major muscle groups are provided in ACSM ([50], chap. 5, Tables 5.1 and 5.4, respectively). The range of motion of selected single-joint movements is provided in ACSM ([2], p.103, Table 4.12). However, the value of specific flexibility tests during pregnancy is questionable because flexibility is temporarily altered and because the anatomic changes will interfere mechanically with some common tests (e.g., sit and reach) [66]. Thus, no single test can characterize flexibility and there are no specific tests to be used during pregnancy. Due to anatomical changes, a good option may be the (modified) sit-and-reach test which is a reflection of hamstring, hip, and lower back flexibility, which, in turn, is important to prevent low back pain [49]. However, specific procedures and norms regarding pregnant women are lacking [50].

Of course, there are other assessment techniques, but those techniques have limited applicability in fitness settings because of the cost and the need of highly trained staff (e.g., body composition with DEXA or three-dimensional gait analysis). Moreover, there is a lack of knowledge regarding safety, validity, reliability, or accuracy considerations with pregnant populations.

Physical performance testing protocols have been used for the assessment of functional status and fitness components of special populations [70, 71]. Postural analysis and body alignment are very important to assess in pregnant women. Physical performance testing is appealing since most performance tests require little space, equipment, and cost; can be administered by lay or health/fitness personnel with minimal training; and are considered extremely safe in healthy and clinical populations [2]. However, to our knowledge, there are no testing batteries validated for the pregnant population, regarding the static and dynamic assessment of posture, functionality, and overall autonomy in pregnant women. Chapter 6 in ACSM [50] provides a comprehensive functional movement assessment for apparently healthy participants.

One option is the Timed Up and Go (TUG) test which is a simple test used to assess a person's mobility and requires both static and dynamic balance. The TUG is a commonly used screening tool to identify patients at risk of falling, sometimes used along with other outcome measures to assess functional mobility or balance. In this test, the time that a person takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down is recorded. Usually applied to older populations, it has been used with pregnant women.

Static changes to the body in pregnancy include anterior displacement of the center of mass, anterior tilt of the pelvis, increased lumbar lordosis, knee hyperextension, and increased length and width of the feet. Angular kinematics and spatiotemporal parameters of gait will suffer changes as well, due to increase body mass and musculoskeletal adaptations [63]. Gait alterations during pregnancy may contribute to pain, falls, and muscle fatigue. Thus, gait assessment may be useful to diagnose and prevent such situations. Further development on this topic is provided in Chaps. 5 [64] and 6 [62].

Monitoring the maternal body fatness, weight gain, and nutritional status is very important [66]. On the one hand, a normal fetal growth depends on adequate maternal energy stores, and specific guidelines for optimal maternal weight gain are available. Nevertheless, excessive gains in body fatness are undesirable. The exercise professional can provide general advice regarding healthy nutrition during pregnancy. However, dietary analysis and tailored nutrition plans should be conducted by a qualified nutritionist. Regarding the assessment of the pregnant women's body composition, body circumferences, body fat distribution markers, and other body indexes can be used. Please refer to Chap. 4 [69] for further explanation.

Other publications provide comprehensive instructions for fitness assessment regarding the different components of physical fitness [2, 49, 50, 72]. However, we do not find in the literature any evidence or guidelines regarding the evaluation of the other components of physical fitness with pregnant women.

8.6 Exercise Prescription for Pregnant Women

Exercise prescription and monitoring during pregnancy require knowledge and expertise from the fields of obstetrics and exercise physiology and on the interactive effects of pregnancy and exercise on maternal-fetal biologic and psychologic functions [66]. For most adults, an exercise program including aerobics, body composition, resistance, flexibility, and neuromotor training is indispensable to improve and maintain physical fitness and health [73]. For pregnant women, we need to add pelvic floor training [74] and preparation for birth exercises [75]. Pregnant women fall into the category of apparently healthy adults, although they are considered a special population. Thus, the general guidelines of ACSM regarding the FITT-VP principle apply to pregnant women, with some modifications [2]. This principle states that there are recommended levels of the following elements that address mainly one or more physical fitness components:

- F—Frequency (how many exercise sessions per week?)
- I—Intensity (how hard or difficult is the exercise?)
- T—Time (how long is each exercise session?)
- T—Type of exercise (which mode of exercise?)
- V—Volume (which amount?)
- P—Progression (how to advance?)

Thus, the recommended exercise prescription for pregnant women should be modified according to the woman's symptoms, discomforts, and abilities during pregnancy [2]. Table 8.1 resumes the ACSM's FITT-VP principle applied to pregnant women.

8.6.1 Type and Mode of Exercise

There are plenty of physical activities to be performed alone or in group, indoor or outdoor, with or without equipment. In the first place, it is important to understand the physical activity pattern of the pregnant women, as addressed in Chap. 1 [76], and choose an activity or activities for which the women are motivated for. Thus, the pregnant woman should select the physical activity or exercise program she is more motivated and able to do, having in mind that those activities or sessions may be adapted according to her health and fitness and trimester of pregnancy (Fig. 8.5).

Table 8.1 Exercise prescription components for pregnant women, adapted from ACSM [2, 49, 50] and Artal [15]

	Type	Intensity	Duration	Frequency	Progression/adaptation
Aerobic	Exercises that activate large muscle groups in a rhythmic and continuous fashion A variety of weight- and non-weight-bearing activities are well tolerated during pregnancy Aerobic exercises can be categorized by the intensity and skill demands	Moderate-intensity exercise (3–5.9 METs; RPE = 12–13; 40%–60% $VO_{2reserve}$) Vigorous-intensity exercise (>6 METs; RPE = 14–17) for women who were highly active prior to pregnancy or for those who progress to higher fitness levels during pregnancy	30 min/day of accumulated moderate-intensity exercise to total at least 150 min/week or 75 min/week of vigorous intensity Previous inactive women should progress from 15 to 30 min/day	Previous sedentary: up to 3 days/week Previous active: 3–5 days/week to most days of the week	The optimal time to progress is after the first trimester (13 weeks) because the discomforts and risks of pregnancy are lowest at that time Avoid activities with risk of fall and trauma Activities that require jumping movements and quick changes in direction which can stress joints should be done with caution to minimize the risk of joint injury
Resistance	A variety of machines, free weights, and body weight exercises are well tolerated during pregnancy	Intensity that permits multiple submaximal repetitions (i.e., 8–10 or 12–15 repetitions) to be performed to the point of moderate fatigue (40%–60% of estimated one repetition maximum)	One set for beginners Two to three sets for intermediate and advanced Target major muscle groups A basic program includes 8–10 different exercises	2–3 nonconsecutive days/week	Consider exercising in adapted supine position after 16 weeks of pregnancy to ensure that venous obstruction does not occur Avoid performing the Valsalva maneuver during exercise Heavy-resistance weight lifting and intense repetitive isometric exercises should be limited until more data is available

(continued)

Table 8.1 (continued)

	Type	Intensity	Duration	Frequency	Progression/adaptation
Flexibility	A series of active or passive static and dynamic flexibility exercises for each muscle-tendon unit	Stretch to the point of feeling tightness or slight discomfort	Hold static stretch for 10–30 s (up to 60 s) 2–4 repetitions of each exercise	At least 2–3 up to 7 days/week	Avoid excessive joint stress
Neuromotor	Exercises involving motor skill (e.g., balance, agility, coordination, gait), proprioceptive training, and multifaceted activities (e.g., Pilates, yoga, tai chi)	Intensity in balance training refers to the degree of difficulty of the postures, movements, or routines practiced An effective intensity (and volume) of neuromotor exercise has not been determined	20–30 to 60 min/day	At least 2–3 up to 7 days/week	Can be included in daily activities The only supervision requirement is the safety considerations and the level of fall risk Avoid positions that are uncomfortable or likely to result in loss of balance and falling
Pelvic floor training	Complex training for pelvic floor muscles should be focused both on their contraction and relaxation Various devices can be used to increase the effectiveness and attractiveness of exercise, e.g., vaginal cones	An effective intensity (and volume) of pelvic floor exercise has not been determined	10–30 min/day	1–7 days/week	Can be done anywhere, anytime Should be incorporated in any prenatal exercise program Ensure proper technique Different exercises should be performed to improve pelvic floor muscle speed, strength, endurance, and muscular coordination and engaging both fast and slow twitch muscle fibers

RPE rating of perceived exertion (6–20 scale), *METs* metabolic equivalents, $VO_{2reserve}$ oxygen uptake reserve ($VO_{2max} - VO_{2rest}$)

Fig. 8.5 Walking, jogging, running, cycling, swimming, water exercise, aerobics, Pilates, flexibility, and resistance training are among the recommended types of exercise during pregnancy

The development of safe and effective exercise programs is a main role and competence of exercise professionals. Each of the several activities available should respect the technical and progression issues of the activity, as well as the associated safety issues. As examples, indoor or outdoor cycling, aerobic and step exercise, or swimming can be performed using a span of intensity and complexity and requires different pedagogical approaches. Each of the activities given as example can be performed by pregnant women who already practiced them and who already acquired the basic aspects inherent in their safety. For a pregnant woman who has never practiced these activities, the entire learning process must be kept in mind so as not to jeopardize her safety in the event of falls or collisions.

In the second place, the several recommended types of exercise for pregnant should address all health-related physical fitness components (i.e., aerobic, resistance training, and flexibility), as well as neuromotor exercises, pelvic floor training, and preparation for birth exercises. In other words, the type or mode of exercise should be selected first using the specificity principle of training [49]. A variety of exercise modes places different impact stresses on the body, i.e., walking, running, swimming, cycling, or stepping uses different muscle groups, and weight-bearing activities produce greater mechanical loading than non-weight-bearing activities. ACSM also recommends loading exercises (i.e., weight-bearing and resistance exercise) to maintain bone health [2].

This means that on the one hand, the exercise program may be focused on one or more types of exercise and on the other hand, each session of the exercise program can be planned having in mind to include at least 30 min of aerobic exercise and also strength and flexibility training, neuromotor exercise, and pelvic muscle training. For example, a step exercise session may combine aerobic, lower limb resistance, and neuromotor training, while a Pilates exercise session may combine upper, core and lower limb resistance, flexibility, and neuromotor training.

The ACOG guidelines [16] refer that the more appropriate and safe physical activities during pregnancy include walking, swimming, stationary cycling, low-impact aerobics, modified yoga, and modified Pilates. Other physical activities, such as running, jogging, strength training, and racquet sports, are considered safe for pregnant women who participated in these activities regularly before pregnancy, upon consultation with an obstetric care provider [16]. Several reviews available in the literature, on the potential benefits of different forms of exercise during pregnancy on health outcomes, can also help to acknowledge the effectiveness of different activities, such as pelvic floor muscle training [74, 77], resistance exercise [78], Pilates [79], yoga [80], aquatic exercise [81–83], swimming [84], aerobic exercise [10, 85], dancing [86], and group exercise [87].

Moreover, according to the Australian Sports Commission [88], recreational and competitive athletes may train safely at higher intensities and volumes throughout pregnancy with the understanding that they are undergoing close obstetric supervision. They can continue their exercise programs or sports, unless prior to pregnancy, the women athletes were engaged in extreme sports [88]. However, although potential impact on neonatal outcomes is unknown, athletes may push beyond a threshold intensity at which fetal well-being may be compromised [89], and there may be a limit to how intense an elite performer should exercise during pregnancy [90].

The ACOG guidelines also point non-recommended physical activities, including contact sports, activities with high risk of falling, scuba diving, skydiving, hot Pilates, and hot yoga [16].

Regarding exercise selection and adaptation, exercise specialists must be aware of the morphological, physiological, and biomechanical changes that occur during pregnancy (addressed in Chaps. 3, 4, and 5, respectively), as well as the trimester of pregnancy, the safety considerations, and the level of experience of the pregnant women. Chapter 9 [91] further develops the methods for planning an exercise program, including exercise selection and adaptation.

8.6.2 Exercise Duration, Frequency, and Intensity

Exercise time or duration is prescribed as a measure of the amount of time physical activity is performed, i.e., time per session, per day, and per week [2]. Frequency is prescribed in sessions per day and in days per week [49]. Exercise duration typically ranges from 20 to 60 min [49]. Most adults, including pregnant women, are recommended to accumulate at least 150 min/week. Most guidelines for exercise during pregnancy [8, 9, 10, 15, 16, 92] suggest 30 min of exercise daily, 5–7 days per week. Pregnant women who have not been regular exercisers should follow a gradual progression of increasing the duration of exercise and can begin with as little as 10 min [15]. Previously sedentary women should begin with 10–20 min of continuous low-intensity exercise three times per week, increasing the intensity, frequency, and duration gradually [2].

According to the overload principle of training, exercising below a minimum intensity or threshold will not challenge the body sufficiently to result in changes in physiologic parameters, including the increased maximal volume of oxygen consumed per unit of time [73]. The individual threshold depends on several factors, and it is important to bear in mind that, in general, the physiologic responses to acute exercise are increased in pregnancy compared to nonpregnancy, as provided in Table 7.4 of ACSM ([2], p. 196).

Several methods can be used to estimate intensity during exercise; however, the intensity is usually prescribed using heart rate reserve (%HRR) [2]. Because maximal exercise testing is rarely performed with pregnant women, Mottola et al. [67] developed and validated heart rate (HR) ranges that correspond to moderate-intensity exercise for low-risk pregnant women based on age and body mass index (BMI) while taking fitness levels into account. Box 7.5 in ACSM [2] and PARmed-X for Pregnancy by CSEP [43] provide the HR ranges.

Regarding maximal heart rate, the estimation equations by Gellish et al. [93] are more accurate than other formulas and were estimated for men and women participants in an adult fitness program with a broad range of age and fitness levels, as follows:

$$\text{HRmax} = 207 - \left(0.7 \times \text{age}\right) \tag{8.4}$$

Fig. 8.6 Borg's rating of perceived exertion (RPE) scale

20	**Maximal exertion**
19	Extremely hard
17-18	Very hard
15-16	Hard (heavy)
13-14	Somewhat hard
10-12	Light
8-9	Very light
7	Extremely light
1-6	**No exertion at all**

$$\text{HRmax} = 192 - \left(0.007 \times \text{age}^2\right) \tag{8.5}$$

Although the nonlinear predictor model (Eq. 8.5) was slightly more accurate than the linear equation (Eq. 8.4), the authors suggest that the linear model is easier to use.

However, due to HR variability during pregnancy, two other simpler and more practical methods may be used to monitor intensity [15, 16]:

- Monitoring perceived exertion: for moderate exercise, ratings of perceived exertion should be 13–14 (somewhat hard) on a Borg Rating of Perceived Exertion scale (Fig. 8.6), where six represents no exertion and 20 represents maximal exertion [94]. The participant is instructed to report the overall sensation of effort [49]
- OMNI scales of perceived exertion for walking/running and cycling are also available [49]
- The "talk test": the individual should be able to carry on a normal conversation with moderate exercise intensity. By comparison, vigorous exercise is associated with substantial increases in breathing, inability to carry on a normal conversation easily, and perspiration [95]. The participant is asked to work at a level that causes a sensation of increased breathing but that still allows comfortable speaking in complete sentences [49].

Independently of the intensity monitoring methods, an exercise program should start slowly and gradually improve intensity, but not leading to the exertion of pregnant women. Each body will naturally provide signals that it is time to reduce the level of exercise she is performing. Pregnant women should not exercise to the point of exhaustion or breathlessness.

8.6.3 Exercise Volume

Exercise volume is the product of frequency, intensity, and duration of exercise. Usually, the exercise volume is used to estimate the gross energy expenditure in metabolic equivalents (in MET-min/week or in kcal/week) with respect to body composition and weight management outcomes [2]. A target volume of 500–1000 MET-min/week is recommended for most adults because it is associated with lower rates of cardiovascular disease and premature mortality. The calculation of exercise volume may use different methods, as follows [2]:

- Metabolic equivalents (METs): an index of energy expenditure. A MET is the ratio of the rate of energy expended during an activity to the rate of energy expended at rest. By convention, 1 MET = an oxygen uptake of 3.5 mL/kg/min.
- MET-min: an index of energy expenditure that quantifies the total amount of physical activity performed in a standardized manner across individuals and types of activities, usually per week or per day (i.e., METs × min).
- Kilocalorie (kcal): by convention, the energy needed to increase the temperature of 1 kg of water by 1 °C. Usually standardized as kcal per week or per day. Conversion of METs to kcal: kcal/min = [(METs × 3.5 mL/kg/min × body weight in kg)/1000)] × 5.

Another form of estimating the exercise volume is the steps per day given by pedometers which are effective tools for promoting physical activity [96]. The goal of 10,000 steps/day is often cited, but it appears that achieving a pedometer step count of at least 5400–7900 steps/day can meet recommended exercise targets [73, 96]. This step count volume is approximately equal to 1000 kcal/week or 150 min/week of moderate-intensity physical activity [2].

Other forms of increasing the volume of physical activity or exercise are by integrating it into occupational activities, active commuting, and daily activities, such as:

- Engage in walking groups.
- Use a pedometer.
- Increase the walking time to a minimum of 10,000 steps per day.
- Playing with other children.
- Walk or bike for active commuting.
- Take stairs instead of the elevator.
- Park far away from office or garage.
- Not standing in the same position for long periods of time.
- Limit the seating time.
- Decrease the time spent in sedentary activities (e.g., television watching, computer use, sitting in a car or at a desk).

8.6.4 Exercise Progression and Adaptation

Exercise goals and progression may vary at different time points during pregnancy, and exercise routines should remain flexible [2]. The progression of exercise during pregnancy may consist of increasing exercise volume or adapting the exercise routine in accordance with the physiological and biomechanical adaptations occurring over the time course of pregnancy.

During the first trimester, the initiation or continuity of physical activity should be established gradually by pregnant women, once the absence of risk is established, and will be adjusted in accordance with participants' clinical situation, fitness level, and the level of adaptation to their new state. In the first trimester, the pregnant woman experiences the typical symptoms of pregnancy, such as nausea, vomiting, dyspepsia, and constipation, which can limit her daily activity and therefore limit her capacity to carry out activities that could aggravate this symptomatology. Depending on the level of symptoms and discomfort, those may prevent the practice of physical activity or exercise. In sedentary pregnant women, it is recommendable to start gradually after week 12. Those pregnant women who exercised regularly or are athletes, they can maintain this physical activity uninterruptedly, adapting the intensity and frequency to their personal needs and abilities. Due to the risk of trauma, for some athletes of contact sports, it may be necessary to plan a different exercise routine with other types of exercise that provide the maintenance of fitness level during this stage. Along with the other fitness components, pelvic floor training should be advised from the first trimester.

During the second trimester, the previously described discomforts of the first trimester are gone in most cases, and the physical limitations of the third trimester have not yet appeared. During this period, women feel emotionally better, since they are better adapted to pregnancy. The anatomic changes allow them to comfortably perform most of the types of exercise included in a program. However, it is important to bear in mind that throughout this trimester, the uterine volume increases, and in the supine position, the inferior vena cava syndrome can develop, which consists in the reduction of the venous return through said vessel, due to the pressure exerted by the pregnant uterus when the pregnant woman is lying on her back. That is why some women may feel discomfort or dizziness in the supine position, and sometimes it is necessary to avoid it while exercising.

During the third trimester, the increase in the volume of the gravid uterus as well as the weight gain of the pregnant woman produces a compromise of space at the abdominal level as well as at the pulmonary level. That is why the pregnant woman tends to decrease the intensity and duration of their physical activity. To avoid this negative effect, it is recommended the start of activities in the aquatic environment, which gives the pregnant woman a situation of weightlessness. The aquatic environment also allows mobilizing joints with passive resistance. It is very important to also take into account the possibility of the appearance of inferior vena cava syndrome, which in water is attenuated by weightlessness. Another aspect to take in consideration is the change in balance and coordination, which can lead to falls. Moreover, hormonal and biomechanical adaptations may be related to the prevalence of joint and low back pain. Many pregnant women experience low back pain, and strengthening of abdominal and back muscles could minimize this risk [16]. This is the period when pregnant women tend to reduce the intensity of exercise, although maintaining pelvic floor exercises and starting a preparation for birth program.

8.7 Exercise Prescription in Special Conditions

Exercise can be planned in a recreational or competitive perspective but also as an adjunct treatment for several disorders, such as gestational diabetes, excessive weight gain and obesity, hypertension and preeclampsia, low back pain, and antenatal depression. In these cases, it is of particular importance the communication between healthcare providers and exercise professionals. Pregnant women in special clinical conditions face substantial barriers to participating in exercise and require support to enable them to benefit from the increased physical activity. Under medical supervision, exercise professionals will need to select appropriate exercise interventions and behavioral strategies which will benefit the pregnant women regarding the disorder or disease.

8.7.1 Gestational Diabetes

A healthy pregnancy can be associated with resistance to the action of insulin on glucose uptake and utilization. This leads to more use of fats than carbohydrates for energy by mother and saves carbohydrates for the growing fetus [97]. In 1–14% of pregnant women, this condition develops into gestational diabetes mellitus (GDM) [98], which increases the risk of macrosomia, birth complications, and maternal diabetes after pregnancy. It may also increase the risk of obesity and type 2 diabetes in offspring later in life [99]. Thus, any strategy to prevent GDM should be considered.

Gestational diabetes is the most common metabolic disorder in pregnancy, and its prevalence is nowadays increasing because there is a higher amount of pregnant women with a body mass index (BMI) or weight gain level in the range of overweight or obesity and also because childbearing age is increasing [100]. There is growing evidence in favor of the fact that exercise and physical activity are basic tools to be able to control this prevalent disorder, as they are easy to be carried out, effective, and with minimum costs [101]. It has therefore been introduced a new tendency in this disorder's therapy that helps to preserve the glycemia levels in a normal range, by modifying pregnant women's lifestyles in a salutary way, thanks to maternal education, acquisition of healthy living habits such as balanced dietary patterns and performing exercise and physical activity, and, finally, a fetal close monitoring [102, 103]. If despite these circumstances, the glycemic control is not in the proper values, glucose-lowering drugs should be prescribed.

Observational studies strongly support the performance of exercise and physical activity not only as a tool that may control glycemia levels in pregnancy but also as a preventive factor by reducing the risk of gestational diabetes. The meta-analysis recently published by Russo et al. [104], in which there are ten described interventional trials suitable for the risk group, has shown a significant reduction of developing a gestational diabetes of 28% (95% IC) in comparison to the control group ($R^2 = 0.72$, $p = 0.0005$), consenting to exercise and physical activity a protective factor.

The exercise that pregnant women with gestational diabetes can perform does not differ from that prescribed to a pregnant woman without this disorder. However, it is necessary to take into account that those pregnant women who need glucose-lowering drugs for the metabolic control of glycemia should be closely monitored, since exercise may misadjust the prescribed pharmacological regimen.

In the management of pregnant women with gestational diabetes, there is evidence that exercise, in particular aerobic and resistance, is the most beneficial [105–107]. Another meta-analysis, which evaluated seven randomized trials, found that exercise and physical activity are helpful as a complement to good gestational follow-up, increasing postprandial blood glucose control, and decreasing the rapid passage of blood into the bloodstream in pregnant women with gestational diabetes compared with the control group [108].

8.7.2 Excess Weight and Obesity

In a systematic review and meta-analysis of randomized controlled trials performed by Choi et al. [109], the authors suggest that supervised physical activity plus diet programs were most effective in managing weight among overweight and obese pregnant and postpartum women. The American College of Obstetricians and Gynecologists in its Committee Opinion, reaffirmed in 2017, states that "in pregnancy, physical inactivity and excessive weight gain have been recognized as independent risk factors for maternal obesity and related pregnancy complications, including gestational diabetes mellitus" ([110], p. 136). The same experts' advice that obese pregnant women should be encouraged to engage in healthy lifestyle modification in pregnancy that includes physical activities and judicious diets [110]. This special population should start with low-intensity, short periods of exercise and gradually increase as able [16]. The effect of exercise among pregnant, obese women in recent studies has demonstrated modest reductions in weight gain and no adverse outcomes among those who were assigned to exercise [111, 112].

8.7.3 Hypertension and Preeclampsia

Hypertensive disorders in pregnancy may produce adverse perinatal outcomes for both the mother and the fetus or newborn. Preeclampsia is an exclusive pathology in pregnancy and postpartum period due to an abnormal development of uterine spiral arteries that furthermore produces an alteration in the placental exchange, leading to oxidative stress and producing antiangiogenic factors in the maternal body that can reach target organs such as the liver or kidney. There are also other pathologies related to hypertensive disorders in pregnancy, such as chronic hypertension, which can produce important complications when associated with preeclampsia. Despite the scientific advances related to the determination of risk factors associated with preeclampsia, and the introduction of preventive measures to try to prevent its appearance, it remains the second most prevalent cause of global maternal mortality, reaching 14% [113]. And these preventive measures do not provide sufficient evidence to be able to reduce it, so that the only treatment known nowadays is the termination of gestation [114, 115].

At present, most research to try to prevent this disease focuses on improving the development of uterine spiral arteries, determining factors related to genetic predisposition, and improving the low immunological response of most pregnant women that develop this pathology [116]. This is why exercise has played a leading role in this pathology because it promotes the improvement of maternal circulation, increasing placental vascularity, thanks to the release with the exercise of an anti-inflammatory component, and stimulates the immune system of women at risk of preeclampsia [117]. Chawla and Anim-Nyame [118] advise that exercise in pregnancy seems to be beneficial in pregnancies complicated by hypertension. In the recently published systematic review by Magro-Malosso et al. [38], aerobic exercise for about 30–60 min two to seven times per week during pregnancy, as compared with being more sedentary, is associated with a significantly reduced risk of gestational hypertensive disorders overall, gestational hypertension. However, the intensity of the exercise to be recommended for specific types of these conditions remains unclear.

8.7.4 Low Back Pain

The majority of pregnant women experience low back pain and pelvic girdle pain during their pregnancy. These circumstances worsen as pregnancy progresses and interferes with their daily routine. In the last few years, various studies showed the effectiveness of exercise in reducing back pain [119–121]. Based on the meta-analysis of 11 randomized controlled trials with 2347 pregnant women, Shiri et al. concluded that exercise reduced the risk of low back pain in pregnancy by 9% and prevented new episodes of sick leave due to lumbopelvic pain [122]**.** Evidence from single studies suggests that acupuncture [123] or craniosacral therapy improves pregnancy-related pelvic pain, and osteomanipulative therapy or a multimodal intervention (manual therapy, exercise, and education) may also be of benefit [124].

Further evidence is very likely to have an important impact on our confidence in the estimates of effect and change the estimates. Studies would benefit from the introduction of an agreed classification system that can be used to categorize women according to their presenting symptoms, so that treatment can be tailored accordingly.

8.7.5 Depression and Mental Disorders

Ohman et al. [125] reported that among the most common concerns raised by pregnant women were fear of labor pain, fear of perinatal complications, fetal health problems, or the possibility of miscarriage. The prevalence of depression during the first trimester of pregnancy was reported as 7.4–11%, in the second trimester reaches 12.8%, and in the third trimester was reported from 8.5 to 12%. The prevalence of depression at 40 weeks of pregnancy was 18.4% [126, 127].

Physical exercise practice is included in the guidelines as a therapeutic recommendation for the treatment of depression, and there is sufficient scientific evidence to support it as a complement to pharmacological treatment even in major depression cases [128]. Padmapriya et al. [129] observed that in Asian women sufficient physical activity was associated with a reduced likelihood of probable antenatal depression and trait anxiety symptoms. A recent meta-analysis by McCurdy et al. [130] has shown that light-to-moderate-intensity aerobic exercise improves mild-to-moderate depressive symptoms and increases the likelihood that mild-to-moderate depression will resolve in the postpartum period.

8.8 Specific Considerations and Safety Issues Regarding Exercise During Pregnancy

There are several special considerations that should be taken into account to maximize the effective development and ensure the safety of an exercise program for pregnant women, including the following.

8.8.1 Weight Gain and Caloric Intake

- During pregnancy, the metabolic demand increases by 300 kcal/day. Caloric intake should increase to meet the caloric costs of pregnancy and exercise. Intake above or below recommended levels with concomitant changes in weight gain during pregnancy may be associated with adverse maternal and fetal outcomes [2]. Chapter 11 [131] provides further information on this topic.
- In order to avoid excessive weight gain during pregnancy, the weight gain guidelines based on prepregnancy BMI, available from the Institute of Medicine (USA) and the National Research Council (USA) [132], should be consulted [2].
- High-intensity or prolonged exercise in excess of 45 min can lead to hypoglycemia; therefore, adequate caloric intake before exercise, or limiting the exercise session, is essential to minimize this risk [16].
- Since competitive athletes tend to maintain a more strenuous training schedule throughout pregnancy and resume high-intensity postpartum training sooner as compared to other pregnant women, they require frequent and closer supervision [16]. Such athletes should pay particular attention to avoiding hyperthermia, maintaining proper hydration, and sustaining adequate caloric intake to prevent weight loss, which may adversely affect fetal growth [16].

8.8.2 Hydration and Urinary Incontinence

- On the one hand, there are recommendations to increase hydration. Pregnant women should drink water before, during, and after exercise. On the other hand, pregnant women experience urinary incontinence during exercise because of mechanical and anatomical changes. Thus, there are considerations to take into account to minimize urinary incontinence related to exercise, such as voiding before activity, avoiding breath holding and use of Valsalva maneuver during exercise, practicing pelvic muscle-strengthening exercises, minimizing high-impact activities when incontinence symptoms appeared, and using an external pad during exercise [49].
- Pregnant women feel better when there is a bathroom available in the (indoor or outdoor) area where the exercise session is taken place [46].

8.8.3 Falls and Injury

- Pregnant women should avoid contact sports and sports or activities that may cause loss of balance or trauma to the mother and fetus (e.g., soccer, basketball, ice hockey, rollerblading, horseback riding, skiing, snowboarding, scuba diving, and vigorous-intensity racquet sports) [2]. However, in the absence of medical contraindications, the decision to stop or continue particular sports activities should be based on the assessment of woman's individual abilities, skills, previous experience, and her sense of security and comfort related to performing this activity.

- During pregnancy an increase in the laxity of the musculoskeletal system is a natural adaptive process. So far, there is a very little scientific data on this subject. Schauberger et al. [133] found a significant increase in joint laxity in five of seven peripheral joints over the course of the pregnancy and postpartum. In the study by Dumas [134], the exercise program employing minimal-to-moderate weight bearing did not result in any measurable increases in knee laxity and, therefore, appears to be appropriate with regard to knee stability. There is no scientific evidence that the prevalence of joint injury related to physical activity increases in pregnant women. However, until more data is available, activities that require jumping movements and quick changes in direction which can stress joints should be done with caution to minimize the risk of joint injury [4, 15].
- Flexibility exercises should be individualized to reduce susceptibility to joint injury. Because of increased relaxation of ligaments in pregnancy, joints are supported less effectively, especially in women with poor muscle mass. Activities that may result in excessive joint stress should be discontinued, modified, or include cautionary advice, with consideration of individual abilities [4, 15].

8.8.4 Nausea and Dizziness

- In any activity, using the Valsalva maneuver, prolonged isometric contraction, and motionless standing should be avoided [2].
- For some women it may be necessary to avoid physical activity in the supine position or to modify this position after week 16 of pregnancy [16]. Due to the weight of the growing fetus, exertion or prolonged periods in the supine position may reduce venous return and cardiac output [2].
- Fast modifications of the movement plan (e.g., stand to sit and sit to stand) may cause dizziness and imbalance [46].

8.8.5 Heat, Humidity, and Environment

- Pregnant women should avoid exercising in a hot humid environment, be well hydrated at all times, and dress appropriately to avoid heat stress [16]. Further information on this topic is available at ACSM ([2], chap. 10] and ACSM [135].
- Prolonged exercise should be performed in a thermoneutral environment or in controlled environmental conditions (air conditioning) with close attention paid to proper hydration and caloric intake [16].
- Pregnant women are quite sensitive to smell. Exercise should be performed in a clean environment, avoiding air pollution and bad smell settings [46].
- When running or cycling, rocky terrains or unstable grounds should be avoided, since the joints are more lax in pregnancy, and ankle sprains and other injuries may occur [46].

8.8.6 Sportswear and Shoes

- Pregnant women should wear comfortable and proper exercise footwear that gives strong ankle and arch support and provides impact-absorbing features, especially during weight-bearing activities and outdoor activities [46].
- Appropriate shoes that provide shock absorption and stability are particularly important for pregnant women. Shoe specialists can provide recommendations or appropriate shoes to meet individual biomechanical profiles.
- The breasts became more sensitive and will grow in size. Sometimes a sports bra is not enough to provide support during exercise. A proper pregnancy bra should provide comfort and support during exercise [46].
- Sportswear should be light and comfortable and allow perspiration. Moreover, it should be seamless, due to the increased sensitivity of the skin.

8.8.7 Session Organization

- All exercise sessions should always start with a 5–10-min warm-up period, including slow walk, light stretching, or movements that will be performed during the main part of the session.
- All sessions should end with a cooldown period, which can include breathing exercises, light stretching, pelvic floor training, movements that were performed during the main part of the session (reinforcing the motor task learning), or movements that will be performed in the next sessions. Further development of this topic can be found in Chap. 9 [91].

8.9 Exercise Supervision and Multidisciplinary Teams

During pregnancy women need to feel safe and professionally framed while exercising [136]. It is important to understand why it is not enough for pregnant women just to join general, nonspecific classes in fitness clubs and why well-trained and qualified exercise professionals are required to conduct pre- and postnatal classes, in order to increase participation rates among pre- and postnatal clients and ensure safety and effectiveness. Supervision is recommended to ensure proper technique, provide confidence, and ensure the progression of appropriate levels of intensity and complexity. The exercise professional should provide regular feedback, positive reinforcement, and behavioral strategies to enhance adherence.

The purpose of the pregnancy and postnatal exercise specialist is to build exercise participation for beginners and already active women at all stages of pregnancy and during the postpartum period. This could be done through group or individual exercise programs that meet their needs and objectives. In addition, the pregnancy and postnatal exercise specialist will be expected to assess overall physical fitness, to develop proper exercise programs, to review participants' progress, and to be able to report on adherence and outcomes to relevant stakeholders [6].

Exercise specialists should consider the multifaceted determinants and outcomes of prenatal physical activity and intervene to promote physical activity before, during, and after pregnancy, helping women to overcome any identified barriers. When working with pre- and postnatal clients, specialized knowledge is needed in the following areas, among others: the official guidelines for exercising during pregnancy, the absolute and relative contraindications to exercise, the symptoms indicating the need for the interruption of exercise, and the methods for planning and delivering adapted exercise programs for this target group [6]. Further development of exercise selection and delivering methods is provided in Chap. 9 [91].

An exercise professional should also provide the safest possible training and testing environment, as well as preventing exercise-related emergencies, and be familiar with the safety and emergency procedures available at the fitness setting where the exercise program is delivered. Further development of this topic can be found in ACSM ([49], chap. 19).

8.10 General Aspects of Exercising in the Postpartum Period

During pregnancy, moderate-intensity physical exercise can be considered safe and provides benefits for both the mother and the fetus and newborn, in general terms. As seen before, there are several international guidelines on exercise during pregnancy that support these claims. Less information can be found regarding the postpartum period. However, there are specific physiological, morphological, and musculoskeletal changes occurring during pregnancy that may persist for 4–6 weeks after birth. Postpartum women's recovery from birth can be assisted through increased physical activity [137].

In this line, health and exercise professionals must take into consideration different phases of the postpartum period, with specific objectives and exercise selection needs. Again, there is the need for a multidisciplinary approach regarding exercise and health professionals since there are different objectives regarding exercise in each period. The time periods can be divided into distinct but continuous phases [138]:

1. The initial or acute period involves the first 6–12 h postpartum. Usually it is hospital-based (i.e., during a hospital stay after delivery). This is a time of rapid change with potential for immediate crises such as postpartum hemorrhage, uterine inversion, amniotic fluid embolism, and eclampsia.
2. Immediate postpartum (i.e., hospital discharge to 6 weeks postpartum, depending on the type of delivery). During this phase, the body is undergoing major changes in terms of hemodynamics, genitourinary recovery, metabolism, and emotional status. Nonetheless, the changes are less rapid than in the acute postpartum phase, and the patient is generally capable of self-identifying problems. These may run the gamut from ordinary concerns about perineal discomfort to peripartum cardiomyopathy or severe postpartum depression.
3. Later or delayed postpartum (i.e., 6 weeks to 1 year, corresponding to the cessation of breastfeeding). Changes during this phase are extremely gradual, and pathology is rare.

The hospital-based period is very limited regarding exercise, and women are very focused on the baby. However, simple exercises to stimulate cardiorespiratory system and improve the blood flow in particular muscle groups can be performed while walking through the hospital corridors or laying in bed. Some postural and light stretching exercises are also possible. Pelvic floor training can be implemented anytime. It is important to stress the importance of performing pelvic floor exercises (also known as Kegel exercises) during pregnancy and in all postpartum periods, in order to strengthen the pelvic floor, reducing the number of episiotomies, improving perinatal results, and providing a much faster recovery [139]. Moreover, Kegel exercises and those that strengthen the pelvic floor are recommended to decrease the risk of urinary incontinence during and after pregnancy [140]. Further information on this topic can be found in Chaps. 6 [62] and 9 [91], as well as in Mottola [140], and Bø et al. [141].

The immediate postpartum period is focused on recovering from delivery and caring for the infant [141]. The later postpartum, which duration can vary regarding breastfeeding and body recovery, is a transition stage to “normal” life. The postpartum period provides an opportunity for women to begin or reengage in an active lifestyle or a specific exercise program. At this stage, exercise professionals, having in mind possible situations not yet recovered, have to understand the main facilitators and barriers to exercise during postpartum.

According to ACOG [16], some women are capable of resuming physical activities within days of delivery (Fig. 8.7). In the absence of medical or surgical complications, rapid resumption of exercise activities has not been found to result in adverse effects. The following topics must be taken into consideration when planning an exercise program during the postpartum period:

- The stages of the postpartum period
- The type of birth and its impacts on musculoskeletal health
- The common pains and discomforts during postpartum and its implications for exercise adaptation (e.g., water exercise and cycling)
- Diastasis recti and exercise modalities requiring the intervention of a physiotherapist
- Low back pain and exercise selection that may require the intervention of a physiotherapist
- Pelvic floor training
- Lactation and exercise adaptation
- Women’s motivations

The short-term benefits of postpartum physical activity and exercise include improvement in mood and cardiorespiratory fitness, promotion of weight loss, and a reduction in postpartum depression and anxiety [142]. However, despite the benefits, the majority of women do not resume their prepregnancy physical activity levels after the birth. This situation sets up the risk of remaining inactive for many years [142].

Thus, it is also of utmost importance to understand and implement the most effective strategies for promoting exercise during postpartum. Saligheh et al. [137] concluded that the provision of specifically tailored and appropriate exercise programs could potentially enable increased physical activity in postpartum women,

Fig. 8.7 Walking, jogging, indoor cycling, pelvic floor training, aerobics, Pilates, flexibility, and resistance training are among the recommended types of exercise during postpartum

thereby improving their health. In the postpartum period, there is a fundamental objective of losing weight (or recovering prepregnancy weight) and the education of the water retention that reaches its maximum levels in the third quarter. For this, the combination of physical exercise with a balanced diet allows reaching higher levels of success in achieving the described objective. This is attested by a systematic review carried out by Lim et al. [143] in which the combination of diet and physical exercise was much more effective in reducing weight than physical exercise alone.

According to Evenson et al. [142], promising strategies include increasing knowledge, regular counseling and support, self-monitoring with diaries and pedometers, increasing self-efficacy, addressing barriers, referral to community resources for physical activity, and use of walking groups. Saligheh et al. [137] concluded that to encourage facilitation of exercise through mothers' groups, mothers' exercise clubs, or postnatal classes suggesting behavioral and social change is needed. Moreover, the interaction between individuals, community, organizations, and policymakers is required.

The World Health Organization's Guideline on Physical Activity [92] recommends that adults age 18–64 years engage in at least 150 min of moderate-intensity aerobic activity throughout the week in bouts of at least 10 min, or at least 75 min of vigorous-intensity aerobic activity, or an equivalent combination of the two. Muscle strengthening should be done 2 or more days per week. The guideline states that postpartum women may need extra precaution and should seek medical advice before striving to achieve these recommendations. Moreover, women should return to prepregnancy exercise levels gradually, not resuming high impact too soon [142]. However, postpartum guidelines for physical activity should help women quickly achieve levels of physical activity that are commensurate with guidelines for all adults [31].

Evenson et al. [142] provided a summary of international guidelines for physical activity following pregnancy, in 2014. This review included published guidelines on physical activity during the postpartum period and peer-reviewed studies published between 1990 and 2013, as well. The authors highlight the importance of resuming physical activity during this time is often not made clear to women [142]. The authors suggest that there should be country-specific postpartum physical activity guidelines that inform both healthcare providers and women about safe levels of physical activity during this unique time period. We also noticed the need for specific exercise guidelines for exercise professionals and sports trainers.

8.11 Further Research

The body of knowledge on prenatal exercise is increasing. Growing evidence has been supporting that moderate exercise is safe for the mother and fetus [144]. However, the information about exercise and its effects on the cardiovascular and musculoskeletal systems of the pregnant body are still relatively limited. More knowledge of the physiologic, biochemical, and musculoskeletal changes that result from various patterns of physical activity in pregnant women, i.e., short- and long-term, sustained and intermittent, isotonic and isometric, low-to-moderate and moderate-to-high intensity, and minimum-intensity threshold required for benefit, is needed. Harrison et al. [144] highlighted the need for large, high-quality studies to clarify the optimal type, frequency, duration, and intensity of physical activity required for beneficial health outcomes during preconception, pregnancy, and postpartum.

Research on better and more effective physical activity and exercise interventions that improve long-term compliance with a physically active lifestyle is also needed. Future studies should focus not only on the benefits of physical activity and exercise but also on exercise adherence strategies and the methods used to facilitate dissemination of present and future knowledge to pregnant women, healthcare providers, and exercise professionals.

Healthy women and female athletes can usually maintain their regular training regime once they become pregnant, but, as suggested by Kehler and Heinrich [145], research is needed to determine the upper limits of exercise frequency and intensity for pregnant women who are already trained.

Exercise interventions are complex interventions because they contain several interacting components [146, 147]. We noticed that there are no validation studies regarding exercise interventions tailored to pregnant women. In addition, there is a lack of standardizing physical activity measurement during pregnancy, as well as specific fitness assessment batteries, allowing to quantify the effectiveness of exercise interventions for pregnant women.

Other focus would be the best types of exercise and parameters that could be beneficial for reducing the prevalence of symptoms, pain, and musculoskeletal disorders commonly associated with pregnancy [92], improving fitness and balance performance, and decreasing fear of falling and incidence of falls.

Regarding clinical conditions, results from systematic reviews and meta-analysis suggest that structured moderate physical exercise programs during pregnancy may be used as adjunct treatment and provide protective effect against the development of gestational diabetes mellitus [103, 104, 107], excessive maternal weight gain [85, 107, 148], low back and pelvic girdle pain [119, 122], hypertensive disorders [114, 115], and depression [128]. Moreover, diet and physical activity-based interventions during pregnancy reduce gestational weight gain and lower the odds of cesarean section [149]. However, further studies evaluating type, intensity, duration, and compliance of physical activity and exercise routines are needed to establish recommendations for exercise practice and best inform obstetric guidelines, as well as to provide advice for pregnant women with such clinical conditions. Moreover, as suggested by Brown et al. [150], further research is required comparing different types of exercise interventions with control groups or with another exercise intervention that reports on both the short- and long-term outcomes for mother and baby.

Hopefully, texts like this will increase the recognition of the need for further research on the abovementioned topics.

8.12 Conclusions

Exercise testing and prescription in pregnancy is the plan of exercise and fitness-related activities designed to meet the health and fitness goals and motivations of the pregnant woman, addressing the health-related fitness components and the pregnancy-specific conditions, based on previous health and exercise assessments, and taking into account the body adaptations and the pregnancy-related symptoms of each stage of pregnancy and postpartum, in order to provide safe and effective exercise.

In this chapter, we have reviewed the guidelines for exercise testing and prescription of pregnant and postpartum women. Moreover, we proposed a sequential order for exercise prescription and planning. There is increasing evidence on the benefits of physical activity and exercise during pregnancy and postpartum. The first step before planning to start or continuing an exercise program during pregnancy is the health screening of the woman by a healthcare provider. The second step is the appropriate pre-exercise evaluation, followed by the testing of determined fitness and postural components. Appropriate exercise prescription is then developed to tailor effective and safe exercise programs. When planning an exercise intervention, practitioners should bear in mind that for each type of exercise, i.e., aerobic, resistance, flexibility, or neuromotor, there is a frame of intensity, frequency, and duration, which will provide a metabolic, mechanical, and psychological stimulus. In addition, pelvic floor training and preparation for birth exercises are specific interventions for this special stage of life. Supervision of exercise programs by qualified exercise professionals is of particular importance to provide safe and effective exercise meeting women' goals and motivations. The synthesis of this information can be found in the infographic of the present chapter (Fig. 8.8).

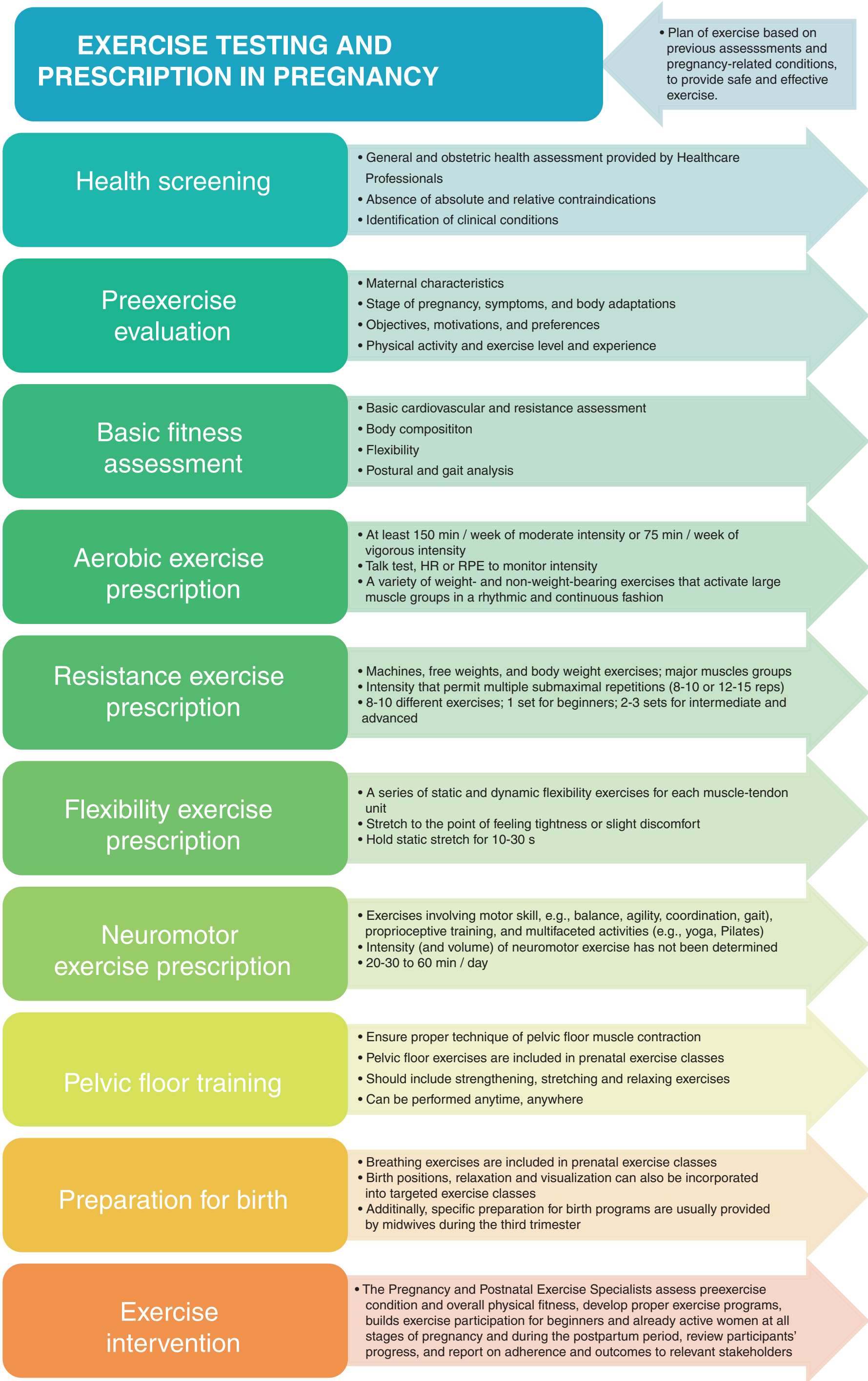


Fig. 8.8 Infographic of the chapter exercise testing and prescription in pregnancy

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Exercise Selection and Adaptations During Pregnancy

9

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Abstract

There are several guidelines supporting the benefits of exercising during pregnancy. Those documents contain very general recommendations on physical activity and exercise during pregnancy, such as general guidelines for health screening and exercise prescription of aerobic exercise and strength training. They also include examples of safe physical activities during pregnancy, such as walking, running, swimming, stationary cycling, low-impact aerobics, modified yoga, and Pilates. However, those guidelines contain little information that exercise professionals could use when programming the contents of targeted exercise classes for pregnant women. This chapter addresses the steps for planning, conducting, and monitoring prenatal exercise classes and explains how to select and adapt the exercises regarding the suggested safe physical activities during pregnancy.

Keywords

Pregnancy · Exercise · Physical activity · Aerobics · Fitness · Exercise planning

9.1 Introduction

Scientific research conducted in the last decades has markedly changed the perception of prenatal physical activity. The conservative approach presented in the 1990s, which could significantly limit exercise during pregnancy [1], now appears to be detrimental to the health of women and their children. In current recommendations, prenatal physical activity is considered a necessary condition for normal pregnancy and fetal development. What is more, physical inactivity in pregnancy is a risky behavior [2]. Exercise in pregnancy is not so much a luxury for the few women, but the responsibility of every future mother.

In the light of available research, the current question is not "if," but "how" a woman should exercise in pregnancy. A literature review [3] indicates that publicly available recommendations on prenatal physical activity do not provide answers on which exercises to choose and how they should be performed. Divergent, often unfounded information undermines the safety of certain exercises or modes of physical activity, higher intensities, and training loads. In addition, misguided social pressure may be a reason why pregnant women paradoxically reduce their physical activity because of the fear of the child's health [4, 5]. It should be noted that there is no clear scientific evidence that some sports activities or particular exercises are indeed dangerous for pregnancy and fetal development. The classification of the modes of physical activity as "not recommended for pregnant women" is rather due to the cautious attitude. Medical experts who took part in the National Forum on Pregnancy and Sport in 2001 in Sydney advised that "damage to the womb of the kind that could injure an unborn child is usually associated with forces equivalent to those occurring in a car accident. All medical experts agreed that falls and direct contact of the kinds that occur during contact sports were unlikely to cause damage to the womb or the unborn child" [6].

Considering the above, there is no reason for a woman to give up a mode of physical activity or a particular exercise just because she has become pregnant. Certainly, one should minimize the risk of injury, bearing in mind that in pregnancy medical interventions, including the use of certain medications, are limited. "Common sense" suggests that pregnancy is not the time to take part in new activities, especially if they are technically difficult. However, if a woman believes that her technical skills provide a sense of security and comfort and she has no medical contraindications, she may continue her current physical activity. An excellent example is a top tennis player Serena Williams who revealed in April 2017 that she was 20 weeks pregnant and won the Australian Open [7].

The updated guidelines for physical activity are addressed in Chap. 7 by Szumilewicz et al. [8] (see Chap. 7), and Chap. 8 by Santos-Rocha et al. [9] (see Chap. 8) addresses and discusses the current knowledge on exercise testing and prescription for pregnant women. In this chapter we present the general principles of planning and implementation of prenatal physical activity and suggestions for exercise adaptation. Exercise in pregnancy not only should be safe but also potentially effective for preventing and relieving typical pregnancy ailments and preparing a woman for childbirth and maternity [3]. We emphasize that the following suggestions do not exhaust the extensive list of exercises that pregnant women can perform. Guidelines for planning and implementing an exercise program for women with pregnancies at risk require a separate evidence-based description.

9.2 Planning, Conducting, and Monitoring of the Prenatal Exercise Sessions

According to the recommendations of the World Health Organization [10] and the US Department of Health and Human Services [11], the beneficial effects of exercise in most adults are indisputable, and the benefits far outweigh the risks. Due to the health benefits of regular physical activity, it is best if it is taken continuously for several months before becoming pregnant and then throughout pregnancy, postpartum, and early motherhood, to smoothly go into lifelong activity until late age.

Unfortunately, after becoming pregnant by the end of the first trimester, many women stop exercising or significantly reduce the training load for fear of miscarriage. In the first trimester, the risk of spontaneous abortion is about 10% [12]. According to the available data, neither the continuation of recreational exercise will increase the risk of miscarriage nor its interruption will lower it [13]. Research indicates that there are no significant differences in the early miscarriage rate between recreational runners, aerobics participants, and physically active, fit controls [14]. It is scientifically justified to think that bounces associated with running or jumping can hinder implantation. Therefore, inter alia due to the alleviation of pregnancy symptoms, prenatal physical activity should be undertaken from the day of conception.

Before starting the exercises, obstetrician-gynecologists and other obstetric care providers should carefully evaluate women with medical or obstetric complications. If no such complications exist [2], both active and inactive women should be encouraged by the medical staff to take up the prenatal exercises. Close cooperation with qualified prenatal exercise specialists is recommended here. They will plan the right type, intensity, frequency, and duration of exercise (see Chap. 8; [9]). Both professional groups should educate women and do their best to refute myths limiting prenatal physical activity. By participating in various forms of activity, women should be convinced of their safety and positive impact on the course of pregnancy and child development.

In working with pregnant women, it should be taken into account that the body is additionally burdened by the development of pregnancy, which significantly determines its response to exercise, manifested, among others, in larger fluctuations in heart rate and respiratory rate [15–18]. It significantly alters the management of the intensity of each training session, which sometimes requires extended warm-up and/or cancelation of interval exercises. It should also be considered that owing to weight gain, the woman at the same exercise has greater training load in the same unit of time compared to the preconception period [19]. Therefore, reducing the time for physical activity or number of exercise repetition is not always associated with limiting physical effort.

In exercise planning, the exercise positions should be properly selected. An exercise specialist should consider both exercise purpose, external conditions (e.g., outdoor activities, available equipment in the rooms), and, most importantly, the well-being of the woman. To ensure the versatility of muscle work, good blood flow in the woman's body, and the attractiveness of exercises, it is a good practice to use frequent changes of position. When planning exercises for women in the second and third trimester, it is worth taking into account that changing positions alone is associated with physical effort and sometimes requires slightly longer time than in nonpregnant women. We've described selected positions for pregnant women in Appendix 1. Nevertheless, a pregnant woman does not have to limit herself to them.

Pregnant women should be informed both what is the correct technique of each exercise and also how to modify it in case of discomfort during its execution. It is a good practice to propose various versions of the exercises, considering trimester of pregnancy and its progress, the level of skills, and abilities of a woman. Due to continuous morphological, biomechanical, and physiological changes in the woman's body, the same exercises on different days may be differently received in terms of comfort. In exercising, women should take into account both the tips of an exercise specialist and signals from their bodies. Especially they should be sensitive to the so-called warning signs that indicate the need to immediately stop exercising (see Chap. 8; [2, 9]).

To participate in prenatal physical activity, a woman should be well nourished and hydrated according to recommendations for proper nutrition during pregnancy [20]. In each exercise session, one should plan rest breaks, inter alia to refill the fluids, depending on the volume and intensity of the exercise (e.g., three to four breaks during a 60-min session). If necessary, a woman should rest more often, according to her own well-being. If she exercises under the supervision of an exercise specialist, she should report any discomfort to him or her, thus enabling proper selection and modification of the physical activity program. A woman should also follow the norms of nighttime sleep and proper rest after the exercise session. The general recommendation is to have rest time during the day equal to the duration of the exercise session [21].

Women should use training clothing and footwear and sports equipment appropriate for the given form of physical activity, the temperature of the environment of the exercise, and its intensity. In addition to paying attention to the increasing abdominal circumference, the same rules apply as for the general adult population. In the case of beginners, in the selection of clothing and equipment, it is recommended to consult a specialist in a given form of physical activity. At the end of pregnancy, an abdominal support and an extra bra may be useful to ensure the greatest possible stabilization for the growing abdomen and sore tender breasts.

The appropriate level of the individual training components should be regularly monitored and evaluated according to the observed progress [21]. The most significant effects are typically observed during the first 6–8 weeks of an exercise program [22]. The following is a useful tool to monitor and record a pregnant woman's well-being during and after exercise session (Table 9.1).

Table 9.1 Exercise monitoring card

Exercise monitoring card								
Name and surname:					Date of the first classes:			
Date	Form of physical activity[a]	The duration of exercise	Subjective intensity perception at RPE scale[b]		Rest time after exercise[c]	Well-being during or after classes/ comments	The reason for absence	Participant's signature
			Aerobic part	Resistance part				
Example	Total body condition class	60 min	7	6	60 min	Good or, e.g., back pain after exercise		

[a]You should enter all forms of physical activity, also individually taken, e.g., walking and cycling
[b]A woman should use the RPE scale from 0 to 10 or 6 to 20, according to exercise specialist's instructions
[c]Rest time after exercises (entered at the next class)

9.3 The Structure of the Exercise Session for Pregnant Women

The important purpose of prenatal physical activity is to stimulate the positive development of pregnancy, provide the greatest possible well-being for the future mother, and prepare her for childbirth and postpartum. Therefore, each training session should include several elements. A combination of aerobic and **resistance** exercises during pregnancy seems to induce the most favorable effect on maternal health during pregnancy [23, 24]. A pregnant woman should also perform flexibility, body posture, neuromotor, and pelvic floor muscle exercises. Preparation for birth part, including breathing exercises, relaxation, birth visualization, and birth position, is recommended, as well [25–29].

Prenatal exercise sessions are usually scheduled for 45–90 min, depending on the capacity of the women. The recommended structure of the 60–90-min class is as follows:

1. Warm-up (7–10 min)
2. Aerobic exercise, e.g., low- or high-low-impact aerobics, walking or jogging on a treadmill, stationary cycling (15–20 min)
3. Resistance exercises (including abdominal exercises), postural and neuromotor (e.g., body balance) exercises (10–15 min)
4. Stretching exercises (5–10 min)
5. Pelvic floor exercises (5–10 min)
6. Cooldown and preparation for birth exercises, e.g., birth position and breathing exercises (5–10 min) and also relaxation and visualization of pregnancy and childbirth (5–15 min)

9.3.1 Warm-Up

The main task of the warm-up part for prenatal activities is, as in any other activity, psychophysical preparation for the more rigorous demands of the cardiorespiratory and muscular and conditioning parts of the exercise session. The recommended time is 7–10 min. In warm-up pregnant woman should pay attention to several elements:

1. Before each activity, the woman should make a self-assessment of her well-being. Even in normal pregnancies, there are occasional discomforts (e.g., pain, dizziness, abdominal pain), which may indicate, for example, fatigue or a beginning of an infection. On such days, it is worthwhile to extend the warm-up, lower the intensity of exercise, or maybe even give up exercises. Observations, however, suggest that moderate physical activity improves the well-being of pregnant women [30, 31]. Therefore, the decision to give up exercise on a given day should not be taken too hastily.
2. It is good to start with the correction of body posture so as not to fix the posture defects in the course of further exercise [32]. Posture exercises improve body

awareness [33], and it is likely that women will be more sensitive to signals from their body. This, in turn, can affect the effectiveness and safety of exercise.

3. During warm-up, simple, rehearsal moves should dominate, engaging all large muscle groups. These can be marches or runs, supplemented by arm swings or circulations. Aerobic moves can be used, too. When music is used in the warm-up, the recommended tempo is 120–136 beats per min [34].
4. Already during the warm-up, a woman should consciously activate the pelvic floor muscles to practice how to prevent the urinary leakage in more intensive exercise in the main part of the exercise class.
5. In the warm-up, pregnant women should perform breathing exercises. First, as in general population, these exercises should help to supply more oxygen during increased muscle work. Secondly, the diaphragm, the major muscle involved in breathing, is like any muscle group and needs time to speed up its work. It is particularly important in the second and third trimesters, when the growing womb hinders the lowering of the diaphragm during inhalation. Thirdly, owing to breathing exercises, a woman can reduce discomfort associated with a feeling of breathlessness appearing at the beginning of physical exertion. This feeling is the result of elevated levels of progesterone, which initiates “overbreathing” by increasing the sensitivity of the central chemoreflex control of breathing to carbon dioxide [35]. Although this is often not pleasant for pregnant women, it increases the efficiency of oxygen uptake from the lungs and the elimination of carbon dioxide from the blood of mother and baby [21].
6. Due to continuous changes in the circulatory system throughout the pregnancy, the increase in intensity during warm-up should be gradual. Especially at the very beginning of pregnancy, when the vessels are already relaxed and dilated and the volume of blood has not yet caught up, the heart rate may be extremely high at one’s usual intensity [21].
7. At the end of the warm-up, the woman should reevaluate her well-being and readiness for greater physical effort in the main part of the class. It’s also time to consume the fluids.
8. If the class is performed by an exercise professional, it is a good time to present to the participants the target of the main part of the exercise session, as well as provide important training tips, such as the importance of maintaining proper posture, proper breathing, monitoring exercise intensity and well-being, and fluid refills. Exercise professional also reminds women of the warning signs for immediate discontinuation of exercises and customization of exercises to individual capabilities, as instructed.

9.3.2 Aerobic Exercise

According to current guidelines [2], healthy pregnant women should perform at least 150 min per week of moderate-intensity aerobic activity (i.e., equivalent to brisk walking). This activity should be spread throughout the week and adjusted as medically indicated. The guidelines advise that “the pregnant women who habitually engage in vigorous-intensity aerobic activity (i.e., the equivalent of running or jogging) or who are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health care provider how and when activity should be adjusted over time" [11]. Women who did not exercise before pregnancy should be encouraged to do physical activity at least three times a week starting from 15 min sessions, gradually lengthening them [2]. Aerobic exercise for pregnant women can be implemented in various forms, depending on the skills and abilities of women.

Typically, aerobic exercises are those that involve the use of large muscle groups in a repetitive, or rhythmic, fashion. Examples of aerobic activities include walking, jogging, running, cycling, swimming, and using aerobic-based machines, e.g., stair climber and elliptical machines [32]. Some activities are weight-dependent, meaning that body weight is moved during the exercise (e.g., walking, running). In other activities, body weight is not a factor because the body is supported (e.g., cycling, swimming). These activities are referred to as weight-bearing and non-weight-bearing exercises, respectively. Use of non-weight-bearing exercises may be particularly useful for women at the end of gestation due to the increasing body weight.

According to ACSM endurance activities have been classified into four groups. Group A includes endurance activities that require minimal skill or fitness to perform, e.g., walking. These activities can easily accommodate individual fitness levels and thus are recommended for all adults, especially for beginners. Based on the review of guidelines on exercise in pregnancy [3], walking was the most frequently recommended form of physical activity for pregnant women (see Chap. 7; [8]). Group B activities are those that require minimal skill but, in contrast to Group A activities, are typically performed at a more vigorous intensity, like jogging and running. Group B activities are appropriate for those who exercise regularly and who have at least an average level of fitness. Although in some countries jogging and running are considered as appropriate forms of physical activity for pregnant exercises, in other countries the sight of a running woman is controversial. It should be emphasized that fears of miscarriage resulting from repetitive bounces typical for more vigorous exercise have not been confirmed in scientific research. Already in the 1980s, Clapp [14] observed that the rate of early pregnancy loss in recreational runners was even lower, although not statistically significant, than in controls (17 vs. 23%, respectively).

Examples of group C activities are swimming and cross-country skiing. This group reflects activities that have a high relationship between skill and energy expenditure. For example, an experienced swimmer may be able to easily swim at a constant intensity whereas a person with poor swimming skill would be very inefficient and would struggle to swim at an appropriate and constant intensity to receive cardiorespiratory benefits [32]. Swimming is the second, most frequently proposed exercise in pregnancy [3], mainly due to its non-weight-bearing form. However, due to the risk of genital tract infections in public swimming pools, not all women can participate in water activities. Other forms of movement from group C should be popularized for those pregnant women who regularly took part in them before conception.

Recreational sports like basketball, soccer, tennis, and other racquet sports are classified as group D activities. These activities are typically vigorous and intermittent. The nature of these activities does not lend themselves to constant, controlled intensity levels. This is even more true when competition is involved. Activities from group D usually are on the list of "not recommended" forms of exercise for pregnant women (see Chap. 7; [8]), although not much data is available on their potential risk.

We presented the most popular aerobic forms of prenatal physical activity below.

9.3.2.1 Aerobics

In an aerobics class, participants perform movements that work the large muscle groups to promote cardiorespiratory fitness and its benefits. These movements are traditionally dancelike and can be executed while keeping one foot on the floor at all times (low impact) or while jumping (high impact). Classes mixing high- and low-impact movements are labeled as high-low (or hi-lo) aerobics. A skilled exercise specialist is able to teach low- or high-impact options of movements in one choreography so that even in group classes, it is possible to adjust the intensity of exercise to the individual needs of the participants [34]. Music sets the cadence and rhythm of the moves [36]. Official guidelines on exercise in pregnancy from different countries advice women aerobics as a form of cardio exercise; however some of them limit this recommendation to low-impact aerobics [3].

Several authors have observed that low-impact aerobics is safe [37, 38] and beneficial for pregnant women, both for various conditions and parameters of the course of pregnancy [39, 40] and labor and delivery [41, 42]. Nevertheless, too low intensity in low-impact aerobics may not be sufficient to stimulate the cardiopulmonary system [38] and not produce the desired health effects. Using high-impact movements during group classes gives the opportunity to increase quickly the intensity of exercise. It is especially important for women with high levels of exercise capacity and accustomed to participate in high-intensity classes before pregnancy. Adding jumps or runs during an aerobics class may be an option for such women.

So far, there is no scientific evidence that the participation of pregnant women in hi-lo aerobics can have negative effects. It is unsubstantiated belief that runs or jumps can cause miscarriage or premature labor. However, with the development of pregnancy and the growing womb, it may be necessary to limit high-impact movements. Potentially they can cause an unpleasant bounce of pregnant belly or growing breasts and intensify urinary incontinence or lower back pain. However, the decision to eliminate high-impact movements should be based on the assessment of the well-being of a woman and not be a general rule for exercising during pregnancy.

The recommended music tempo for hi-lo aerobics classes is 134–150 BPM (beats per minute) depending on the group's abilities [34]. With the progression of pregnancy and gaining weight, the training workload of a pregnant woman increases, so it may be necessary to use slower music in the third trimester. During the entire choreography, the woman should be able to breathe freely and maintain an exercise intensity of 14–16 on the RPE scale from 6 to 20 or 6–8 on the RPE scale from 1 to

10 (see Chap. 8; [9]). Concerning the level of expertness, Laukkanen et al. [43] reported that intensity management during aerobics classes is generally successful regardless of the participants' prior participation in aerobics; however, in their study, some individuals who were older and/or had less prior participation tended to exceed the targeted heart rate.

The technique of performing aerobics moves does not differ significantly from the technique for the general population. Special attention should be paid to the correct body posture, not to deepen its defects. Perhaps at the end of pregnancy, due to the falling belly, it will be uncomfortable for a pregnant woman to perform the *front knee-up* move, which can be replaced by *side knee-up* move (see Appendix 2). It is certainly worthwhile to include conscious pelvic floor muscle contractions at the end of each exercise (e.g., when attaching legs in *step touch* move or before jump or run). To prevent urine leakage during exercise, Bourcier [44] proposed to use "the knack"—a quick, strong, well-timed pelvic floor muscle contraction before and during physical stress increasing intra-abdominal pressure.

In aerobics one should also incorporate upper body moves to activate the whole body, increase the exercise intensity, and improve coordination. The arms can move bilaterally (right and left sides perform the same movement simultaneously) or unilaterally (right and left sides move individually or perform different movements simultaneously) [34]. Some women are afraid to raise their arms above their heads, for fear of miscarriage. This is an unfounded opinion, which unnecessarily limits the range of exercises during the classes. Likewise, there is no justification for avoiding in pregnancy frequent changes in direction or any turns during choreography. Although the center of gravity, balance, and coordination are changing in pregnancy, there is no scientific evidence that these changes increase the risk of collapse or collision during aerobics compared to the general population. As mentioned above, the inclusion of changes in direction and turns in a choreography as well as cadence will depend on participants' level of expertise. However, there should always be an "easier" and "more challenging" option included in the session plan for the cases there are participants with different levels of fitness and experience in the same group class. We presented examples of aerobics movements for pregnant women in Appendix 2.

9.3.2.2 Step Aerobics

Step aerobics is a classic cardio workout that uses a 10, 15, 20, or 25 cm height bench of approximately 102 cm (length) × 38.5 cm (width) (Fig. 9.1) to step up and down, around the step forward, sideways, and backward, and over the platform, usually combined in choreography. Different patterns of steps can be used to boost heart rate and breathing, as well as lower limb muscles resistance. Core muscles stabilize the trunk. Upper limb movements can also be added. Upbeat music sets the cadence, the number of moves, and the rhythm and provides motivation. Exercise specialists show the moves, the appropriate technique, and the progression of choreography. Moves' sequence building is important in order for participants to feel successful. Usually, participants are in a gym, in front of a mirror. However this equipment can be used at home to follow video classes and exercise to music. If used outdoors, precautions should be taken regarding the type of floor: it must be

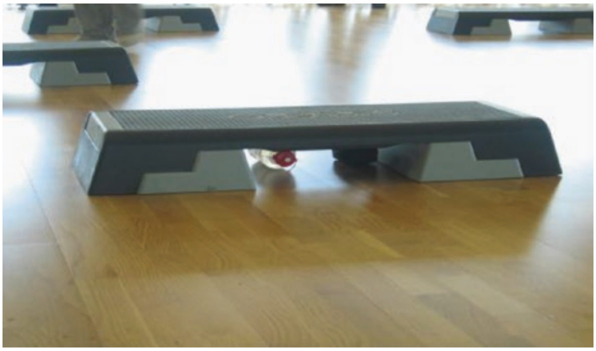


Fig. 9.1 Image of a 15 cm height Step Reebok™ bench

flat and not slippery. Moreover, if the participant feels tired or she is a complete beginner, she can perform the moves on the floor, i.e., without a bench step (e.g., draw a rectangle on the floor with duct tape). A step aerobics class typically lasts 45–60 min.

The *Step Reebok*™ program was originally introduced as a low-impact activity (with a medium-impact version called Power Step Reebok) since its proponents claimed that ground reaction forces were similar to those of walking [45, 46]. Step classes currently include propulsive movements that have changed the nature of impact of the activity [47]. The objectives of this group exercise are based on the improvement of cardiovascular and muscle efficiency, as well as motor coordination, balance, spatial orientation, body composition, and fun. One important characteristic of Step exercise is the repetition of exercises (or techniques, called "steps") that induce forces of low magnitude (around 1–2 BW—body weight) and of high frequency (around 3750–4050 times on a 30 min session, using music speed of 125–135 beats per min) [47, 48].

Step aerobics moves range from simple to advance depending on low or high impact, coordination, balance, change in position, speed, and combination of choreographed steps. Regarding impact loading and being a weight-bearing exercise, low-impact moves mean that there is always one foot on the bench or ground (e.g., basic step, knee lift, knee repeater, marching, mambo). High-impact moves mean that for a moment both feet are off the ground (e.g., run step, knee hop, jump step, knee leap). Regarding leading leg loading, step moves can be symmetrical or asymmetrical, i.e., the sequence of moves always starts with the same leading leg followed by the impulsion leg, or the sequence of moves always starts with alternated leading legs. The step aerobics low-impact basic moves are the asymmetric "basic step" (right step up, left step up, right step down, left step down, etc.) and the symmetrical "knee lift" (right step up, left knee lift, left step down, right step down, left step up, etc.). The step aerobics medium-impact basic moves are the asymmetric "run step" (right leap step up, left leap step up, right step down, left step down, etc.) and the symmetrical "knee hop" (right step up, left knee lift with hop, left step down, right step down, left step up, etc.). Regarding the dominant leg of each move, instructors must plan a session with a balanced number of asymmetrical moves. This is a very important point of the session since it will influence mechanical load.

Regarding technique, the head should be up, shoulders down and back, chest up, abdominals lightly contracted, and buttocks gently tucked under the hips. Knees and back should never hyperextend at any time. When stepping up the body should lean from the ankles and not the waist to avoid excessive stress on the lumbar spine. The entire sole of the foot should contact the bench, stepping softly and quietly to avoid unnecessary high impacts. The heel should not land over the edge of the bench to avoid Achilles tendon injury. When stepping down, the step should be close to the bench (no more than one shoe length away), and the heel should contact the floor to help to absorb shock [45].

The class starts with a warm-up, followed by choreographed routines on the step, and a cooldown at the end. The intensity can vary from low, medium, and high, depending on the type of moves (impact, repeaters, amplitude, overhead upper limb moves, etc.), cadence, choreography, and bench height. This means that a session can be planned with the following objectives of meeting different fitness and skill levels: (1) low to medium intensity, low to medium impact, and easy to follow (i.e., pregnant women, older adults, children, some clinical populations, and beginners); (2) medium to high intensity, impact, and complexity (i.e., skilled participants, including pregnant women); or (3) medium to high intensity and impact but easy to follow (i.e., cross-training for athletes). There are no advantages of adding weights while stepping. The use of ankle and hand weights failed to enhance training adaptations [49]. After the cardio part, the set bench can also be used to perform strength training and stretching exercises. The only contraindications for step aerobics are the conditions of hip, foot, ankle, or knee pain or recent back and knee injury.

Step aerobics is one of the main trends of activity undertaken by pregnant women [50]. Unfortunately, to our knowledge, only one prospective randomized controlled trial designed to assess the benefits and possible risks of aerobic exercise during pregnancy used step aerobics in the exercise intervention [51]. With a general population of pregnant women, the program should include low- to medium-impact moves and benches of 10–15 cm height, without too many changes of direction and jumps over the platform, in order to prevent falling or loss of balance. Pregnant women should always maintain visual contact with the platform. On the other hand, each woman feels safer on her own bench and space around it, compared to an aerobics class. It does not require much space and equipment and provides a good cardiovascular, resistance, and neuromotor exercise. Thus, it is a safe and effective exercise to start or continue during pregnancy, as long as intensity (e.g., slower cadence, lower bench) and complexity can be adjusted to fitness and skill level as pregnancy progresses. Important precautions include to lower the bench as the belly grows and the center of gravity changes, to drink water before and during exercise, and to not overheat. We presented examples of step aerobics movements for pregnant women in Appendix 3 of the present chapter.

9.3.2.3 Indoor and Outdoor Cycling

Indoor cycling is a non-weight-bearing cardiovascular and lower body resistance exercise. An indoor cycling class typically lasts 45–60 min. Indoor cycling requires a stationary or "spinning" bike (Fig. 9.2a). The position of the saddle must adjust to participants' measurements (i.e., when standing beside the bike, the saddle must be at the same plan of the hips; when seated in the saddle, with foot on the pedal at the bottom of the stroke, the knee must be slightly bent; when seated, with the crank arms parallel to the ground, the horizontal distance from the handlebars to the saddle must be set when the knee line intersects the leading edge of the forward crank arm). Intensity depends on the speed, load on the bike, time (duration of the session), and change in position (sit or stand). Other options include a stationary bike (Fig. 9.2b) or a reclined bike (Fig. 9.2c) at a gym or at home.

Outdoor cycling is non-weight-bearing cardiovascular, lower body resistance, and neuromotor exercise. The findings by Skreden et al. [52] indicate that so-called active transportation, including cycling, is one possible approach to prevent excessive weight gain in pregnancy. An outdoor cycling session may last from a very short period to several hours depending on fitness level and comfort. Outdoor cycling requires a regular bike, usually, specific to the road, mountain, or urban/fitness (Fig. 9.3a–c). However, there are other types available, such as tandem,

Fig. 9.2 Indoor cycling is a non-weight-bearing activity to be performed on: (**a**) a spinning bike; (**b**) a stationary bike; (**c**) a reclined bike

Fig. 9.3 Outdoor cycling requires (**a**) a road bike; (**b**) a mountain bike; (**c**) an urban/fitness bike, among other types

touring, tricycle, hybrid, electric, etc., and bikes designed around female anatomy and dimensions. The frame, weight, and dimensions of the bike must be adjusted to participants' size, fitness level, comfort, and training objectives.

The characteristics of the bike will of course influence its price. However, the main question to have in mind is technique and a correct fit. Being a repetitive movement, sustained up to several hours, appropriate technique is of particular importance in order to perform effective and safe training, avoiding falls and preventing injuries.

Pregnant women that are regular or competitive cyclists will have very light and expensive bikes. Competition and training for racing should be in standby during pregnancy, but athletes may wish to continue to training until the abdomen expands to the point that it is no longer comfortable to cycle, especially if the woman is a road bike athlete. In these cases, switching to a mountain or fitness bike, indoor cycling, and using a more comfortable bike that allows a more upright position can be good options, taking into account that most of the body weight shifts onto the saddle, compressing intervertebral disks. For those who are recreational bikers or use the bike for active commuting, they may wish to continue as long as pregnancy progresses. In these cases, mountain bikes and urban/fitness bikes can offer very comfortable equipment regarding size, feminine geometry, suspension, woman's saddle, number of gears, and lightweight equipment. There are many brands that offer from very affordable to very expensive bikes. For those who do not know how to use a bike, starting this activity after the childbearing period may be a better option, unless using a stationary bike or a tricycle. Learning how to use the bike is a very demanding activity regarding balance skills, and pregnant women should avoid falling and trauma situations.

When cycling outdoors several precautions should be taken:

1. To ensure proper technique: to use proper bike and ensure correct bike fit; feet should be properly placed on the pedals, with or without cycling shoes with a strapless pedal binding system (this system must be fitted to the cyclist' experience level).
2. To adjust the trunk position and the handlebar of the bike (in height and width) as belly grows.
3. To be sure of the condition and maintenance of the tires, brakes, and gears.
4. To know how to fix or replace a flat tire and how to pump.
5. Always use a helmet.
6. To avoid bad weather (too cold or too hot) and slippery ground.
7. To know the conditions of the weather and ground in advance.
8. To drink water before, during, and after exercising (and carry light snacks).
9. To avoid air pollution and car traffic.
10. To be aware of traffic rules and hazards.
11. To use sun protection for skin (lotion) and eyes (glasses). Glasses also protect from dust and bugs.
12. To use cycling routes, lanes, and parks; preferably engage in a cycling group or ride with a partner (on two bikes or using a tandem).

13. To use proper sportswear: bike or cross-training shoes, breathable shirt and jackets, supportive and comfortable bra, breathable underwear, shorts or leggings with saddle pads (or extra comfortable women's saddle).
14. To use fingerless or full cycling gloves to prevent blisters and to protect skin if the hands contact the ground in case of falling.
15. To avoid riding in the dark and to know how to deal with dogs (e.g., carrying some cookies, shouting back, or dismounting and placing the bike between the body and the dog).

Some modifications may occur in accordance with common pregnancy-related symptoms and discomforts. If the pregnant woman has pelvic girdle pain, hemorrhoids, varicose veins in legs, varicose veins in the vulvar area, or vaginal yeast infection, just sitting in the saddle or sitting in the saddle for a long time will be uncomfortable. In some cases, there might be temporary vision changes due to hormonal effects, and glasses may not be enough to ensure safety while riding outdoors. Other safety concerns are related to changes in the sense of balance and dizziness (in these cases indoor cycling is the best option).

An indoor or outdoor cycling training includes a warm-up, cardiovascular exercise, lower limb resistance exercises, and a cooldown part with stretching exercises. Any change in the bike will affect muscle activity and pedaling form, which in turn, will affect intensity. Cycling also allows monitoring heart rate, using a heart rate monitor, a GPS (global positioning system), or a smartphone.

9.3.2.4 Walking, Jogging, or Running

Walking provides a good cardiovascular and lower limb resistance and core exercise to be performed outdoors (with or without poles) or using a treadmill (Fig. 9.4). Walking briskly requires attention to posture and technique: keeping the head up and looking forward, keeping head straight with chin parallel to the ground, properly blended arms swing with loose shoulders (arm counterbalance leg movements), hip aligned with shoulders avoiding sway back, and proper leg swing and stride length [53].

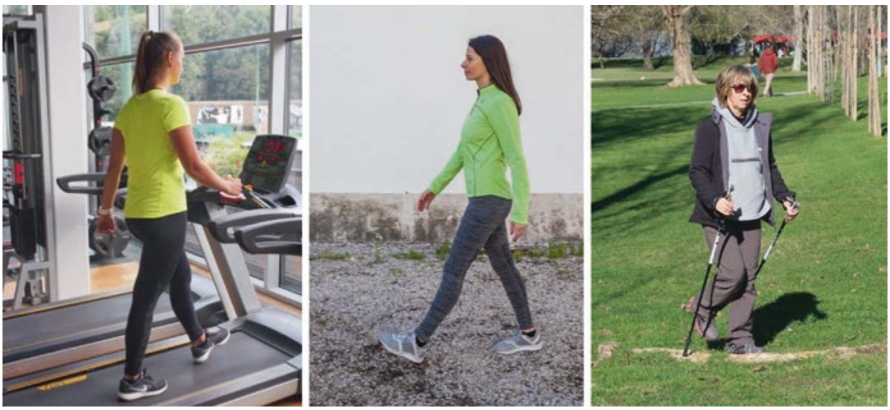


Fig. 9.4 Walking can be performed either outdoors (with or without poles) or using a treadmill

Walking is the most commonly reported form of exercise during pregnancy [54]. Walking is an affordable exercise that requires no special equipment or facility, and it is very good for beginners and active women. There is no contraindication from its practice during pregnancy, except recent lower limb injury or pain. Several clinical trials have used walking as an intervention to assess the effects of exercise on maternal and perinatal outcomes and have found it to be an effective intervention [37, 55–57]. Running is a time-efficient aerobic activity [53] and is a good option for those who were recreational or competitive runners before pregnancy. Those athletes may wish to continue their training, although some adaptations may be needed, regarding intensity and impact. There have been several experimental trials [14, 58, 59] on the influence of regular running on maternal and/or fetal health, and no adverse effects were observed.

One important characteristic of walking and running is the repetition of strides (loading cycles) of low impact (inducing ground reaction forces of low magnitude, i.e., 1–2 BW) or medium impact (i.e., 2–4 BW), with high frequency (around 3570–5710 steps) during a 30-min session, at speeds of 5 km/h (~83 m/min) to 8 km/h (~133 m/min), respectively (assuming that the mean stride length of a woman is ~70 cm). There may be some changes needed as the belly grows, regarding the speed, balance, and gait pattern. Moreover, joints and ligaments more vulnerable to strains or sprains, augmented pelvic pressure, Brixton Hicks contractions, and urinary frequency, especially during the third trimester, are factors that may lead to cease running and substitute it for walking or other activities.

Proper stretching exercises both before and after a walking or running session are helpful to prevent injuries. When walking, hiking, or running outdoors, several precautions should be taken:

1. To ensure proper posture, technique (arm and leg swing), and breathing
2. To avoid bad weather (too cold or too hot) and slippery ground
3. To get familiar in advance with the conditions of the weather, trails, and ground, as well as bathroom facilities
4. To avoid steep ascent or descent
5. To drink water before, during, and after exercising
6. To avoid air pollution and car traffic
7. To avoid hiking at high altitudes due to the decrease in oxygen
8. To use sun protection for skin (lotion), head (cap), and eyes (glasses)
9. To use eyes protection (glasses) against dust and bugs
10. To use walking lanes and parks
11. Preferably to engage in a walking/running group
12. To use proper sports shoes: walking, running, or cross-training shoes that provide comfort, ankle support, cushioning, and shock absorbing features
13. To use comfortable socks with extra padding to prevent friction and blisters
14. To use proper sportswear (and underwear): breathable shirt and jacket, pregnancy supportive bra, seamless and breathable underwear, shorts or leggings
15. To ensure frequent rest and water breaks if exercising for a long time

9.3.2.5 Water Exercise and Swimming

Water exercise is also a commonly reported form of exercise during pregnancy [54], very good for beginners and active women (Fig. 9.5). Water exercise and swimming take the weight off the joints while exercising. It has been shown that water exercise is safe [60, 61] and beneficial for pregnant women [39]. In the study by Vallim et al. [62], the great majority of pregnant women considered that the practice of water aerobics had benefitted them in some way.

Most water workouts are done in the shallow end of the swimming pool, and participants stand in chest-deep water. They can also stand in shoulder-deep water to perform other upper body exercises keeping the arms under water. It is a low-impact exercise and the buoyancy of the water is supporting the body weight. Different patterns of lower limbs and upper limbs moves performed in the water can be used to boost heart rate and breathing, as well as muscular resistance and flexibility. Core exercises (abdominals and back muscles) may include lunges, side leg lifts, etc., or exercising with legs and arms at the same time. Upper limb moves may include underwater bicep curls, etc. Lower limb exercises may include water walking, water jogging, jumping jacks, squats, high knee kicks, and underwater kicks and jumps. Pelvic floor exercises can be performed by incorporating them in other stretching or strengthening exercises. Pool noodles, paddles, barbells, balls, kickboards, aqua joggers, foam weights, and other specific equipment can also be used for added resistance.

Upbeat music sets the cadence, the number of moves, and the rhythm and provides motivation. Workout intensity can be increased by doing more repetitions of each move, increasing speed, or using some equipment to increase resistance. An advanced class might include underwater interval training. Classes also are performed in outdoor pools where and when the weather allows. Usually the exercise specialist, placed in the dock of the swimming pool, shows the exercises putting emphasis on technique and breathing. A water exercise class typically lasts 45–60 min.

Swimming is also a popular exercise among pregnant women, recommended in several guidelines [3]. A swimming class may include adaptation to water environment exercises, arms' exercises, legs' exercises, technique exercises, assisted or resisted exercises, breathing exercises, and backstroke, freestyle (crawl), breaststroke, and butterfly styles of swimming (including flip turns). Some small equipment can

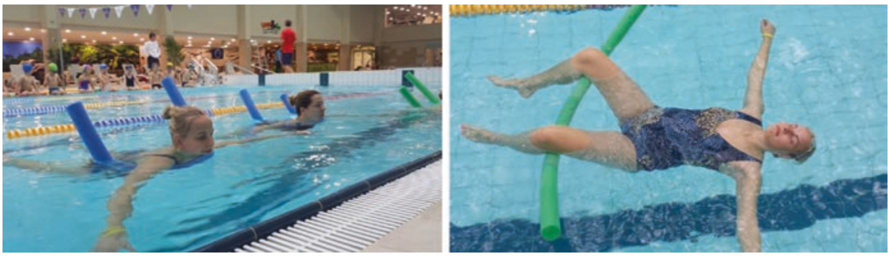


Fig. 9.5 Water exercise is a popular activity among pregnant women

also be used to focus the exercise only on the arms or lower limbs (kickboard, pull buoys, or another flotation device) and increase resistance (hand paddles) or propulsion (swim fins) of the swimming exercises. The selection of exercises for each session will depend on the level of experience, skill, and fitness. Butterfly stroke is the most demanding regarding technique and effort. Each swimming stroke has a specific arm and movements' technique and performance, but general aspects of swimming include efficient movement of the body through the water, keeping the strokes long and relaxed, and trying to get as much distance as possible with each stroke (and increase speed).

As pregnancy progresses, some lower back movements will probably become difficult or painful (butterfly and breaststroke), and the expanded abdomen will create more resistance (drag) in the water (butterfly, breaststroke, and freestyle) making body alignment in water more difficult as well. The same reason applies to flip turns. Thus, the speed work usually performed by competition swimmers should be postponed to after childbirth. Moreover, the hormonal changes provoking the relaxation of hip and pelvic joints may promote discomfort during the frog kick of breaststroke. For the same reason, the neck movements of the breaststroke and freestyle (assuming that the participant breathes alternately to the right and left sides or every three arm strokes) may also become uncomfortable. The alterations of spine alignment may also interfere with backstroke. Nevertheless, the best technique is the one that the pregnant woman is able to perform correctly and without pain and discomfort and is more motivated to practice.

A swimming session can last 30–60 min. However, a short interval of 10–15 min can be added to a regular water exercise session, especially when the pregnant women are able to swim backstroke.

A water aerobics class or a swimming training includes a warm-up, cardiovascular exercise, muscular resistance exercises, and a cooldown with stretching exercises. When swimming or practicing water exercise, several precautions should be taken:

1. To ensure proper posture, technique, and breathing regarding water exercises and swimming strokes
2. To avoid too cold or too hot water
3. To ensure the hygienic conditions of the pool
4. To ensure that the swimming pool is supervised regarding safety and emergency conditions
5. To drink water before, during, and after exercising
6. To use skin (lotion) and eyes (glasses) sun protection when exercising in outdoor pools
7. To avoid jumping into the pool or diving activities
8. To use proper and comfortable maternity swimwear
9. To use proper water goggles (to protect from irritation), swim cap (to protect hair from damage), and maternity swimwear with bra support included
10. To ensure the availability of bathroom facilities
11. To avoid sharing a lane with other swimmers (because of potential shocks)
12. To avoid swimming alone when exercising outdoors in a lake, river, or sea

9.3.3 Resistance, Postural, and Neuromotor Exercises

9.3.3.1 Resistance Exercises

So far, there is sparse knowledge on strenuous strength training in the general pregnant population, and no studies on its effects in pregnant elite athletes have been conducted [63]. According to Bø and coauthors [63], women who are considering heavy strength training in pregnancy should understand that the Valsalva maneuver used during weight training precipitates a rapid increase in blood pressure and intra-abdominal pressure [64, 65] and therefore potentially may temporarily decrease blood flow to the fetus. The consequences of this process for the fetus development remain unknown. Heavy strength training potentially may lead to pelvic floor disorders. Research is needed to explain the above issues.

Nevertheless, in pro-health resistance training with a light-to-moderate load of free weights or weight machines (Fig. 9.6a–d), researchers have observed no adverse health effects during pregnancy [24, 58, 66, 67]. Prenatal exercises strengthening particular body parts can improve both their appearance and functionality specific

Fig. 9.6 Resistance training can be performed: (**a**) with body weight; (**b**) with light-to-moderate load of free weights; (**c**) with stability ball; or (**d**) with weight machines

to pregnancy and motherhood. The fear of adverse effects of resistance training such as inadequate blood flow to the fetus during exercise was not supported by scientific research [24].

Resistance exercises for pregnant women follow the same training rules as for the general adult population. When applying the principle of training progression, one should consider the increase in body weight (at the end of pregnancy, it may be over a dozen or more kilograms). Additional body weight should be considered in exercises with body resistance. For example, it will be important in doing squats, but it will not matter in straightening the legs with the resistance of the machine in supine position. Keeping the same number of repetitions in exercises with body resistance until the end of pregnancy should be treated as training progress.

In the selection of the training load (also external load in the form of, e.g., dumbbells, resistance bands, medicine balls, the resistance of machines), the individual level of fitness of the woman and her well-being during and after the exercises should be taken into consideration. There is no (and probably will not be) a maximum load allowed during pregnancy either in absolute values, e.g., in kilograms, or relative, e.g., in the percentage of maximum possibilities. There is no scientific basis for women to reduce workload in exercise simply because they became pregnant. It is good practice to self-assess the load. It is optimal when during the whole series of exercises the woman maintains a free breathing rhythm and during the last repetition in the working muscle group she feels a noticeable tension and fatigue. Exhalation is performed during muscle work/muscle contraction, and inhalation while muscles are relaxed. Until the determination of the impact of Valsalva maneuver (increased exhalation against closed airways) on the course of pregnancy, it is rational to limit it in both exercises and daily activities.

In 60-min sessions, after 30 min of aerobic exercise, the organization of 8–9 exercises strengthening groups in two sets of 12–16 repetitions fits very well. This is of course only a suggestion. Depending on the training goals and fitness of the woman, exercises can be performed at endurance and strength intervals, in the form of circuit training and others. There is no scientific basis to exclude specific training methods or techniques due to pregnancy. Special attention should be paid to the technique of exercise, including body posture, in order not to increase lordosis in the lumbar region. There are typical rules for teaching new exercises, from known to unknown and from simple to complex. There is no scientific basis to exclude technically difficult exercises from a training session if a woman is able to do them properly and does not experience discomfort in them.

It should be taken into account that in everyday activities the back muscles of a pregnant woman do intensive work to balance the abdominal mass [68]. Therefore, in the last weeks of pregnancy, it may be necessary to exclude or limit the range of the exercises for the spinal erectors. Leg muscles also work hard in locomotion. One must keep this in mind when planning an exercise program. We presented examples of resistance exercises in Appendix 4. Because abdominal and pelvic floor muscles are of particular importance for the course of pregnancy, we described them separately.

9.3.3.2 Pilates Mat

Pilates is an exercise technique which focuses on body-mind balance, muscle strengthening, flexibility, muscle control, posture, breathing, and the power center of stabilization [69]. The equipment required for a Pilates class may vary from a single mat and small and big balls to specific machines called "reformer." The exercises are usually done in a specific order, one right after another, starting on a standing position, to other positions such as knees and hands, seating, and laying positions. The movements have names, like the "100," the "swan," the "crisscross," the "elephant," etc. Regarding intensity, Pilates can be very easy or very demanding, depending on the difficulty of the movements. The movements are usually performed in slow motion requiring precision and control to enhance muscle resistance and flexibility. This resistance and neuromotor exercise is a great addition to an aerobic program. Usually, the exercise specialist shows the exercises putting a strong emphasis on technique and breathing. Due to precision and control of movements, the supervision of movements by a qualified exercise professional is helpful even with experienced participants.

It is a safe and effective exercise to start or continue during pregnancy, as long as intensity (e.g., the amplitude of movements, repetitions, sustained time and position, lying positions) and complexity (muscles involved, resistance and flexibility required) can be adjusted to fitness and skill level as pregnancy progresses. However, pregnant women may need to avoid certain Pilates moves if they do not feel comfortable (i.e., head down, lying backward, etc.). Usually, participants are in a gym, in front of a mirror. However, a mat can be used at home to follow video classes if the participant is experienced and is able to use the appropriate technique. If the mat is used outdoors, precautions should be taken regarding the type of floor: it must be flat and not slippery. Although these exercises could have interesting intersections with pregnancy musculoskeletal adaptations, there is insufficient data in the literature to assess the effect on pregnant women.

A Pilates class typically lasts 45–60 min. However, short periods of 10–15 min of Pilates exercises can be included in a complete prenatal exercise session. A recent back or knee injury may be contraindications for Pilates exercise program. However, Pilates would be a good choice if the pregnant woman has low back pain.

9.3.3.3 Abdominal Exercises

Due to, inter alia, the growing uterus, changes in the curvature of the spine, and the effect of pregnancy hormones, abdominal muscles are heavily stretched [70]. As a result, almost 70% of all pregnant women experience lower back pain [71]. To minimize this risk, ACOG [2] recommends the strengthening of abdominal and back muscles. Strong abdominal muscles also play an important role in the pushing mechanism necessary during natural delivery. Although this still requires scientific evidence support, abdominal muscles maintained in good condition throughout pregnancy are more likely to recover quickly after delivery.

Despite the many obvious advantages of abdominal muscle exercises, this is a controversial topic. The reason for this phenomenon may be opinions appearing in the society that the abdominal muscle exercises during pregnancy can lead to miscarriage or a more painful childbirth [72]. Even a significant part of exercise professionals are convinced that women should not exercise abdominal muscles in pregnancy [73]. It should be emphasized that so far no studies have been published that could confirm the allegedly negative impact of abdominal muscle exercises on the course of pregnancy, childbirth, or development of a child.

The most important principles recommended for the implementation of abdominal muscle exercises during pregnancy:

1. When selecting the exercises for abdominal muscles, the stage of pregnancy should be taken into account. A large uterus will certainly hinder the abdominal muscle shortening during contraction. A growing fetus takes up space in the abdominal cavity. Therefore, in the high pregnancy, it is rational to limit the movements which additionally will reduce it, like in crunches. Nevertheless, it is the uncomfortable feeling of a woman in a given exercise that should be an indicator for its elimination or modification. Creating the so-called list of abdominal muscle exercises forbidden in pregnancy seems to have no scientific justification.
2. During exercise, one must remember to breathe properly; exhalation should be performed with muscle contraction and inhalation when relaxing.
3. After a series of exercises to strengthen the abdominal muscles, it is recommended to relax them by conscious abdominal breathing (the abdomen protrudes as the diaphragm is lowered). The ability to quickly move from the state of tension to the relaxation of the abdominal muscles seems to be useful during delivery.
4. Due to the increase in lumbar lordosis during pregnancy, special attention should be paid to lay down on the back with the legs straightened as a starting position for exercise, e.g., in raising straight legs. In such exercises, the lumbar spine should be as far as possible on the ground by shortening the abdominal muscles throughout the entire period of motion.
5. The supine position should be individually considered for a woman. Jeffreys et al. [74] observed that in women after 28 weeks of gestation, performing 60- to 90-s periods of abdominal crunches and leg exercise at moderate/high intensity (Borg's rating of perceived exertion 14 ± 1), uterine blood flow decreased twice as much as in women resting in the supine position. However there is still no scientific evidence that such temporary decrease in uterine blood flow has any negative influence on the course of pregnancy, fetus development, and its well-being.
6. Exercises from the front or side plank positions are recommended mainly for advanced women.
7. It is recommended to activate pelvic floor muscles in abdominal muscle exercises. This may prevent unwanted urine leakage during increasing intra-abdominal pressure.
8. Owing to the permanent stretching of the abdominal muscles by the growing uterus, it seems justified to limit the exercises stretching this muscle group after the abdominal bulge. An alternative in this regard is to perform abdominal breathing.
9. Attention should be paid to the occurrence of prodromal uterine contractions (Braxton-Hicks contractions). Although they are not dangerous, if they are

intense, they can cause tension in the abdominal area [75]. The Braxton-Hicks contractions may make women anxious and discourage them from being physically active [5]. Although it has not been proven scientifically, when prodromal uterine contractions strongly interfere with the pregnant woman, it is rational on the given day to limit the contraction stimuli by giving up exercises strengthening the abdominal muscles and replacing them with breathing and relaxing exercises.

10. Bearing in mind the fact that in some societies strengthening abdominal muscle exercises are considered dangerous [73], exercise professionals and obstetrics care providers should pay special attention to educating women in this area.

Both before and during the exercise program, pregnant women should control the condition of their abdomen in terms of diastasis recti abdominis (DRA). It is a separation of the two rectus abdominis muscles along the linea alba, which appears in 66–100% of women in the third trimester [70]. The etiology of this condition is not clear. In the light of the available scientific evidence, there are no grounds to argue that intense exercises to strengthen abdominal muscles before conception or during pregnancy increase the risk of abdominal muscle separation. On the other hand, no reliable data are available, confirming whether diastasis recti abdominis can be prevented or treated with abdominal or other exercises during pregnancy.

Diastasis recti abdominis test should be performed as follows: lying back, legs bent, and head and shoulder blades raised (as in abdominal crunch). One should check along the linea alba if there is no space between the abdominal muscles. The test is positive (Diastasis recti abdominis is diagnosed) with palpation of ≥ 2 fingerbreadths from 4.5 cm above to 4.5 cm below the umbilicus [76, 77]. A woman with a positive test requires consultation with a doctor or physiotherapist. To date, there is no consensus on whether to measure the distance along the linea alba or on the cut point for diagnosing the condition [70].

Before the results of high-quality research are available, for abdominal muscle exercises in pregnant women diagnosed with abdominal muscle separation, it is worth introducing rules based on movement biomechanics analysis:

1. Limit or completely eliminate exercise positions, in which the trunk is parallel to the floor and the uterus rests on the front wall of the abdomen as in a hammock, for example, front plank, supported kneeling.
2. Limit the range of trunk rotation and lateral flexion not to intensify mechanically the separation of the abdominal muscles.
3. Shorten the range of motion or eliminate exercises in which a bulge appears along linea alba.
4. Pay particular attention to exhalation during the abdominal muscle contraction to minimize intra-abdominal pressure.
5. Utilize the work of the hands to mechanically bring the abdominal muscles toward the linea alba (Fig. 9.7), especially in places where their separation has been observed.

Fig. 9.7 Using hands in the abdominal exercises in the prevention of the diastasis recti abdominis

The validity of the above recommendations should be confirmed by experimental research. We presented examples of abdominal exercises, also in the presence of diastasis recti abdominis in Appendix 5. See Chaps. 6 and 10 for further explanation on this topic.

9.3.3.4 Postural Exercises

Proper posture can alleviate many of the muscular and skeletal discomforts, especially back pain [78], improve breathing efficiency [79, 80], as well as improve one's self-confidence [80]. In pregnancy postural exercises are particularly important due to various biomechanical changes in the musculoskeletal system [81]. The growing uterus and breasts intensify women's tendency to protrude the belly and pull the shoulders forward.

Postural exercises should be a regular element of prenatal classes. It is recommended to perform them at the beginning of each exercise session and to repeat them a few times throughout the session, especially before those exercises, in which incorrect technique could consolidate postural defects. Postural exercises can be performed in standing, sitting, kneeling, and lying positions. In addition to the immediate effect of the posture correction, they should increase the body awareness and promote a habit of proper body alignment in everyday activities. A mirror is a good tool for giving feedback for postural exercises.

The correct posture in the standing position should be performed as follows:

- Feet slightly apart, the body weight rests in the middle of the feet, avoiding excessive heel load.
- Legs straightened in the hip and knee joints (avoiding hyperextension), knees are over the feet, hips over the knees.
- The pelvis is set in a neutral position, avoiding excessive tilts backward or forward.
- Arms straight down along the body.
- Abdominal muscles activated.
- Chest "open," but not too far forward.
- Shoulder blades pulled back, without causing nonphysiological backward movement of the shoulders.
- Shoulders lowered, maintained at the same level.
- Spine elongated.
- The head in the extension of the torso, not tilted back, the chin should not be extended forward.
- The back of the head, shoulder blades, and buttocks should be in one plane.

We presented examples of flexibility exercises for pregnant women in Appendix 6.

9.3.3.5 Neuromotor Exercise

A special place should be occupied by neuromotor exercises, e.g., balance and coordination exercises [32] (Fig. 9.8). Although the center of gravity changes during pregnancy, women who continue previously practiced form of activity are able to perform exercises requiring a high level of balance. Coordination exercises are typically included, e.g., in a step aerobics or dance session. Balance exercises can be included as a part of other sessions, e.g., Pilates session, aerobics, and resistance training session.

The balance-enhancing activities are those, which include:

- Narrowing the base of support
- Perturbation of the ground support
- Decrease in proprioceptive sensation
- Diminished or misleading visual inputs
- Disturbed vestibular system input
- Increased compliance of the support surface
- Movement of the center of mass of the body away from the vertical

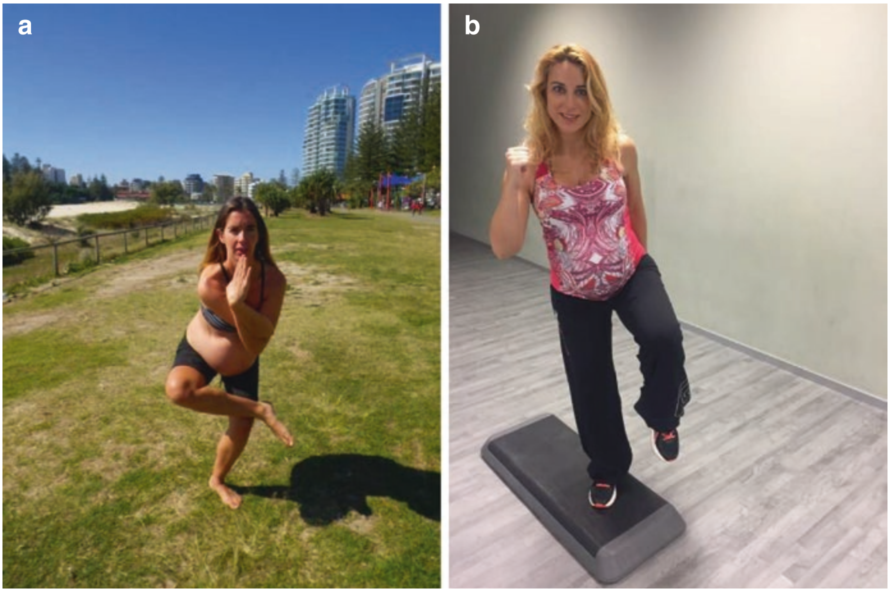


Fig. 9.8 Exercises requiring balance (**a**) and coordination (**b**) skills are examples of neuromotor exercises

General techniques for neuromotor exercise can include the following elements:

- Narrowing the base of support for the body
- Displacing the center of mass to the limits of tolerance
- Removing or minimizing contributions of visual, vestibular, and proprioceptive pathways to balance

The validity of the above recommendations should be confirmed by experimental research. We presented examples of balance exercises for pregnant women in Appendix 7.

9.3.4 Flexibility Exercises

Flexibility (stretching) exercises should be part of a comprehensive exercise program, inter alia to reduce muscle tension and soreness, increase relaxation, improve range and ease of moves, and prevent injury [32, 82]. There are negligible scientific data on changes in the level of flexibility during pregnancy. Price et al. [51] observed that the sit-and-reach flexibility scores did not vary significantly between exercising pregnant women and sedentary control group. Their intervention circuit sessions ended with 5 min of hamstring, quadriceps, and calf stretching. No study participants reported injuries related to the exercise regimen. In studies analyzing various aspects of prenatal exercise programs including stretching exercises [37, 38, 40, 41], also no negative impact on musculoskeletal system was indicated. Therefore, the opinion that due to the action of pregnancy hormones that increase tissue relaxation, prenatal stretching exercises can be dangerous, leading to “excessive stretching of the muscles,” is unfounded. With the current state of knowledge, the selection and execution of stretching exercises in pregnancy should be guided by the same principles as for the general adult population. It should only be remembered that the large belly will limit the trunk flexion. Stretching exercises should be performed in positions recommended for pregnant women (see Appendix 1). Due to the large weight load in standing positions, it is advisable to perform stretching exercises in the sitting, kneeling, and lying positions.

An interesting research issue is the use of abdominal stretching exercises during pregnancy. As the fetus grows, the abdominal muscles remain in permanent stretching until the day of delivery. The negative effect of this may be the separation of the abdominal muscles (see Chap. 6). Therefore, approaching it logically, one should concentrate on the stimuli compensating the effect of pregnancy development, i.e., limiting the stretching of the abdominal muscles by the proper selection of position and intensification of exercises that relax this muscle group, e.g., by abdominal breathing. Nevertheless, we have no evidence that stretching exercises for abdominal muscles during pregnancy may intensify or reduce the feeling of unpleasant tightness or expansion of the abdomen or predispose to the diastasis recti abdominis.

Stretching exercises are a good tool to regulate the intensity of activities. Their performance in the main part immediately after exercises strengthening a given muscle group effectively reduces the intensity and extends the break time. Therefore, this solution is proposed for beginners with a lower level of performance. In turn, for advanced women, it will be more reasonable to perform strengthening exercises directly after each other and to leave stretching for the final part. Before performing a stretching exercise, one must remember to relax the whole body, especially the muscle group being stretched, and to breathe deeply and calmly [32].

During pregnancy, it is worth paying special attention to stretching:

1. The anterior (hip flexors) and medial (hip adductors) compartments of thigh muscles in preparation for a natural birth
2. The hamstrings and hip abductors, in the prevention of the piriformis syndrome (pain and/or numbness in the area of the buttock radiating down the buttock and the leg, resulting from compression of the sciatic nerve around the piriformis muscle)
3. The back muscles to lower their excessive tension and soreness caused by balancing the posture with the growing belly
4. The muscles of the chest and the anterior shoulder girdle that have a tendency to shorten during pregnancy

We presented examples of flexibility exercises for pregnant women in Appendix 8.

9.3.5 Pelvic Floor Muscle Exercises

Pelvic floor muscles stabilize the body, support pelvic organs, and determine the quality of sexual life [83, 84]. Systematic reviews have shown that pelvic floor exercises should be recommended for prevention and treatment of urinary incontinence [85, 86], a chronic health complaint occurring in 14–69% of European women [87]. Pregnancy and vaginal birth are causal factors for pelvic floor disorders [88], which relate to symptoms of urinary or anal incontinence, pelvic organ prolapse, sensory or emptying abnormalities of the lower urinary tract, defecation dysfunction, sexual dysfunction, and pelvic floor pain syndromes. Although adults of all ages should exercise pelvic floor muscles, in pregnancy it is particularly important.

Correct contraction of pelvic floor muscles in exercise training is described as contracting and inward lifting of the muscles around pelvic openings while keeping outer abdominal, gluteal, and hip adductor muscles relaxed [89–91]. In recent studies the proportion of women who were unable to correctly activate the pelvic floor on initial exam varied from 14 to 53% [92–94]. Only two-thirds are confident that they were doing pelvic floor exercises correctly [95], while at least one in five may have had misplaced in their confidence [96]. That is why good instructions how to exercise pelvic floor muscles are essential [94, 96, 97]. Some authors recommend biofeedback sessions to learn the technique of contracting pelvic floor muscles [98, 99].

Various pelvic floor muscle exercises [100] have been published, but none of them has been considered a gold standard. However, in the implementation of pelvic floor muscle exercises, it is worth taking into account the following principles:

1. The first stage is the location of the pelvic floor muscles. A woman must be convinced that she is operating the right muscles. A typical mistake is to activate synergistic muscles (e.g., abdomen, buttocks, and thighs) or pushing (strain) of the pelvic floor muscles by increasing intra-abdominal pressure, often while inhaling [101]. Examples of exercises on the location of pelvic floor muscles and the ability to isolate them in a conscious contracting are presented in Appendix 9.
2. In order to properly locate it, it is worth using specialist equipment providing biofeedback and visualization (e.g., imagining the feeling of tightening a vaginal tampon or a small balloon). The so-called "pee-stop" exercise is controversial. Undoubtedly, it gives excellent feedback on both the location of the pelvic floor muscles and on their strength (e.g., the urinary stream can be weakened or completely stopped). On the other hand, there are views that such an action may cause a urinary retreat from the lower urinary tract contributing to infections and it may interfere with the micturition mechanism. To date, there are no studies confirming the harmfulness of this exercise in healthy women. Until reliable data are available on the subject, it seems rational to use "pee-stop" exercise sporadically as a kind of self-assessment but not as a basis for regular training.
3. A complex training for pelvic floor muscles should be focused both on their contraction and relaxation [89]. Contractions are to improve, among others,

supporting functions for pelvic organs and continence. Relaxing exercises are helpful for the correct process of micturition, defecation, and delivery.

4. In the pelvic floor muscle exercises, the proper breathing technique should be maintained—the same as in the case of exercises of other muscle groups: exhalation is performed during contraction and inhalation during relaxation [32].
5. One should start from simple exercises (e.g., short contractions, the so-called quick flicks), gradually moving to more complex tasks (e.g., several-second holds at different rates) [102].
6. It is important to have a comprehensive impact on the motor skills of pelvic floor muscles, improving their speed, strength, endurance, and muscular coordination and engaging both fast and slow twitch muscle fibers [103].
7. Exercises should start with an isolated form, i.e., when the pelvic floor is taut the rest of the body should be relaxed. According to Bø and Morkved [101], the simultaneous activation of large synergistic muscles may mask the awareness and strength of pelvic floor muscle contraction.
8. Due to the low intensity of the isolated pelvic floor muscle exercises, they should be planned for the end of the exercise sessions.
9. Gradually, it is useful to incorporate pelvic floor muscle exercises in exercises that condition other muscle groups, e.g., abdomen, buttocks, and thighs. Thanks to this, in one exercise session, one can get more training stimuli for pelvic floor muscles [101, 103].
10. Conscious activation of pelvic floor in marching, running, or aerobics movements is a more difficult stage but may be helpful to prevent urine leakage during these activities.
11. An important task is to implement a conscious habit of contracting the pelvic floor muscles in daily activities, against the increase of the intra-abdominal pressure, e.g., before lifting heavy objects, before coughing, laughing, sneezing, etc. [102].

See Chaps. 6 and 10 for further explanation on this topic.

9.3.6 Cooldown

The cooldown should be a part of every exercise session [34], also for pregnant women. Its main task is to calm the body systems after intense physical effort. It's good when after this part the respiratory rhythm and the heart rate return close to pre-exercise values [32]. In the cooldown, the woman should assess her well-being and the intensity and difficulty of the exercises. If they were conducted by an exercise professional, there should be a summary and motivation for the next exercise sessions. It is also time to ask questions and provide professional information to build women's beliefs about the safety and benefits of prenatal exercise. In the cooldown it is recommended to perform stretching exercises, according to the exercises carried out in the main part. It is also a great time to do exercises to prepare women for natural labor and delivery.

Natural birth, i.e., a birth without any medical intervention, is the best end of the pregnancy for the mother and the baby, both from the psychophysical and the social point of view [104]. Methods of childbirth other than physiological should be used only when justified [105]. Preparation for natural birth should be one of the main goals of the future mothers, their families, and the healthcare system during antenatal education course [29]. Regular participation in the prenatal exercise program can significantly support this goal.

The onset and course of delivery are significantly influenced by the interaction of hormones, including an appropriate production of oxytocin. Its secretion can be affected by too high catecholamine levels, specific to the state of threat [104]. Russell et al. [106] observed among strenuous exercising athletes that catecholamines elevated by exercise may interact with female hormones. Magann et al. [107] found that heavy physical exercise in military training during pregnancy significantly increased the risk of induction or augmentation of labor with oxytocin and longer first stages of labor resulting in total longer labors. It is likely that the direction of women's mind to the aggressive, non-maternity tasks reduced their psychological and physical readiness for the birth, manifested in disorders in its initiation and progression. Research by Magann et al. [107] may be evidence that not only the quantity but also the quality of prenatal exercise is important in order to get their positive impact on pregnancy and childbirth.

Both for hormonal balance and for mental and physical preparation of women for childbirth and motherhood, there are proposed, inter alia, birth positions, breathing exercises, relaxation, and visualization [25–29]. The cooldown part usually takes 5–10 min, but when planning visualization, it is worth prolonging it for an additional 15–20 min.

9.3.6.1 Birth Positions

According to the global trend of promoting natural birth, it is important to prepare a woman for the so-called use of birth positions. There is not one universal, most convenient birth position. The choice of position by the woman, the way of breathing, or movement should be completely intuitive and may change with the progress of labor [108, 109].

Many women thinking about childbirth have a picture of childbearing in the so-called classic position or lithotomy position, i.e., lying on your back with legs gaping, raised up. However, this position is the least favorable from the point of view of labor physiology and biomechanics of movement, because a woman has to push the child against the force of gravity [108, 109]. In vertical (or upright) positions, the force of gravity supports the maternal effort of pushing and facilitates proper descent of the child into the birth canal and cervical dilation. Thanks to this, the time of delivery may be shortened, and the necessity of using labor augmentation is reduced. In turn, the kneeling positions with the flexed trunk and the lying positions reduce the pressure of fetal head on the perineum area. They are particularly helpful in the first stage of delivery, when the laboring woman shouldn't push because the cervix is incompletely opened, and also in long deliveries when the woman lacks the strength to maintain her vertical position. The use of different birth positions decreases perineal injury. In addition, it positively affects the psyche of the woman giving birth: it reduces the sense of anxiety, encourages active participation in childbirth, and increases the satisfaction with its course.

To fully take advantage of the various birth positions, physical preparation for them is necessary. Some require strengthening or stretching of specific muscle parts. When planning prenatal physical activity, birth positions should be treated as one of the functional exercises and performed in each session, in accordance with generally accepted principles of teaching movement and training progression. The educational aspect is also important here. It is likely that a woman who during pregnancy has learned various birth positions, both theoretically and practically, will try to use them during the delivery. The study by Miquelutti et al. [28] showed that women who during antenatal education received instructions to adopt the vertical positions, comparing to controls, spent significantly more time in the upright positions and considered them more comfortable than the horizontal positions.

Recommended principles of performing birth positions in prenatal classes are as follows:

1. Exercises of birth positions can be performed as cooldown exercises at the end of the training session. They can also be included as relaxation or stretching exercises between a series of exercises strengthening various muscle groups.
2. In all birth positions, the coccyx bone should be maximally bent backward and pelvis tilted anteriorly to increase pelvic dimensions.
3. The whole body of a woman and in particular the pelvic floor muscles, abdominals, thighs, and buttocks should be maximally relaxed, which is to build the ability to relax during painful contractions.
4. It is good to do breathing exercises in the birth positions, which helps to build the ability to breathe properly during delivery.
5. Birth position exercise may be accompanied by rhythmic pelvis movements to the front and back or up and down, which during the delivery may reduce the pain. This technique is particularly effective when it is combined with a rapid respiratory rhythm (e.g., pant breathing).
6. It is recommended to maintain birth positions by min. 20–30 s to get the right training stimulus (e.g., for muscle stretching).

We presented examples of birth position exercises in Appendix 10.

9.3.6.2 Breathing Exercises

Breathing exercises bring many health benefits, including a reduction in the level of stress [110] and in the muscle fatigue [111] and an improvement in function of the circulatory system [112]. They are particularly recommended for pregnant women as, among others, they may compensate for physiological and biomechanical changes in breathing pattern induced by pregnancy and increase the amount of oxygen transported to the fetus [113]. Owing to breathing exercises, a woman can reduce discomfort associated with a feeling of breathlessness appearing at the beginning of physical exertion. Breathing exercises are particularly important in the second and third trimesters, when the growing womb hinders the lowering of the diaphragm during inhalation.

Breathing exercises are an important element of preparation for delivery [27, 28]. Boaviagem et al. [114] observed that 6-week stress management program including relaxation breathing and progressive muscle relaxation twice a day contributed to the reduction of perceived stress and increased the sense of control in pregnant women. Abdominal breathing or so-called "belly breathing" technique is advocated to improve the excursion of the diaphragm [115]. It may increase the efficiency of child displacement during childbirth. In addition, appropriate breathing techniques help to cope with pain during delivery [116] and protect against perineal damage during labor [117].

Research indicates that the occasional use of breathing exercises does not bring the desired effect. In the study by Bergström et al. [118], four 2-h sessions with training in breathing and relaxation techniques during natural childbirth preparation did not decrease the use of epidural analgesia during labor, nor did it improve the birth experience or affect parental stress in early parenthood in nulliparous women, compared with a standard form of antenatal education. Boaviagem et al. [114] in turn have shown that breathing techniques offered to women during the first period of labor were not effective to control anxiety, pain, fatigue, and maternal satisfaction.

The above studies suggest that in order to achieve the effectiveness of breathing exercises and the possibility of their use during labor, it is necessary to perform them systematically throughout pregnancy. Breathing exercises perfectly blend in prenatal exercises, both in the cooldown part and in breaks between the series of strengthening exercises. The easiest way to do it is in a sitting position, which provides space in the chest and abdominal cavity and facilitates relaxation of the abdominal muscles and observation of their work. One can treat breathing exercises performed in other positions, for example, lying on the back or side, as a functional exercise. In most exercises inhaling is done through the nose and exhaling through mouth and nose. We presented examples of breathing exercises in Appendix 11.

9.3.6.3 Visualization of Pregnancy and Birth

In mental visualization training, one uses imagination to program the mind to perform in particular situation in the best possible manner. Such exercises performed systematically and repeatably lead to the development of neuronal connections between muscles and the central nervous system. Mental visualization training is commonly used in elite sports training and rehabilitation [119]. Visualization is increasingly becoming an important element of preparation for childbirth [29]. The randomized control study by Rakhshani et al. [120] on yoga-based visualization and relaxation in high-risk pregnancy has shown significantly better uteroplacental and fetoplacental blood flow velocity in the yoga group compared to the control group.

During visualization, a woman can imagine the proper development of a child during pregnancy and/or the delivery process. These ideas have a positive effect on the hormonal balance, reduce the level of anxiety, and build a positive attitude to delivery, including faith in their own strength to give birth to a child. Although the impact of visualization has not yet been well researched, certainly exercises of this type are a good form of rest after exercise. Women should take a comfortable position, preferably lying on their side or on the back, if in this position the pressure of the uterus does not cause discomfort. It will be useful to cover the body, due to the significant reduction in body temperature after intense physical exercise in the main part. They can use ready-made materials with a recorded voice or create pictures themselves. It is important that they evoke positive emotions and do not perpetuate fear. Depending on the organizational possibilities, the visualization may last from several to between 10 and 20 min.

9.4 Further Research

Due to the fact that many unjustified ideas limit prenatal physical activity (like the need to wait up to 12–13 weeks of gestation to start exercising, the need to avoid raising hands above shoulder level or abdominal exercises, etc.), it is necessary to conduct research in this area and disseminate the findings. It seems reasonable to classify forms of physical activity, as safe for pregnancy or not, on the basis of multidimensional research analysis, not only on implied opinions. Certainly, there is a lack of scientific data on how strenuous, high impact, and/or technically complex activities can influence the course of pregnancy, labor and delivery, and child development and how one can reduce their potential risks.

Insignificant information is available on flexibility exercises for pregnant women. A particularly interesting issue is whether the stretching exercises of the abdominal muscles predispose pregnant women to the diastasis recti abdominis or reduce its prevalence. Also worth investigating is whether any prenatal exercise program (including or excluding concrete exercises) can have a preventive or therapeutic effect on the separation of the abdominal muscles in pregnancy and postpartum. The validity of the recommendations for DRA prevention presented in this chapter should be confirmed by experimental research, as well. It is also interesting to evaluate the possibility of alleviating other pregnancy and puerperal symptoms and complications through specific exercise programs.

No information is available on neuromotor exercises for pregnant women. A particularly interesting issue is whether balance and coordination exercises included in a prenatal program would be effective in preventing falls.

There is a need for experimental studies confirming the effectiveness of exercises preparing for birth (including various breathing techniques, birth position exercises, relaxation and visualization) in improving the delivery outcomes.

We also notice a heterogeneous way of reporting exercise programs and a lack of information regarding the validity of experimental studies using "prenatal exercise programs" described as a complex intervention in the context of healthcare [121]. A particularly interesting issue is validating such programs before a pilot, feasibility, or a protocol study is performed, since it would be helpful in understanding whether, which, and how the exercise program was effective.

9.5 Conclusion

This chapter addresses the steps for planning, conducting, and monitoring prenatal exercise classes and explains how to select and adapt different forms of exercises to achieve their maximum safety and efficiency. With the current state of knowledge and scientific negation of the existing myths associated with the alleged harmful effects of physical activity on the course of pregnancy, birth, and fetal development, prenatal exercises can be more and more diverse and available to women with different needs.

Appendix 1: Exercise Positions for Pregnant Women

1. Standing position (Fig. 9.9):

   Execution: Feet apart to the width of the hips, buttocks slightly contracted, abdominal muscles activated (shortened), pelvis in neutral position, relaxed knees, straight back, shoulders lowered and retracted, head in the spine extension. The modification is standing upright with various foot settings (e.g., parallel, outside).

Fig. 9.9 Standing position

Recommendations: The best position for body posture correction. Half-squats, squats, and lunges are performed from this position. Exercises for other muscle groups with equipment (e.g., dumbbells) or without may be performed. Standing position should be used in such activities, where it is impossible or contraindicated to sit or lie down (e.g., in outdoor exercises or directly after aerobics classes when the heart rate is still high).

Contraindications and remarks: In some guidelines there is the recommendation to avoid motionless standing [122]. Carvalho et al. [123] noted that the **standing** position for a long time worsened low back pain in 27.2% of pregnant women in the third trimester. Although there is no clear scientific evidence, it seems that owing to the force of gravity the standing position is inappropriate for women with pubic symphysis [124].

2. Sitting positions (Figs. 9.10 and 9.11):

Execution: Sit-downs can be done in different versions: with straight legs or bent legs and with legs in parallel or in a straddle. The back is straight, the shoulders are lowered and retracted, and the head is in the extension of the spine.

Recommendations: Sit-downs, whether on the floor or in a chair or stability ball, are a very good alternative for women who for some reason should not do exercises in standing positions. Due to the fact that the torso is still upright, they are suitable for the posturing exercises in the upper body. They are a good starting position for exercising arm muscles, torso, and front legs, with equipment (e.g., dumbbells, exercise bands) or without, and for breathing exercises.

Fig. 9.10 Sitting positions on the ground

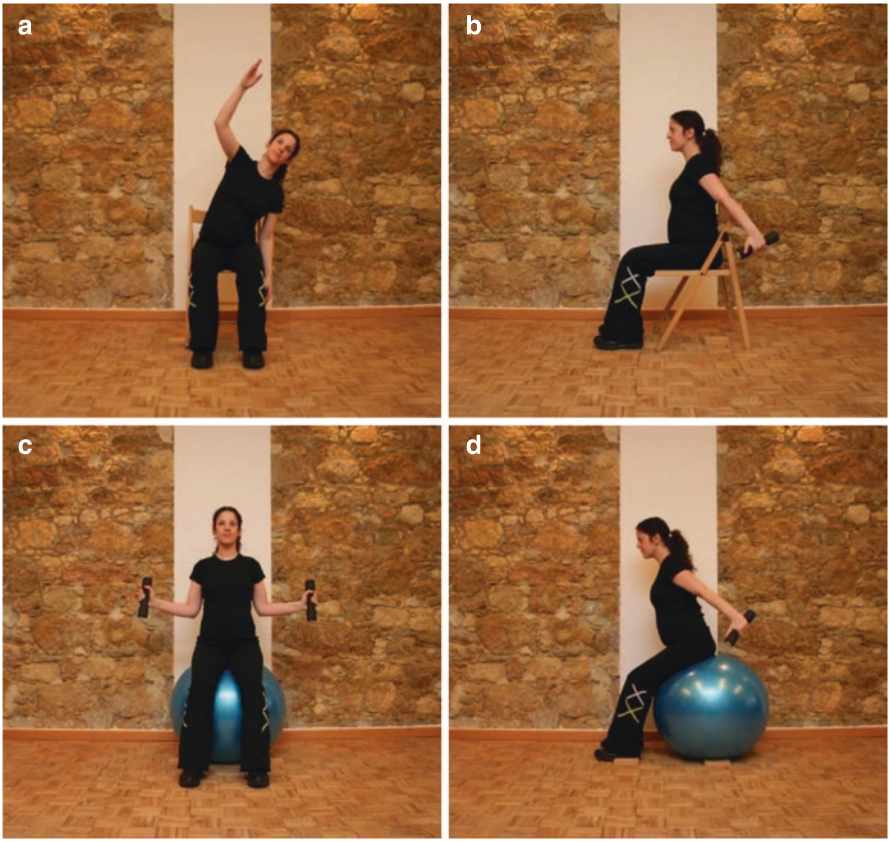


Fig. 9.11 Sitting positions: (**a**) on the chair; (**b**) on the stability ball

3. Vertical kneeling position (Fig. 9.12a):

   Execution: Thighs are parallel, in natural spacing, buttocks slightly contracted, abdominal muscles activated (shortened), pelvis in neutral position, the back straight, shoulders lowered and retracted, and head in spine extension.

   Recommendations: Kneeling is a good alternative for women who for some reason should not do exercises in standing positions. It is a good position for the posturing exercises in the upper body and the starting position for muscle training of the arms and torso with equipment (e.g., dumbbells) or without.

   Contraindications and remarks: Not recommended for people with injuries or painful knees and in the case of worsening back pain in this position.

4. Kneeling sit-down position (Fig. 9.12b):

   Execution: Thighs are parallel, in natural spacing or apart, buttocks are resting on the feet, the back is straight, shoulders are lowered and withdrawn, and the head is in the extension of the spine.

   Recommendations: Kneeling sit-down position is a very good alternative for women who for some reason should not do exercises in standing positions,

Fig. 9.12 Kneeling positions: (**a**) vertical kneeling position; (**b**) kneeling sit-down position; (**c**) supported kneeling position

especially for those with back pain (the hip flexion reduces lumbar lordosis). Due to the fact that the torso is still upright, they are suitable for the posturing exercises in the upper body. They are a good starting position for exercising the muscles of the arms and torso with equipment (e.g., dumbbells) or without and for breathing exercises. The performance of kneeling alone is an exercise stretching the quadriceps muscles, anterior muscle group of the lower leg and foot.

Contraindications and remarks: Not recommended for women with injuries or painful knees. Kneeling sit-downs can be problematic for women with excessively shortened and tight quadriceps and/or flexors of the foot. Change position if leg numbness occurs.

5. Supported kneeling position (so-called on all fours) on forearms or hands (Fig. 9.12c):

   Execution: The weight of the body rests evenly on the knees and hands; thighs and arms are arranged parallel, in natural spacing, hips over the knees, shoulders over the hands, active elbow joints, straight back, back and abdominal muscles activated, and head in the spine extension.

   Recommendations: When the abdominal and back muscles are properly activated, the position of the supported kneeling may be a good position for the exercise of the hamstrings and gluteus muscles, posterior muscles of the trunk, shoulders and neck, and also chest muscles (various versions of push-ups).

   Contraindications and remarks: Although there is no scientific evidence, taking into account the force of gravity, this position may deepen the diastasis recti abdominis (heavy uterus rests on the abdominal muscles as in a hammock, weakened abdominal tissue due to uterine pressure may be further separated). Therefore, the position in the supported kneeling should be used in moderation in asymptomatic women, and in women with confirmed separation of the rectus abdominis muscles, it seems reasonable to completely exclude this position. For a wider use of the supported kneeling for prenatal exercises, one can support the abdomen on a stability ball or big bean bags.

6. Frontal plank position (Fig. 9.13):

   Execution: The weight of the body rests evenly on the feet and hands (or forearms); the arms are parallel, in natural spacing, the shoulders over the hands, active elbow joints, straight back, trunk muscles activated, and head in spine extension.

   Recommendations: A position directed to advanced women who used it before pregnancy. It can be a good position for the exercise of the chest muscles (various versions of push-ups), hamstrings and gluteus muscles, posterior muscles of the trunk, shoulders, and neck.

   Contraindications and remarks: Although there is no scientific evidence, taking into account the force of gravity, this position may deepen the diastasis recti abdominis (heavy uterus rests on the abdominal muscles as in a hammock, weakened abdominal tissue due to uterine pressure may be further separated).

Fig. 9.13 Frontal plank position: (**a**) on the forearms; (**b**) with legs supported on the stability ball

Therefore, the position in the supported kneeling should be used in moderation in asymptomatic women, and in women with confirmed separation of the rectus abdominis muscles, it seems reasonable to completely exclude this position. Increasing weight of the uterus can hinder proper maintenance of the spine and abdominal contraction; therefore it is necessary to systematically evaluate the technique of exercises performed in this position.

7. Supine position (Fig. 9.14):

   Execution: The back of the body lies on the floor, the legs can be straight or bent, and the arms along the body, sideways, or up.

   Recommendations: Excellent relaxation position, relieving the spine, good position for pelvic floor muscle exercises, breathing exercises, and visualization.

   Contraindications and remarks: Majority of guidelines on exercise in pregnancy recommended avoiding or limiting the supine position after the first trimester, or after 16 weeks of gestation, or after the fourth month of gestation (see Chap. 7; [8]). In this position, the heavy uterus presses on the inferior vena cava and decreases the uterine blood flow [74], which may result in discomfort, dizziness, or anxiety in a pregnant woman. The observation, however, shows that not all women experience a worsening of well-being in this position [125]. Therefore, the complete elimination of exercises in supine positions is not justified and should be supported by an individual assessment of the woman's well-being. An alternative solution is to put a pillow or towel underneath one hip [126], change the position for lying on the side, or support the back to get a less horizontal body position (Fig. 9.15).

8. Lying on the side (Fig. 9.16):

Fig. 9.14 Supine positions

Fig. 9.15 Supine position with the support of the back

Fig. 9.16 Lying on the side

Execution: The weight of the body rests on one side, evenly from the legs to the shoulders, the head rests on the lower arm stretched along the torso, the trunk muscles can be relaxed, and for balance you can support the front on the palm of the upper hand and/or bend the legs in the hip joints and/or knee joints (according to the purpose of the exercise being performed).

Recommendations: Perfect relaxation position, relieving the spine, good position for pelvic floor muscle exercises, breathing exercises, and visualization. It is a good alternative to changing positions for women who feel discomfort in lying on their backs. For longer lying, a left-sided position is more desirable [127], facilitating the free flow of venous blood to the heart. A comfortable way to change the side of lying down seems to be going through lying on the back.

Contraindications and remarks: A frequent mistake is supporting the head on the hand of the lower arm bent in the elbow or lifting the torso through support on the forearm of the lower arm. This position unnecessarily affects one side of the neck spine.

9. Prone position (lying on the front):

Due to the growing uterus, lying on the front is a very uncomfortable position for pregnant women, especially in the second and third trimester. Until more information becomes available, ACSM suggests avoiding prone position [128]. So far, however, there is no scientific evidence that the prone position is dangerous to the course of pregnancy.

Recommendations: Before the belly protrudes, a good position for the hamstrings, gluteus muscles, and posterior muscles of the trunk, shoulders, and neck.

Contraindications and remarks: As the pregnancy progresses, a woman may feel both physical and psychological discomfort associated with the pressure on the abdomen.

Appendix 2: Examples of Aerobics Movements for Pregnant Women

1. Step touch—from the basic standing position, step side to side transferring the body weight with the leading leg and putting a foot to the foot (Fig. 9.17). The movement to the side should be extensive to involve the adductors and abductors of the thigh as much as possible. When the body weight is completely trans-

Phase 1 Phase 2

Fig. 9.17 Step touch

ferred, the pelvic floor should be contracted. Modification of the step touch is performed in various spatial variants, e.g., double step touch, L-step, square step (step touch in a square), step touch traveling diagonally (zigzag).

2. Step out (or side to side)—standing with feet apart by a slight bent of both knees (count of 1), the weight of the body is transferred toward the movement being performed, and the other leg rests with the toes on the ground (count of 2). When the body weight is completely transferred, the pelvic floor should be contracted. The step is performed alternately in both directions. The torso is in a straight line, the foot of the stepping leg is fully attached to the ground, while the second emphasizes the movement with the toes only. Both feet are in one line (Fig. 9.18).
3. Heel back. The step is performed as a step-out step, but in the last phase, the second leg is detached from the ground, bent at the knee joint to about 90°, the heel pointing toward the buttock (count of 2). When the body weight is completely transferred, the pelvic floor should be contracted. It is necessary to eliminate the forward movement of the hips in the final stage of the step that increases the lumbar lordosis (Fig. 9.19).
4. Knee up or knee lift. The knee can be raised forward (front knee up – Fig. 9.20a) or sideways (side knee up – Fig. 9.20b). The step is performed as a step-out step, but in the final stage, the second leg is detached from the ground, bent at the knee joint to about 90°, with the knee pointing forward or sideways at the thigh (count of 2). When the weight is completely transferred to the side and the knee is lifted up, the pelvic floor should be stretched. It is necessary to eliminate the forward movement of the hips in the final stage of the step that increases the

Phase 1 Phase 2

Fig. 9.18 Step out

Phase 1 Phase 2

Fig. 9.19 Heel back

Fig. 9.20 Knee up ((**a**) to the front; (**b**) to the side)

lumbar lordosis. When detaching the lower limb from the ground and lifting the knee, focus on maintaining the balance of the body. In women with advanced pregnancy, it may be necessary to shorten the lift of the leg so as not to cause the abdomen to be hit from the bottom by the thigh.

The knee-up step can be made in repetitions, e.g., twice or four times (four knee-up repeats). Done four times it is a step changing the leading leg in choreography.

5. V-step (Fig. 9.21). The step is performed in the shape of the letter V, hence its name. From the basic standing position, step one foot diagonally forward,

Fig. 9.21 V-step

outside (count of 1); then step the second leg diagonally forward, outside to the position of feet apart (count of 2); return of the first leg to the starting position (count of 3); and return of the second leg to the starting position (count of 4).

The forward movement is carried naturally from the heel; the feet are directed toward the outside. When returning to the back, the feet are in a parallel position, the entire sole attached to the ground. When the feet are joining in the final stage of the step, the pelvic floor should be contracted. The center of gravity should be as far as possible at the same level, without raising it or lowering it too much. The step is performed alternately in both directions. When the movement starts from the backward direction, the step is called A step.

6. Mambo forward and backward (Fig. 9.22)—from the basic standing position, moving the leading leg forward with the body weight (count of 1), returning the weight of the body onto the second stationary leg (count of 2), moving the leading leg back together with the weight of the body (count of 3), and returning the weight of the body to the stationary leg (count of 4). The stationary leg is always in contact with the ground and remains in the same place; the feet are arranged in parallel with each other. The pelvic floor muscle contraction should be performed when the body weight is moved back and forth (on the counts of 1 and 3). To make the step from the second leg, it is necessary to change the leading leg.
7. Grapevine (Fig. 9.23). From the basic standing position, step the leading leg sideways with the body weight transfer (count of 1), the crossing of the second leg at the back (count of 2), another step with the leading leg sideways with the

Phase 1 Phase 2

Fig. 9.22 Mambo forward and backward

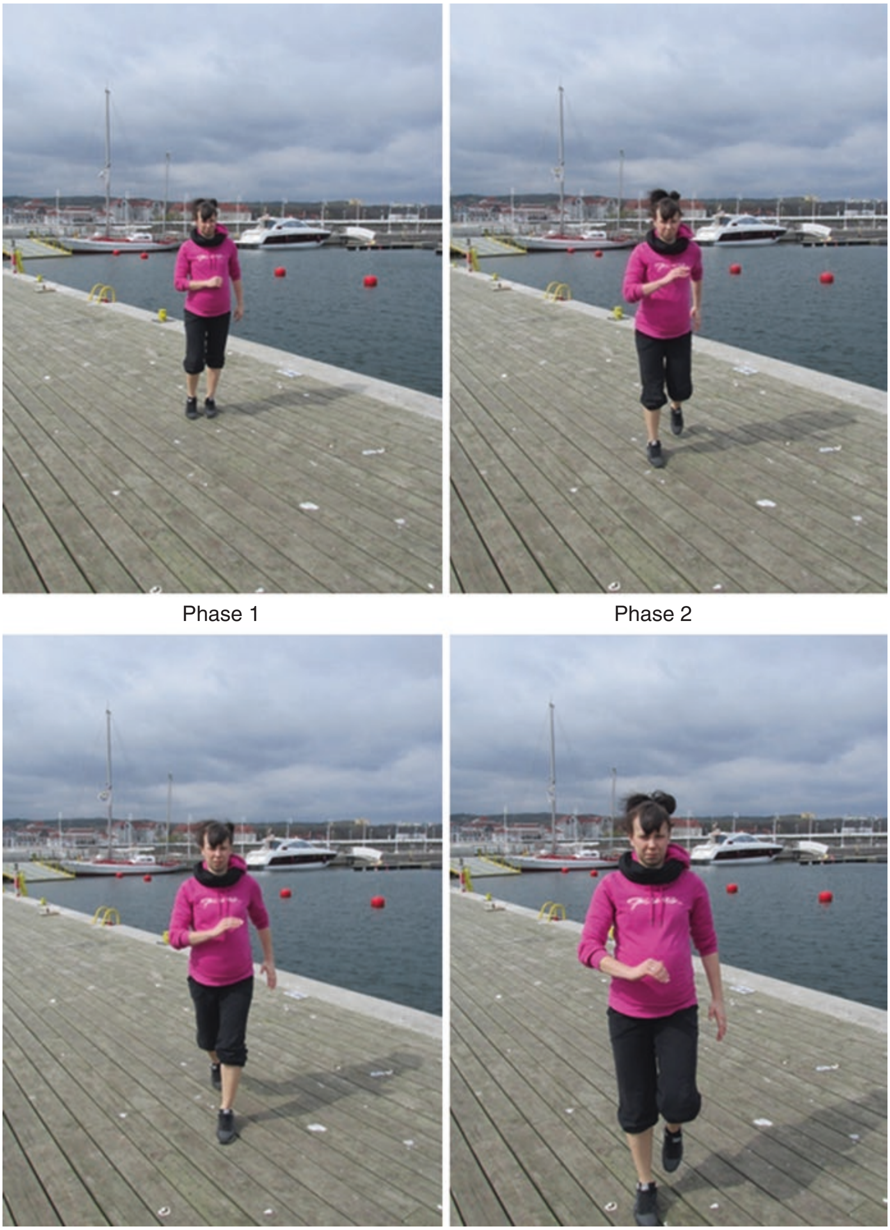
Fig. 9.23 Grapevine

weight transfer (count of 3), and bringing the second leg to the leading one (count of 4). The feet are directed slightly to the outside, all the time in one line. To increase the work of the abductor and adductor muscles, the feet are set far to the sides. The pelvic floor muscle contraction should be performed at the moment of crossing the legs (on the count of 2) and with joining the legs in the final step (on the count of 4). The step is performed alternately in both directions.

8. Marching forward/backward (Fig. 9.24)—is a modification of the march. The march forward is performed on 1, 2, 3, attaching legs, the so-called tap on 4 (can be made with knee up or a kick). Return to the starting position by moving backward to 1, 2, 3, attaching legs to 4. Both legs should be loaded evenly. The pelvic floor muscle contraction should be performed at the moment of performing the tap (at count of 4).

   In order to increase the intensity of exercises, it is possible to perform high-impact movements. Adding jumps and hops most often takes place in the final phase of the exercise, e.g., in step touch at the moment of joining the legs (on the count of 2, Fig. 9.25). For the prevention of urinary incontinence, the woman should be advised to maintain the pelvic floor muscle contraction when jumping, and the intra-abdominal pressure is at its greatest. It is easier to maintain the pelvic floor muscle activation and the continence in movements where the thighs are together. It is likely that urine leakage may occur in movements where thighs are apart at an increase in intra-abdominal pressure, e.g., in jumping jacks. Although there is a lack of scientific research on the relationship of the frequency and intensity of stress urinary incontinence in high-impact aerobics in pregnant women, it is common sense not to recommend high-impact aerobics for those who already experience this discomfort.

9. Examples of combinations:
   (a) Step touch right (2 beats) + step touch left (2 beats) × 8 times [32 beats]
   (b) Double step touch right (4 beats) + double step touch left (4 beats) × 4 times [32 beats]
   (c) Repeat sequence (a) [32 beats]
   (d) Repeat sequence (b) [32 beats]
   (e) Step touch right (2 beats) + step touch left (2 beats) × 8 times [32 beats]
   (f) Grapevine right (4 beats) + grapevine left (4 beats) × 4 times [32 beats]
   (g) Repeat sequence (e) [32 beats]
   (h) Repeat sequence (f) [32 beats]
   (i) Grapevine right (4 beats) + 3 step touch left and right (12 beat) [16 beats]
   (j) Grapevine left (4 beats) + 3 step touch right and left (12 beat) [16 beats]
   (k) Repeat sequence (i) and (j) [32 beats]
   (l) Repeat sequence (i) and (j) [32 beats]
   (m) Repeat sequence (i) and (j) [32 beats]
   (n) Grapevine right (4 beats) + step touch left and right (4 beats) + 2 V step left (8 beats) [16 beats]
   (o) Grapevine left (4 beats) + step touch right and left (4 beats) + 2 V step right (8 beats) [16 beats]
   (p) Repeat sequence (n) and (o) [32 beats]



Phase 1 Phase 2

Phase 3 Phase 4

Fig. 9.24 Marching forward/backward

Fig. 9.25 Adding high-impact elements to the aerobics movements

(q) Repeat sequence (n) and (o) [32 beats]
(r) Repeat sequence (n) and (o) [32 beats]
(s) Progression: replace 2 V step for 2 mambo (or 1 mambo +1 mambo with pivot)
(t) Progression: replace 2 V step for 3 steps forward +1 knee lift +3 steps backward +1 leg curl
(u) Intensity: adding jumps and hops, adding arm moves, increasing cadence

Appendix 3: Examples of Basic Step Aerobics Exercises for Pregnant Women

Technique considerations: Head up, shoulders down and back, chest up, abdominals lightly contracted, and buttocks gently tucked under the hips. Knees and back should never hyperextend at any time. When stepping up the body should lean from the ankles. The entire sole of the foot should contact the bench, stepping softly and quietly to avoid unnecessary high impacts. When hopping or jumping, softly contact the bench or the floor. The heel should not land over the edge of the bench to avoid Achilles tendon injury. When “touching” the bench, the toes should be used. During knee lift, leg curl, and leg abduction, avoid hyperextending the other knee and the back. When stepping down, the step should be close to the bench (no more than one shoe length away), and the heel should contact the floor. Keep a comfortable distance between the body and the bench (neither too close nor too far).

1. March: Walk/steps in the same place.
2. Basic step: Moves up and down facing the step (Fig. 9.26).
3. Step Touch: Step from side to side, on the step (Fig. 9.27).
4. Step Knee: Step from side to side, lifting your knee, each side on the step (Fig. 9.28).
5. Leg Curl: Step from side to side, kicking your heel back, each side on the step (Fig. 9.29).
6. V Step: Move forward by stepping out wide in front of you with one leg at a time. Then step backward with one leg at a time closing the distance between your feet. Imagine you’re making a V shape on the floor with your steps (Fig. 9.30).
7. Tap: Tap one foot up on the step and then the other foot (Fig. 9.31).
8. Mambo: The mambo involves stepping forward the step and then backward in the floor (or in the bench), repeatedly with the same foot while shifting the weight between the supporting, static foot and the moving foot (Fig. 9.32).

Fig. 9.26 Basic step

Fig. 9.27 Step touch with step bench

Fig. 9.28 Step knee

9. Examples of combinations:
   (a) Front tap right and left (4 beats) × 8 times [32 beats]
   (b) Cross tap right and left (4 beats) × 8 times [32 beats]
   (c) Repeat sequence (a) [32 beats]
   (d) Repeat sequence (b) [32 beats]

Fig. 9.29 Leg curl

Fig. 9.30 V step

Fig. 9.31 Tap

Fig. 9.32 Mambo

(e) Right step up and touch (4 beats) + left step up and touch (4 beats) × 4 times [32 beats]
(f) Repeat sequence (e) [32 beats]
(g) Right step up and knee lift (4 beats) + left step up and knee lift (4 beats) × 4 times [32 beats]
(h) Repeat sequence (g) [32 beats]
(i) Right step up and leg curl (4 beats) + left step up and leg curl (4 beats) × 4 times [32 beats]
(j) Repeat sequence (i) [32 beats]
(k) Right step up and knee hop (4 beats) + left step up and knee hop (4 beats) × 4 times [32 beats]
(l) Repeat sequence (k) [32 beats]
(m) Knee repeater right (8 beats) + knee repeater left (8 beats) × 2 times [32 beats]
(n) Repeat sequence (m) [32 beats]
(o) Repeat sequence (m) [32 beats]
(p) Repeat sequence (m) [32 beats]
(q) Knee repeater right (8 beats) + 2 basic steps left (8 beats) + knee repeater left (8 beats) + 2 basic steps right (8 beats) [32 beats]
(r) Repeat sequence (q) [32 beats]
(s) Knee repeater right (8 beats) + 6 basic steps left (24 beats) [32 beats]
(t) Knee repeater left (8 beats) + 6 basic steps right (24 beats) [32 beats]
(u) Knee repeater right (8 beats) + 2 basic steps left (8 beats) + 2 basic steps left over the top (8 beats) + 2 basic steps left (8 beats) [32 beats]
(v) Knee repeater left (8 beats) + 2 basic steps right (8 beats) + 2 basic steps right over the top (8 beats) + 2 basic steps right (8 beats) [32 beats]

(w) Repeat sequence (u) [32 beats]
(x) Repeat sequence (v) [32 beats]
(y) Knee repeater right (8 beats) + 2 step up knee lift left/right (8 beats) + 2 basic steps left over the top (8 beats) + 2 mambo left (8 beats) [32 beats]
(z) Knee repeater left (8 beats) + 2 step up knee lift right/left (8 beats) + 2 basic steps right over the top (8 beats) + 2 mambo right (8 beats) [32 beats]
(aa) Repeat sequence (y) [32 beats]
(bb) Repeat sequence (z) [32 beats]
(cc) Progression: replace 4 step up knee lift side-to-side for 4 step up knee lift “around the world”
(dd) Progression: replace 2 mambo for 1 mambo +1 mambo with pivot
(ee) Progression: replace knee repeater for L step forward-side +L step side-backward
(ff) Progression/intensity: replace step up knee lift for step knee hop
(gg) Intensity: adding jumps and hops, adding arm moves, increasing cadence, using different approaches to the bench

Appendix 4: Examples of Resistance Exercises for Pregnant Women

1. Squats—from a standing position with feet apart to the width of the hips, bend the legs in the ankles, knees, and hips lowering the center of gravity, and then return to the starting position. Throughout the exercise the soles fully touch the ground; the weight of the body rests more on the heels and the outsides of the feet. The torso remains in the neutral position, the abdominal muscles are activated, and the head is in the extension of the torso. The arms are moving forward for the balance. Returning to the starting position should be done with exhalation and simultaneous contraction of the pelvic floor muscles.

   Working muscles: muscles of the lower extremities.

   Difficulty options: the intensity of the exercise can be adjusted by the range of movement; the simplest version is a quarter-squat, intermediate half-squat, and advanced full squat. For a balance exercise, you can add the raising of the bent leg to the front. Squats can be performed with a load, such as dumbbells in the hands or barbells on the shoulders. Arm work can be attached to squats, for example, elbow flexion to activate biceps brachii (Fig. 9.33).
2. So-called sumo squats – squats performed in the straddle, feet directed outward.

   Working muscles: as above and additionally thigh adductor muscles are more engaged.
3. Backward, forward, or sideways lunges – from a standing position, a large step backward, forward, or sideways, lowering the center of gravity, and then return to the starting position. The torso remains in the neutral position, the abdominal muscles are activated, and the head is in the extension of the torso. The arms are

Fig. 9.33 Quarter-squat with elbow flexion

moving forward for the balance. Returning to the starting position should be done with exhalation and simultaneous contraction of the pelvic floor.

Working muscles: in backward and forward lunges mainly flexors and extensors of the lower extremities, in sideways lunges additionally work the hip abductor and adductor muscles.

Difficulty options: the intensity of the exercise can be adjusted by the range of deflection in the joints of the legs, the smaller the deflection the easier the exercise option. For a balance exercise after backward or forward lunges, you can add the raise of the bent leg forward, with sideways lunges—raising a straight leg to the side. Lunges can be done with a load, such as dumbbells in the hands or barbell on the shoulders. Arm exercise can be added to lunges, for example, the raising of arms to the front or side (activation of the shoulder muscles, Fig. 9.34).

Exercises in high positions (various options of squats and lunges) are good functional exercises, preparing the body of a pregnant woman to move with the growing belly. Due to the fact that they engage several large muscle groups, they are more intensive compared to exercises performed in low positions

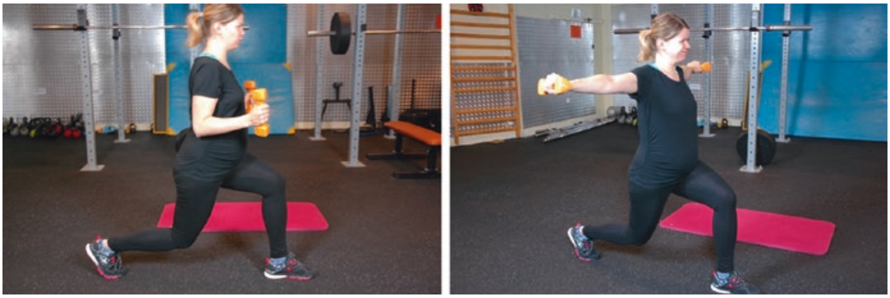


Fig. 9.34 Lunges with different arm moves

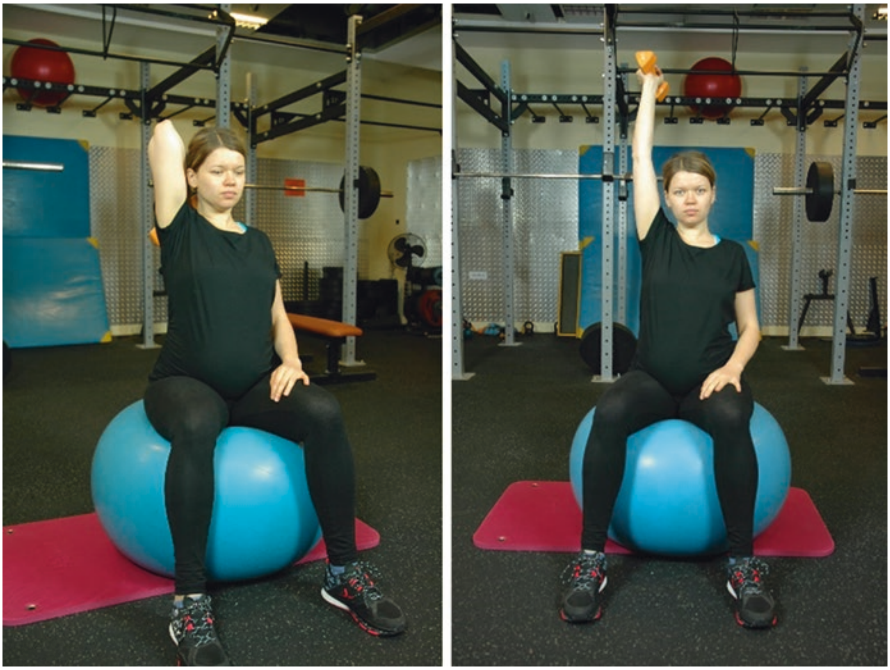


Fig. 9.35 French press

(sitting, kneeling, or lying). Nevertheless, in the case of worsening back pains, it is recommended to replace them with exercises performed while sitting, kneeling, or lying down.

4. French press—from a sitting position with legs resting against the ground for stabilization, perform the elbow extension (Fig. 9.35).

   Main working muscles: triceps brachii.

   Difficulty options: the exercise can be done single-handed or with two-handed weight, e.g., a dumbbell or exercise band.

Starting position Exercise

Fig. 9.36 Modified unilateral behind the neck press

Easy option Advanced option

Fig. 9.37 Pelvic bridging

5. Modified unilateral behind the neck press (Fig. 9.36)—from sitting position on a stability ball, with legs resting against the ground for stabilization, shoulders lowered, arms bent in the elbow joints, straighten arm in the elbow joint upward.

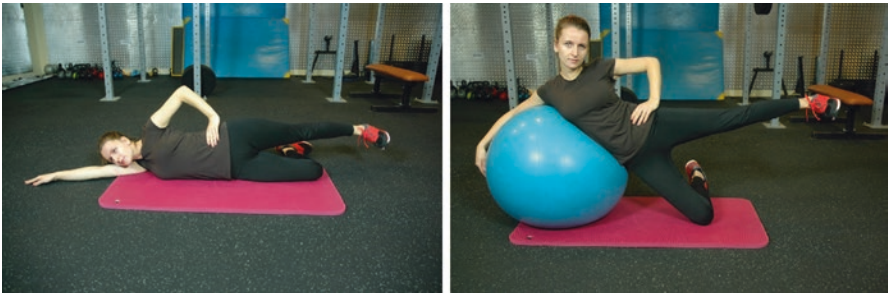
   Main working muscles: triceps brachii, shoulder, and upper back muscles.

   Difficulty options: exercise can be done with both hands with a load, such as a dumbbell.
6. Pelvic bridging (Fig. 9.37)—from lying on the back, knees flexed, feet on the ground, lift hips together with hip joint extension, while feet, shoulders, and head maintain contact with the ground. It is recommended to contract pelvic floor muscle together with lifting the hips.

   Main working muscles: hip extensor muscles.

   Difficulty options: the intensity and difficulty of the exercise can be increased by putting feet on a platform or a stability ball or by performing the exercise on one leg.
7. Outer thigh lift (Fig. 9.38)—from lying on the side, hip and knee of the lower leg flexed to stabilize the body, lift (abduct) the upper leg.

   Main working muscles: thigh abductors.



Easy option Advanced option

Fig. 9.38 Outer thigh lift

Fig. 9.39 Inner thigh lift

Difficulty options: the intensity of the exercise can be adjusted by increasing the time of the abductor muscle contraction by keeping the upper leg up or by putting the body on the stability ball (which activates the core muscles).

8. Inner thigh lift (Fig. 9.39)—lying on the side, hip and knee of the upper leg flexed to about 90°, placed in front of the body, lift (adduct) the lower leg. It is recommended to contract the pelvic floor muscle together with the leg lift.

   Main working muscles: thigh adductors.

   Difficulty options: the intensity of the exercise can be adjusted by increasing the time of the adductor muscle contraction by keeping the lower leg up.

9. Squeezing the ball with your knees and hands (Fig. 9.40)—from the seated position, knees flexed, feet on the ground, stability ball in the front between the thighs, hands on the upper part of the ball. At exhalation there is simultaneous pressure of thighs and hands on the ball, with exhalation—relaxation. It is recommended to contract abdominal and pelvic floor muscles together with the activation of the thigh and chest muscles.

   Main working muscles: thigh adductors, chest muscles, optionally abdominal and pelvic floor muscles.

Fig. 9.40 Squeezing the ball with your knees and hands

Fig. 9.41 Sideways push-ups

Difficulty options: the intensity of the exercise can be adjusted by increasing the time to maintain muscle contraction (squeezing the ball).

10. Sideways push-ups (Fig. 9.41)—in the position of lying on the side, hips and knees flexed to stabilize the body. The hand of the lower arm covers the abdomen, the hand of the upper arm on the ground at the chest level. Straighten the upper arm.

    Main working muscles: triceps brachii, unilateral trunk muscles.

    Difficulty options: advanced exercise, toward the end of pregnancy, it may be necessary to shorten the extension movement in the elbow joint (incomplete extension).

11. Modified side plank (Fig. 9.42)—in lying on the side position, in the position of lying on the side, hips and knees flexed to stabilize the body, the forearm of the lower arm is a support for the trunk. Lift the hips laterally. It is recommended to contract pelvic floor muscles together with the hips lift.

    Main working muscles: unilateral trunk muscles, hips abductors.

12. Difficulty options: advanced exercise, toward the end of pregnancy, additional support of the torso on the upper hand may be necessary.

Fig. 9.42 Modified side plank

Appendix 5: Examples of Abdominal Exercises for Pregnant Women

1. Breathing abdominally, air pushing the belly forward, increasing the waist circumference (inhale through the nose, exhale through the mouth). Exercise can be performed in any position.
2. Sit on the ball, arms crossed on the chest, tilt the trunk back while rotating the pelvis forward and performing a full exhalation, return.
3. Sit on the ball, arms along the torso, bend the trunk to the right, return, and change the side. You can add a load in your hands (e.g., dumbbells, kettlebells).
4. Sit on the ball, arms to the side. Twist the trunk to the right, return to the starting position, change sides.
5. Sit on the ball, circular movements on the pelvis.
6. Sit on the ball, alternating the lift of the bent leg. A more difficult option of this exercise is the alternate lift of the bent leg from the semi-squat position, with the back resting against the wall (the ball may be under the back).
7. Sitting down with legs bent on the floor, hands are holding the back of the thigh. Tilting of the trunk back, back to the starting position. Exercise recommended for beginners. A more difficult version of this exercise is to keep your hands crossed on the chest. The more the trunk tilts back, the greater the activation of the abdominal muscles.
8. Sitting down with bent legs, torso twists. A more difficult version of the exercise is the twist of the torso with simultaneous tilting back. The more the torso tilts back, the greater the activation of the abdominal muscles.
9. A kneeling sit, a "cat's back" or emphasizing the thoracic and lumbar part of the spine, activating the abdominal muscles. In women with no diastasis recti abdominis, the exercise can be performed in the position of a supported kneeling (see Appendix 1).
10. Lying back, legs bent. Arms along the torso. Pelvic lift, return to starting position.
11. Lying on the side. Side-lying trunk lifts.

Suggestions for Exercises in the Presence of Diastasis Recti Abdominis

The following exercises are recommended for both pregnant and postpartum women with the separation of abdominal muscles.

12. Sit on the ball, back straight, arms along the torso. Raise the right knee, or gently bend the lower limb in the hip joint. Lower, change sides. It is important that the back remains in the same position during the exercise.
13. Standing, back based on the wall (alternatively using a stability ball). Perform elongation of the spine with the simultaneous activation of the abdominal muscles. Try to make sure that your entire back is leaning against the wall. Make a slight flexion in the knee joints while trying to keep the spine straight.
14. Sit cross-legged or sit on the ball, hands on the abdomen. Inhale through the nose, abdomen forward. Exhaling with the mouth, direct the navel toward the spine. Imagine that you hug the baby with the outer part of the abdomen (exercise combined with visualization, activating the transversus abdominis muscles).
15. Straddle sit with legs bent. The ball in the front is held with the inner side of the thighs and palms, simultaneous pressure with the legs and hands on the ball with the exhalation and conscious abdominal contraction.

Appendix 6: Examples of Posture Exercises for Pregnant Women

1. In a standing position balancing from the front to the back of the foot and back looking for the moment when the weight of the body rests exactly in the middle of the foot. Exercise can be done with eyes closed.
2. Exercise as above balancing on both sides of the body.
3. In standing position, the head, shoulders, buttocks, and feet are touching the wall; the task is to touch the wall with the largest part of the back.
4. In standing, sitting, or kneeling position, keeping your hands on the belly, conscious activation of the abdominal muscles by making a loud grunt or an energetic exhalation through the mouth. The back and head remain in an unchanging vertical position.
5. Maintaining the correct posture in march and/or aerobic movements.
6. In sitting position consciously “opening” the chest, making the maximum inhale, pushing out the chest, and pulling the shoulders back.
7. In the standing, sitting, or kneeling position, performing the elongation of the spine, independently checking the position of the head, shoulders, and shoulder blades and activation of the abdominal muscles.
8. In supine position, arms to the side, shoulder blades touching the floor, the task is to touch the floor with the largest part of the back. Note: for some women this position may be uncomfortable. The alternative is to practice this exercise in standing back to the wall.

Appendix 7: Examples of Balance Exercises for Pregnant Women

1. In a standing position, maintaining correct posture, checking the elongation of the spine; the position of the head, shoulders, and shoulder blades; and activation of the abdominal muscles (Fig. 9.43).
2. Difficulty can be increased by adding arm moves, by increasing the time of the exercise, or by performing the exercises with eyes closed.
3. Difficulty can be decreased by performing the exercises with support (wall, chair, etc.).

Fig. 9.43 Examples of balance exercises

Appendix 8: Examples of Flexibility Exercises for Pregnant Women

1. Hip flexor stretch—from the kneeling position, the stability ball held on the side for balance, forward step, shifting the weight of the body on the forward leg with the maximum movement of the hips down and forward. Exercise is performed alternately, first on one and then on the other side (Fig. 9.44).
2. Inner thigh (thigh adductors) stretch with both legs bent—from the sitting position with the soles of the feet together, moving the knees maximally downward. Optionally, one can gently press the inner parts of the thighs with a smooth motion (Fig. 9.45).
3. Inner thigh (thigh adductors) stretch with one leg bent—from the position of sitting with straight legs, bending of one leg and its maximum move outward. A hand on the same side of the body can hold the leg and support the movement (Fig. 9.46).

Fig. 9.44 Hip flexor stretch

Fig. 9.45 Hip flexor stretch with both legs bent

Fig. 9.46 Inner thigh stretch with one leg bent

Fig. 9.47 Trunk muscle stretch

4. Trunk muscle stretch in kneeling position—from the kneeling position, the trunk flexion with the maximum extension of the arms forward. Optionally, the exercise can be performed with a roller or a ball (Fig. 9.47).
5. Back muscle stretch in sitting position—from the sitting position with legs slightly bent, in a slight stride, the maximum rounding of the back with the chin pulled toward the sternum (stretching of the upper back muscles and posterior neck muscles). When the trunk flexion is deepened, the stretching of the lower part of the back muscles also intensifies. When performing this exercise in a sitting position with straight legs, the hamstrings will also be stretched (Fig. 9.48).
6. Chest muscle stretch—from the supine position, the roller under the chest, the arms to the side, the bulge of the chest up. Optionally, the exercise can be performed on a stability ball. Due to the lack of data on the potential impact of stretching exercises on the intensification of abdominal muscle separation, it is recommended to limit the stretching movement at abdominal level in this exercise (Fig. 9.49).

Fig. 9.48 Back muscle stretch in sitting position

Fig. 9.49 Chest muscle stretch

Fig. 9.50 Trunk muscle and thigh abductors stretch

7. Trunk muscle and thigh abductors stretch in lying back position—from the supine position, one-sided flexion in the hip and knee joints and then performing internal rotation trying to put the inner part of the knee on the floor. Throughout the exercise, both shoulders should be in contact with the floor. This is a very good position for strengthening the diaphragm by abdominal breathing (Fig. 9.50).

Appendix 9: Examples of Exercises for Proper Pelvic Floor Muscle Contraction

1. It is best to perform the exercises lying on one's back with bent knees and feet resting on the floor (alternatively lying sideways or sitting with your back leaning against the wall or stability ball).
2. Contract pelvic floor muscles for 3–5 s, as if you were trying to stop a flow of urine or squeeze a tampon. Then relax these muscles. Try recognizing the difference between contracting and relaxing these areas.
3. Put your hands on your abdomen and contract abdominal muscles for 3–5 s as if you wanted to grunt or cough. Then relax those muscles. Try feeling the difference between contracting and relaxing abdominal muscles.
4. Put your hands on your buttocks and contract gluteal muscles for 3–5 s, lifting slightly your hips off the floor. Then relax those muscles. Try feeling the difference between contracting and relaxing gluteal muscles.
5. Put your hands on the inner parts of thighs, and contract thigh adductor muscles for 3–5 s pushing one knee into the other. Then relax those muscles. Try feeling the difference between contracting and relaxing the thigh adductor muscles.
6. Breathe deeply in and out relaxing all the above muscles.
7. Try keeping the abdominal, gluteal, and thigh muscles relaxed, and once again contract the pelvic floor muscles for 3–5 s, as if you tried stopping urine flow or squeezing a tampon.

Appendix 10: Examples of Birth Position Exercises

1. Standing birth position—the pregnant woman is standing with feet apart; hands are based on thighs. In this position, the woman can perform any movements of the pelvis, circular, forward, and backward. Another version of this position is a standing position leaning against the wall or hanging on ladders.

   Recommendations and remarks: The position is proposed between a series of exercises strengthening the muscles of the legs in high positions, i.e., squats, half-squats, and lunges. Recommended for beginners as an alternative to squatting position (Fig. 9.51).
2. Squatting position (Fig. 9.52)—typical for the primitive human during the physiological, instinctive push. It provides the most effective biomechanics during the pushing. A full squat should be made, feet pointing outward, while bending the torso. The abdomen, buttocks, and pelvic floor muscles should be maximally relaxed. Thighs can touch the stomach and chest, compressing the ribs and making the diaphragm's work easier, thus shortening the pushing phase. The inclination of the body forward along with the weight transfer on hands based on the floor ensures correct positioning of the pelvis and the coccyx bone, increasing the space of the birth canal. In addition, laying the body close to the ground responds to the instinctive need of the woman. The position allows the woman to give birth to a child on her own.

Fig. 9.51 Standing birth position

Fig. 9.52 Squatting position

Recommendations and remarks: The position is proposed between a series of exercises strengthening the muscles of the legs in high positions, i.e., squats, half-squats, and lunges. Performing the above position requires strong leg muscles, as well as stretching of the anterior and inner thigh and shank muscles. As most Western adults find it difficult to squat with heels down, compromises are

Fig. 9.53 Sitting birth position

Fig. 9.54 Horizontal kneeling

often made such as putting a support under the elevated heels or another person supporting the squatter. For beginners it is recommended to start from a standing delivery position (Fig. 9.51), gradually increasing the flexion in the joints of lower extremities.

3. Sitting birth position (Fig. 9.53)—the pregnant woman is sitting with her legs apart, knees are bent, her hands can hold her thighs or lower legs, and her torso is slightly bent forward.

   Recommendations and remarks: The position is proposed between a series of exercises strengthening the abdominal muscles from the sitting position.

   An option of this position can be performed sitting on the ball with legs apart, her hands resting on her thighs, her torso leaning slightly forward, and her feet on the floor. One can add circular movement of the hips. The position is proposed between a series of exercises strengthening the various muscle groups made from the sitting position on the ball. The elasticity of the ball supports the rhythm of the up-down movement of the hips and facilitates relaxing of the pelvic muscles. Both sitting positions are a good alternative for women who for some reason cannot execute the standing or squatting positions.

4. Horizontal kneeling or so-called child position (Fig. 9.54)—the pregnant woman is in the sit-on kneeling position (sitting on the heels), the torso maximally bent, arms forward, and the forehead can be based on the hands.

Fig. 9.55 "All fours" position

Fig. 9.56 Knee-elbow position

Recommendations and remarks: The position is proposed between a series of exercises strengthening various muscle groups from the position of kneeling or kneeling sit-down. It is a very good position for relaxation and exercise stretching the muscles of the back, buttocks, chest, and arms.

5. "All fours" position (Fig. 9.55)—kneeling supported on the straightened arms, thighs in a slight straddle, and the coccyx high up. Birthing in this position requires the help of a third party.

   Recommendations and remarks: The position relieves the spine. Proposed between series of exercises strengthening different muscle groups from the position of kneeling or kneeling sit-down. It is not recommended for women with a diagnosed diastasis recti abdominis.

6. Knee-elbow position (Fig. 9.56)—it is a variation of a kneeling position, with the upper body resting on bent forearms. Thanks to this, it is possible to lift the pelvis higher up. Birthing in this position requires the help of a third party.

   Recommendations and remarks: The position relieves the spine. Proposed between series of exercises strengthening various muscle groups from the position of kneeling or kneeling sit-down. It is not recommended for women with a diagnosed diastasis recti abdominis. One should be cautious about using it for women with a tendency to a headache (blood flows to the head with gravity).

7. Side lying with open legs (Fig. 9.57)—lying sideways, upper leg bent, moved apart, knee pointing up, the hand of the upper arm grabs the leg below the knee and pulls it toward the chest. Birthing in this position requires the help of a third party.

Fig. 9.57 Side lying with open legs

Fig. 9.58 Side-lying curled up

Recommendations and remarks: The position relieves the spine. Proposed between a series of strengthening exercises performed from the position lying sideways. During labor, it is recommended to lie on the left side to ensure the proper flow of venous blood to the heart. However, during the exercise classes, to ensure the bilateral balance of muscular work, one should change the sides of the exercises of this position.

8. Side lying curled up or so-called fetal position (Fig. 9.58)—lying sideways, body curled up, legs bent and drawn toward the chest. Birthing in this position requires the help of a third party.

Recommendations and remarks: As for the side lying with open legs position (see step 7).

Appendix 11: Examples of Breathing Exercises for Pregnant Women

1. Abdominal (belly or "diaphragmatic") breathing—the abdominal cavity expands during inhalation and decreases during exhalation. During the exercise, take a deep breath, directing the air to the abdomen, and then perform a calm maximum exhalation. In this exercise the diaphragm maximally drops into the abdomen, creating more space for optimal oxygen intake. This way of breathing improves blood flow to the abdominal region and helps to relax abdominal muscles. It also

calms the nervous system and that is why it is recommended for relaxation, also during labor.

2. Chest breathing—in this exercise women should focus on working the rib cage during breathing. At the time of inhalation, the chest should clearly increase in volume, rising up, forward, and sideways. Abdominal muscles should be activated throughout the entire duration of the exercise. A good position to perform this exercise is standing, requiring constant activation of the abdominal muscles to maintain the correct posture. They can be performed on a walk or during other exercises involving large muscle groups, e.g., during squats. Chest breathing is useful especially in the last weeks of pregnancy, when a large uterus makes it difficult to lower the diaphragm.
3. "Three-dimensional breathing"—both above exercises can be supported by an additional sensory stimulus. While breathing, the woman puts her hands in the front and on the side of the abdomen or chest and then on the back. With each breath, the hands should float slightly, with the exhalation slightly falling.
4. Breath visualization—the effectiveness of the breath can be increased by visualization. For example, you can imagine your abdominal cavity or lungs as a large vase, which when you inhale fills with water and is emptied during exhalation. In another exercise, a woman can imagine that during the breath her child performs inhalation and exhalation together with her. Such exercises are to increase the awareness of breathing.
5. Diaphragm exercises in trunk lateral flexion and rotations. Exercise for strengthening the diaphragm is deep abdominal breathing. It is difficult to breathe this way when the trunk is laterally inclined or twisted, which changes the biomechanical conditions for diaphragm operation.
6. Breathing exercises preparing for delivery. Painful uterine contractions during delivery disturb the respiratory rhythm and may lead an inexperienced woman to hold her breath. The task of the pregnancy exercise session is to prepare the woman's body for a quick and shallow breath, which can help her to overcome the pain of childbirth. The breathing resembles the panting or blowing out of a candle or feather flame, hence the name pant breathing or feather blowing. Acceleration and shallowness of breath impede gas exchange and may cause hyperventilation in a beginner. Therefore, this exercise should start from 15–20 s gradually extending to 60–90 s. Respiratory delivery exercises are good to perform in delivery positions, including visualization of labor and delivery pain. Each breathing sequence can be ended with a long, deep inhale through the nose followed by a long, deep exhale through the mouth, recommended for pushing. The exercise of the pushing itself is not recommended during pregnancy.

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Therapeutic Exercise Regarding Musculoskeletal Health of the Pregnant Exerciser and Athlete

10

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Abstract

Physical activity during pregnancy is recommended and has been shown to benefit most women. However, some modification to exercise routines may be necessary due to normal anatomic and physiologic changes and fetal requirements. Therefore, knowledge about the systemic changes of pregnancy should be taken into account when counseling women who wish to exercise through their pregnancy and should be complemented by the knowledge about the potential effect of exercise (therapeutic exercise) for prevention and resolution of some common pregnancy-related musculoskeletal conditions. Therapeutic exercise is the systematic and planned performance of exercises which aims to improve and restore physical function.

This chapter presents the scientific evidence foundation on the effect of therapeutic exercises for the prevention and resolution of three common pregnancy-related musculoskeletal conditions: pelvic floor dysfunction, diastasis recti abdominis, and low back and pelvic girdle pain. The chapter emphasizes the potential effect of exercise on prevention and resolution of these musculoskeletal conditions and provides useful information when tailoring therapeutic exercise programs for pregnant women.

Keywords

Pregnancy · Diastasis recti abdominis · Low back pain · Pelvic girdle pain
Pelvic floor muscles · Urinary incontinence

10.1 Introduction

Physical activity during pregnancy is recommended and has been shown to benefit most women. However, some modification to exercise routines may be necessary due to normal anatomic and physiologic changes and fetal requirements [1]. Pregnant women, therefore, represent a particular gender-based clinical challenge for the therapist and exercise promotor. During pregnancy, the female body undergoes many morphological and physiological changes that affect the musculoskeletal system. The most obvious change in pregnancy is related to the growth of the fetus and the stretching of the abdominal muscles, which may influence the mother's posture and balance. These factors in combination with hormones and weight gain may contribute to a variety of musculoskeletal impairments, trigger the development of musculoskeletal dysfunction, or alter the course of preexisting conditions. The most common pregnancy-related musculoskeletal impairments are pelvic floor dysfunctions, diastasis recti abdominis, and low back and pelvic girdle pain.

Therapeutic exercise is the systematic and planned performance of exercises which aims to improve and restore physical function. Additional goals of therapeutic exercises include pain relief, increased strength, and increased range of motion.

This chapter presents the scientific evidence foundation on the effect of therapeutic exercises for prevention and resolution of three common pregnancy-related musculoskeletal conditions: pelvic floor dysfunction, diastasis recti abdominis, and low back and pelvic girdle pain. A generic description of each condition is followed by information that could be useful for the development of therapeutic exercise programs for pregnant women.

10.2 Pelvic Floor Muscle Training

In general, it is possible to affirm that all women can benefit from education regarding the role of pelvic floor muscles (PFM) during pregnancy on pelvic floor dysfunctions. The specific treatment of the pelvic floor muscles is critical for the quality of life of women suffering from urinary and anal incontinence, pelvic organ prolapse, and a variety of pelvic pain syndromes. Therapeutic exercises focusing on education and of pelvic floor muscle training should be incorporated as a key component for pregnant exercisers and pregnant athlete women.

Several hypotheses have suggested that a trained PFM might reduce the risk of UI during pregnancy and after childbirth [2]. For example, a trained PFM may counteract the hormonally mediated increased laxity of the pelvic floor and the increased intra-abdominal pressure during pregnancy. In addition, it may encompass a greater functional reserve so that childbirth does not cause loss of muscle function to develop urinary leakage. Further, a trained PFM may recover better after childbirth as the appropriate neuromuscular motor patterns have already been learned [2].

PFM training (PFMT) and the importance of PFMT in restoring function after childbirth were introduced as early as 1948 by Kegel [3]. In an uncontrolled clinical trial from 1952, he reported that 84% of his patients with UI were cured after performing PFMT [4]. According to Bø [5], there are two main rationales for why PFMT works:

- Women learn how to consciously precontract the PFM before and during situations causing increased abdominal pressure (e.g., coughing).
- Increased PFM strength and enhanced hypertrophy take place, building up long-lasting muscle volume to provide structural support, closing the levator hiatus, and lifting the anatomical position of the pelvic floor.

10.2.1 Pre-contraction

During situations with increased abdominal pressure, the supportive action of the PFM is believed to be important [6–9]. Miller et al. [10] found that older women with SUI could acquire the skill of a well-timed PFM contraction just ahead of and during a cough ("the Knack") and by this maneuver significantly reduce leakage. The positive effect of the Knack maneuver in reducing leakage during coughing has later been confirmed both among nonpregnant and pregnant women [11]. The rationale to acquire such a skill is to prevent the urethra and bladder base from descending during increased abdominal pressure and thereby prevent leakage. An actual stabilization of the bladder neck by performing pre-contraction just ahead of and during a cough has subsequently been shown in observational studies, using perineal ultrasound, both among both nulliparous continent women [12, 13] and older incontinent parous women [12].

10.2.2 Strength Training

Strength training of the PFM increases PFM strength, provides increased urethral closure pressure, and prevents urethral descent [5, 14]. The PFM, as other skeletal muscles, respond to strength training by improved neuromuscular function, increased cross-sectional area, increased number of activated motor neurons, increased frequency of excitation, and improved muscle "tone" [5, 14, 15]. Specificity and overload are two fundamental principles that carefully must be addressed for effective strength training [14, 16].

To improve a specific skill, that specific skill must be performed. To become a good skier, you need to ski. To effectively improve PFM strength, specific PFM contraction performed in a correct manner needs to be carried out [14]. This means an inward lift and squeezes around the urethra, vagina, and rectum [4, 17, 18]. Avoiding co-contraction of other muscles should be emphasized, as this may mask the actual strength of the PFM contraction being performed [14]. The principle of specificity also draws attention to the fact that a correct PFM contraction may be difficult to perform for some women. Studies on women with UI have actually shown that >30% were unable to perform a correct PFM contraction [4, 19–21], even after a thorough verbal instruction on how to contract. Assessment of the ability to contract the PFM can easily be performed by visual observation and vaginal palpation [22, 23]. Proper assessment, instruction, and teaching on how to contract correctly are considered crucial in order to gain benefit from PFMT [24].

To achieve increased cross-sectional area and increased contractile force, the muscles need to be exposed to an overload that is larger than the common load encountered during everyday life [16]. Overload in PFMT can be achieved by performing close to maximal contractions, lengthening the holding periods for each contraction, increasing the number of repetitions and the number of sets completed, and reducing the rest intervals [14]. Strength training recommendations for skeletal muscles are 8–12 maximal contractions, three to four series, three to four times per week [15, 25, 26]. It takes time to achieve increased PFM strength, endurance, and muscle volume [14], and the American College of Sports Medicine recommends the exercise duration period to be at least 15–20 weeks [25]. Strength training with contractions close to maximum and short rest intervals between the contractions usually also increase local muscle endurance [27, 28].

10.2.3 Evidence for Pelvic Floor Muscle Training to Prevent and Treat Urinary Incontinence During Pregnancy

Based on the current evidence presented in a recent Cochrane review by Dumoulin [29], PFMT is better than no treatment, placebo drug, or inactive control treatments for women with UI (any type). The current evidence supports the widespread recommendation (Grade A) for offering supervised PFMT as the first-line treatment for female stress, urgency, or mixed UI [29, 30].

Boyle et al. [31] performed a Cochrane review during pregnancy, and 22 trials involving 8485 women (4231 PFMT, 4254 controls) were included in the analysis. Pregnant women without prior UI (prevention) who were randomized to intensive antenatal PFMT were about 30% less likely to report UI up to 6 months after delivery when compared to women randomized to no PFMT or usual antenatal care (risk ratio (RR) 0.71, 95% CI 0.54 to 0.95, combined result of five trials). The results of seven studies showed a statistically significant result favoring PFMT in a mixed population (women with and without incontinence symptoms) in late pregnancy (RR 0.74, 95% CI 0.58 to 0.94, random-effects model). The 5th International Consultation on Incontinence [30] recommends that pregnant women having their first child should be offered supervised PFMT (Grade A recommendation). To date, there is not enough evidence to conclude on the long-term effect, and there are no randomized controlled trials in pregnant recreational or elite athletes.

10.2.4 Can Pelvic Floor Muscle Training Compromise Vaginal Birth?

There has been some concern that a tight and strong pelvic floor might obstruct labor and result in instrumental delivery, perineal trauma, and/or injury of peripheral nerves, connective tissue, and muscles [32]. A recent systematic review including 12 RCTs/quasi-RCTs involving 2243 primigravida women concluded that PFM training significantly shortened 1st (mean 28 min) and 2nd stage (mean 10 min) of labor. In addition, antenatal PFM training did not increase the risk of episiotomy, instrumental vaginal delivery, and perineal laceration [33].

10.3 Diastasis Recti Abdominis

Pregnancy and childbirth bring along several changes to a woman's body, especially to the musculoskeletal system [34]. The most obvious change is related to the growth of the fetus and the stretching of the abdominal muscles, which may be influencing the mother's posture and balance [34].

Today there is a strong focus on the pregnant woman's appearance, especially through social media. Web pages and apps recommend how women should stay thin and get back into shape and regain "a flat tummy" at an early stage of the postpartum period.

Diastasis recti abdominis (DRA) or the increased inter-rectus distance is a common condition in women during pregnancy and postpartum [35]. As the fetus grows, the two muscle bellies of the rectus abdominis, connected by the linea alba, elongate and curve round as the abdominal wall expands, with most separation occurring at the umbilicus [36–38]. The augmented inter-rectus distance is described as a change in the abdominal musculature, specifically in the linea alba and the rectus abdominis sheath, with onset in the last trimester of pregnancy and whose peak of incidence occurs immediately after birth and the first weeks following childbirth [36, 39, 40].

Using the search terms "diastasis recti" and "exercise" 278,000 hits were obtained on Google. In addition, there is easily available advice on how to get rid of what is named "the mum's belly" (e.g., www.mammamage.se; www.breakingmuscle.com; www.befitmom.com; www.babybellybelt.com; www.tummyzip.com). A systematic review of the scientific literature has found none or very weak evidence behind any of these advices [41].

10.3.1 Prevention and Treatment

Exercise and surgery are the two available methods to treat diastasis recti abdominis. Akram and Matzen [42] identified 15 studies on surgery and found only one randomized controlled trial (RCT). The RCT compared the results of using two different sutures. The authors concluded that both groups had an adequate correction of DRA 6 months after surgery. This was supported by a recent RCT [43]. However, there are no RCTs comparing surgery with no treatment or exercise, no long-term effect studies, and sparse report of complications after surgery.

The huge activity in social media recommending a variation of abdominal exercise programs to prevent and treat DRA is in strong contrast to the lack of evidence for any positive effect shown in RCTs. In a systematic review by Benjamin et al. [41], eight studies in the treatment of DRA using abdominal exercises were found: four case studies, two retrospective observational studies, one quasi-experimental posttest study, and one small RCT of a brief training intervention [44]. A new search on PubMed of August 2017 found only three additional RCTs [43, 45, 46]. These studies score low on PEDro rating scale of methodological quality (5, 6, and 6 of 10 possible scores of internal validity, respectively) and exercise protocols, assessment methods, cutoff points for diastasis, and results differ (Table 10.1). None of the studies included exercise during pregnancy, and to date, there is, therefore, no knowledge whether the condition can be prevented or reduced with abdominal training or other exercises programs during pregnancy.

It has been suggested that antepartum activity level may have a protective effect on DRA and exercise may improve postpartum symptoms of DRA [42].

Table 10.1 Randomized trials on different exercises on diastasis recti abdominis (DRA)

	Participants	Intervention	Outcome & cutoff value for DRA	Results
Mesquita et al. [44]	50 women (18–40 years) After vaginal delivery Intervention: $N = 25$ Control: $N = 25$	Intervention: two supervised sessions with physical therapists 6 h (10 repetitions) and 18 h (20 repetitions) postpartum Abdominal and pelvic floor muscle contractions Diaphragmatic breathing, pelvic tilt with transverse abdominal and oblique's contraction. Co-contraction of pelvic floor muscles during all exercises Control: no follow-up	IRD measured using a caliper 4.5 cm above the umbilicus 4.5 cm below the umbilicus Diastasis: IRD > 3 cm	0 dropouts Significant larger reduction in IRD in intervention [mean 3.45 cm (SD 0.43) to 2.64 cm (SD 0.45)] compared to control [3.16 cm (SD 0.26) to 2.99 cm (SD 0.28)]
Walton et al. [45]	Nine women (18–45 years) Cesarean section and vaginal delivery Experimental group: $N = 5$ Control group: $N = 4$	6 weeks intervention (3 times/week of 3 × 10 repetitions). Increasing progression in repetitions. External support by a towel. Both groups: pelvic tilt, pelvic floor muscle exercises, and oblique's contraction Experimental: plank 10 s with knees on the floor. Control: modified sit-up	IRD measured by ultrasound 4.5 cm above the umbilicus 4.5 cm below the umbilicus Oswestry disability index. Pelvic floor distress index. Diastasis: cutoff value not defined	One dropout Experimental: IRD: mean 8.75 mm (SD 0.87) to 7.58 mm (SD 2.01) Control: mean 10.97 mm (SD 1.96) to 6.63 mm (SD 1.65) No significant difference between groups, $p = 0.2$ and $p = 0.6$ above and below umbilicus, respectively

(continued)

Table 10.1 (continued)

	Participants	Intervention	Outcome & cutoff value for DRA	Results
Emanuelsson et al. (2014)	89 participants (27–67 years) 87 women, two men Surgery with mesh: $N = 29$ Surgery with Quill: $N = 28$ Abdominal exercise: $N = 32$	3 months (three times/week with a physical therapist). Exercise for rectus abdominis, obliques, and transversus abdominis	IRD measured by a ruler (half way between xiphoideus and navel and navel and pubic symphysis) SF-36. Ventral hernia pain questionnaire. Abdominal strength: VAS scale and Biodex system 4. Diastasis: IRD: ≥3 cm	Three dropouts No significant improvement on VAS in exercise group compared to surgery groups
Kamel and Yousif [46]	60 women (25–35 years) After normal vaginal delivery 2 months postpartum Inclusion: diastasis > 2.5 cm at any point of linea alba	Neuromuscular electrical stimulation + abdominal exercise group: $N = 29$ Abdominal exercise group: $N = 28$ Abdominal exercise: sit-up, reverse sit-up, trunk twist, U-seat exercise. Both groups had a scarf around abdomen for support. Each exercise 20 repetitions +4 extra repetitions per week. Diaphragmatic breathing	Body mass index. Waist/hip ratio IRD abdominal strength: isokinetic (Biodex Multi-Joint System Pro, Model 850-000; Biodex Medical Systems Inc.) Peak torque, maximum repetition total work, average power	Three dropouts Inter-rectus distance: Neuromuscular electrical stimulation + abdominal training: 50% reduction Abdominal training: 25.9% reduction, $p < 0.001$ Abdominal strength: Neuromuscular electrical stimulation + abdominals: 75.9%, 95.5%, 76.3% Abdominals: 53.5%, 40.3%, 32.9% increase in peak torque, maximum repetition total work, and average power, respectively. $p < 0.05$ for all comparisons

IRD inter-rectus distance, *VAS* visual analogue scale, *SD* standard deviation

Physiotherapists and exercise instructors prescribe exercises to this population every day, but given the limited research data, there is currently no consensus on which abdominal exercises to recommend narrowing the diastasis. Recent research has questioned the use of the commonly used and recommended indrawing exercises as these appear to widen, rather than narrow, the gap measured with ultrasound [35, 47, 48]. Furthermore, one research group recommended contracting the pelvic floor muscles to activate the transverse abdominal muscles to stabilize the linea alba before performing curl-ups [49]. The results of the latter study conferred that contractions of the pelvic floor muscles increased the gap. There are currently no data from RCTs to support the new theory that activation of the transverse abdominal muscles via a pelvic floor muscle contraction can stabilize the linea alba, the validity of the formula used, and what this may mean for the diastasis. Furthermore, the effect of different abdominal exercises to treat low back pain has also recently been questioned. In a systematic review, Smith et al. [50] concluded that stabilization exercise is not more effective than any other form of active exercise in the long term. Based on the current published high-quality RCTs of abdominal training for low back pain, they stated that further research is unlikely to considerably change this conclusion. Nevertheless, abdominal training and especially core training with a focus on the transverse abdominis muscle continues to be highly recommended for both DRA and low back pain [49].

According to the IOC 2016 evidence summary [34, 51], there is no knowledge of the prevalence, risk factors, and prevention and treatment of diastasis in recreational exercisers and elite athletes. However, athletes of most sports are dependent on well-functioning abdominals for sports performance and therefore may be more vulnerable to the presence of a diastasis than other women. This and the effect of exercise interventions on this specific group of women need further investigation. Benjamin et al. [41] concluded that there is an urgent need for more studies on the effect of conservative treatment for DRA.

10.4 Low Back and Pelvic Girdle Pain

Although exercise is recommended during pregnancy, some women are inclined to reduce their levels of physical activity [52, 53]. Women with complicated pregnancies or women suffering LBP and/or PGP may have been advised not to participate in exercise activities. The effect of exercise in the prevention of low back and pelvic girdle pain during pregnancy is uncertain. Few trials have been reported to examining prevention of LBP and/or PGP, and they mainly lacked evidence of a positive effect [54]. Recently, a randomized controlled trial found that group fitness classes for pregnant women, exercising twice a week with a focus on cardiovascular endurance training and strength training, had no effect on the prevalence of LBP and PGP during pregnancy or postpartum [55]. Whereas more years of regular physical activity before pregnancy reduced the risk of LBP and/or PGP during pregnancy in one follow-up study [56], a retrospective study comparing athletes who performed plenty of exercise prepregnancy with nonathletic controls found no difference in the prevalence of LBP and/or PGP [57]. In a longitudinal cohort study, a greater loss of physical condition seems to be not a cause but rather a consequence of LBP and/or PGP in pregnancy [58].

10.4.1 Therapeutic Exercise for Pregnancy-Related Low Back and Pelvic Girdle Pain

A number of reviews have examined physical therapy interventions for LBP and PGP during pregnancy [59–68]. A recent systematic review showed that exercise reduced the risk of LBP in pregnancy by 9%, whereas it had no protective effect on PGP [69]. One systematic review of the Cochrane Collaboration included 26 randomized controlled trials that examined the effects of a variety of interventions for LBP and PGP during pregnancy [54]. Eleven trials examined LBP, four examined PGP, and a further 11 trials examined a combination of LBP and PGP (lumbopelvic pain). Evidence of moderate quality suggests that exercise or acupuncture significantly reduced evening PGP or lumbopelvic pain more than normal care alone. A more recent systematic review, including 22 randomized controlled trials, supported the conclusion of the moderate evidence for a positive effect of exercise therapy on pain, disability, and/or sick leave for the treatment of lumbopelvic pain during pregnancy [70]. According to this review, also patient information seems to be a useful intervention, especially when combined with exercises. However, when the authors analyzed LBP and PGP separately, the results were more robust for LBP than for PGP. The European guideline for PGP recommends individualized exercises in pregnancy [68], and a systematic review investigating the effectiveness of complementary and alternative medicine for the management of LBP and/or PGP in pregnancy found limited evidence to support the use of these interventions [71]. A review of yoga interventions during pregnancy indicates positive outcomes but leads to conclusions that more studies are needed [72].

Whereas individualized exercise and appropriate information to reduce fear and anxiety are recommended for pregnant women, the European guideline for PGP postpartum recommends giving appropriate information and reassuring the patients as part of an individualized multifactorial treatment focusing on specific exercises for motor control and stability [73]. The level of evidence for interventions for PGP postpartum is, however, limited, because few randomized controlled trials have been performed. One systematic review has investigated the effectiveness of physical therapy for the treatment of LBP and PGP related to pregnancy postpartum [74] and included four randomized controlled trials [75–78]. All used exercises for motor control and stability of the lumbopelvic region but with different interventions. The studies showed high methodological quality. However, only the study by Stuge et al. [75] demonstrated statistically and clinically significant positive and long-lasting effects, where disability was reduced by more than 50% for the exercise group compared to negligible changes in the control group. One more recent randomized study [79] concludes that core stabilization exercises and postural correction are effective in the management of postpartum lumbopelvic pain; however, the methodological quality was low. No studies examining a treatment program for LBP or PGP in elite athletes have been found [34, 51].

The lack of clear evidence supporting the diagnosis, prevention, and treatment of musculoskeletal conditions in the pregnancy and the postpartum period is challenging. Despite the desire of women to stay physically active during pregnancy [80], only a low proportion of pregnant women seem to follow current guidelines for exercise during pregnancy [73]. Even though group exercises during pregnancy have not been shown to influence the prevalence of LBP and/or PGP [55, 81–83], women who exercised seemed to handle their pain disorder better, with reduced need for sick leave [83]. Adhering to an exercise regime is a challenge [55], and it is important that exercises should not provoke pain during or after exercising. It might be that group exercise classes, even supervised, with a focus on cardiovascular endurance training and strength training are not addressing the pain-provoking factors in individual women. Including heterogeneous samples with and without pain, unspecified LBP and/or PGP, as well as combining prevention and treatment is likely to be a weak study design and potentially allows for a washout effect caused by the heterogeneity of the patient populations included [84].

The only randomized controlled study showing significant and long-lasting effects included a homogeneous group of patients based on clinical examination and criteria for PGP [75]. The treatment program studied was also individualized and focused on exercises for motor control and stability of the pelvic girdle. The focus of the exercises was to improve force closure with coordination of the local and overall muscle system, especially addressing the dynamic control of a neutral position of the lumbopelvic, subsequently to develop strength and endurance to manage the physical demands facing each individual. Additionally, essential points addressed were sacroiliac joint restrictions, posture, breathing, and cognitive-behavioral perspectives. Cognitive aspects were an important part of the intervention, in addition to the exercises. The women were ordered to perform their 30–60 min exercise program 3 days a week and they adhered closely to this regime. A qualitative study elucidating this treatment program found that by being active agents in managing their PGP, the women learned to set themselves proximal goals [85]. Perceived hope and self-efficacy appeared to be essential for developing capacity for self-management and an enhanced ability to benefit from appropriate learning experiences. To improve the quality of treatment, physiotherapists ought to have evidence-based skills, listen attentively, and individualized treatment. The women found the discussion and individualized guidance as positive factors in helping them to cope with their daily lives.

Even though no single exercise therapy has proven to be obviously superior [86], core stabilization exercises have grown in popularity [87], and two different core stabilization strategies exist, with controversy about which is the optimal strategy [88, 89]. The motor control exercise approach emphasizes specific exercises for local muscles, whereas the general exercise approach focuses exercises on global muscles [90, 91]. A recent review has suggested that therapeutic exercises purporting to restore motor control of specific selected local muscles are unnecessary [88]. However, it has also been emphasized that generic approaches using stabilizing exercises do not address the individual motor control deficits identified in the patients [84]. In both, LBP and PGP, increased co-contraction of trunk-stabilizing muscles was reported during tasks that provoke pain and an inability to relax muscles [84, 92]. Consequently, interventions should focus less on specific stabilizing muscles and more on daily activities and optimal dynamic control of movements. Inherent underlying maladaptive movements might act as potential ongoing peripheral nociception rather than a strategy to avoid pain [84]. The examination of daily activities can determine whether the movement and pain behaviors are adaptive or maladaptive. With this in mind, individually designed treatment programs of supervised home exercise with regular therapist follow-up sessions to encourage adherence and achieve optimal dosage are recommended for patients with pregnancy-related LBP and/or PGP [75, 93]. Contradictory evidence exists whether motor control or stabilizing exercises are better than general exercises [94, 95], with one systematic review showing strong evidence that stabilization exercises are not more effective than any other form of active exercise in the long term [50]. Nevertheless, positive changes in motor control have been found to be associated with relief of pain and disability for PGP [75, 96].

In conclusion, pregnant and postpartum women, even those with LBP and/or PGP, should be encouraged to be physically active, and health-care providers should help the women to find the kind of exercise or physical activity that is optimal for each individual, in her own environment.

To assess activity limitations and symptoms, there is a need for suitable outcome measures that are reliable and valid for patients with PGP in research and in clinical practice [97]. A condition-specific measurement, the Pelvic Girdle Questionnaire, was developed for pregnant and nonpregnant women [98]. The questionnaire consists of 20 activity items and five symptom items on a 4-point response scale. The Pelvic Girdle Questionnaire is reliable and valid for both pregnant and postpartum women with PGP; it is simple to administer and feasible for use in research and clinical practice. The Pelvic Girdle Questionnaire has also shown acceptable responsiveness and been shown to discriminate significantly both between pregnant and nonpregnant patients as well as between different locations of pain [99, 100].

10.5 Further Research

This chapter presents the current scientific evidence on the effect of exercise on prevention and treatment of three common pregnancy-related musculoskeletal conditions: pelvic floor dysfunctions, diastasis recti abdominis, and low back and pelvic girdle pain.

To date, there is not enough evidence to conclude on the long-term effect of PFMT. To our knowledge, there are no available studies specifically addressing the effect of PFMT among pregnant recreational or elite athletes. These two topics should be explored in further studies.

A lack of evidence exists about the consequences of the diastasis recti abdominis on abdominal wall integrity. Further research should focus on the effect of abdominal strengthening exercises in the reduction of diastasis recti abdominis.

Regarding low back and pelvic girdle pain during pregnancy, high-quality randomized studies are needed to clarify the preventive and/or resolution effect of core stabilization exercises and postural correction. Further, the effect of therapeutic exercise programs for low back or pelvic girdle pain in pregnant elite athletes is unexplored and needs further attention.

10.6 Conclusions

This chapter presents the current evidence on the effect of therapeutic exercise programs in prevention and resolution of three common pregnancy-related musculoskeletal conditions: pelvic floor dysfunction, diastasis recti abdominis, and low back and pelvic girdle pain.

The Sect. 10.2 underlines the importance of PFMT during pregnancy. A trained PFM may counteract the hormonally mediated increased laxity of the pelvic floor and the increased intra-abdominal pressure during pregnancy. Further, a trained PFM may encompass a greater functional reserve so that childbirth does not cause the sufficient loss of muscle function to develop urinary leakage. Additionally, a trained PFM may recover better after childbirth as the appropriate neuromuscular motor patterns have already been learned. The current evidence supports the widespread recommendation (Grade A) for offering supervised PFMT as the first-line treatment for female stress, urgency, or mixed UI. During pregnancy, the current evidence support PFMT as this is shown to prevent and treat UI during pregnancy and also prevent UI postpartum. The 5th International Consultation on Incontinence recommends that pregnant women having their first child should be offered supervised PFMT (Grade A recommendation).

The Sect. 10.3 explores the effect of exercise on diastasis recti abdominis (DRA) prevention or correction. The potential effect of the abdominal exercise programs on DRA prevention and treatment in pregnant women has been discussed as well as the consequences of this condition on abdominal wall integrity. To date, there is no knowledge whether DRA can be prevented or reduced with abdominal training or other exercises programs during pregnancy.

The Sect. 10.4 discusses the existing scientific evidence about the effect of exercise on prevention and treatment at low back pain (LBP) and pelvic girdle pain (PGP) during pregnancy. Pregnant women, even those with LBP and/or PGP, should be encouraged to be physically active. Health-care providers should help women to find the most appropriate exercise or physical activity for each individual, in her own environment. Identification of women's activity limitation and symptoms should be done prior to engaging in the exercise. For this purpose, there is a need for suitable outcome measures that are reliable and valid for patients with PGP. A condition-specific measurement, the Pelvic Girdle Questionnaire, was developed for pregnant and nonpregnant women. The questionnaire consists of 20 activity items and five symptom items on a 4-point response scale. The Pelvic Girdle Questionnaire is reliable and valid for both pregnant and postpartum women with PGP; it is simple to administer and feasible for use in research and clinical practice. The Pelvic Girdle Questionnaire has also shown acceptable responsiveness and been shown to discriminate significantly both between pregnant and nonpregnant patients as well as between different locations of pain.

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Nutritional Requirements for the Pregnant Exerciser and Athlete

11

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Abstract

The purpose of this chapter is to identify special groups of pregnant exercisers and pregnant athletes such as (1) athletes practicing aesthetic sports, weight competing sports, and sports of long duration, (2) pregnant exerciser women who restrict or prohibit certain dietary practices or the consumption of important sources of energy and nutrients, (3) adolescent pregnant exercisers, and (4) other pregnant exerciser women in high-risk categories. In addition, risk factors as eating disorders or low energy availability related to their energy and nutritional requirements are also included. Micronutrients' needs increase much more than for macronutrients. Even prior to conception, an increased average intake of folate, iodine, and iron is recommended. However, only in the beginning of the second trimester, a marked increase in vitamins and minerals is observed. A pregnant exerciser or athlete who continues to train during pregnancy may have total energy expenditure quite high; this will depend on the type, intensity, frequency, and duration of the activities performed. Therefore, dietary intakes before, during, and after physical exercise are crucial for the maintenance of adequate energy availability. In addition, some unhealthy behaviors such as the consumption of alcohol, smoking, caffeine, and/or non-nutritive sweeteners and the lack of sleep should be avoided.

Keywords

Pregnancy · Energy needs · Nutritional intakes · Athletes · Exercisers Eating disorders · Sleep

11.1 Introduction

During pregnancy, extra energy is needed for the growth of the fetus, placenta, and associated maternal tissues. Basal metabolism rises partly due to the increased mass of active tissue (fetal, placental, and maternal), the increased maternal effort (e.g., cardiovascular and respiratory work), and the tissue synthesis.

Several studies from the 1950s to 1960s [1, 2] showed that pregnant women with insufficient weight gain presented higher rates of premature birth than those with appropriate weight gain. Therefore, in that time, undernutrition was seen as a negative influence factor for the pregnancy outcome. Nowadays, the opposite significant complication of pregnancy, which is maternal overweight and obesity worldwide [3, 4], is preoccupying medical and scientific communities, since the fetus may be exposed to an excessive energy availability. In a recent systematic review and meta-analysis of 90 dietary studies among pregnant women in developed countries (n = 126.242), energy and fiber intakes were generally lower, carbohydrate intake was borderline or lower, and total fat and saturated fat intakes were higher than nutritional recommendations of each specific country [5].

Moreover, it was recently indicated that micronutrient intake during pregnancy is less than optimal [5], which is of great concern since the current consensus lies on the impact of maternal nutrition in both short- and long-term health of the child [6].

In addition, although there are various factors that can negatively affect the maternal nutritional status, such as inadequate energy availability [6], physical inactivity, overweight or obesity [3], and other complications (multiple pregnancies, being an adolescent, alcohol and tobacco consumption, and drugs) [7], maternal physiological changes influence nutritional status by increasing energy and nutritional needs [8–11]. Those changes can influence not only the mother's health but also fetus growth and development [8].

In well-nourished populations from developed countries, the weight gain during pregnancy is about 12.5 kg, and the median infant birth weight is 3.3 kg with a coefficient of variation of 15% [11]. Nevertheless, the average extra energy cost of this typical pregnancy has been calculated to be about 80.000 kcal over the 9-month period, distributed as an extra of 150 kcal per day during the first trimester and 350 kcal per day during the second and third trimesters [12]. Therefore, recommendations for energy intake of pregnant women should be population-specific, because of differences in body size and lifestyles [13].

Anatomical and physiological changes during pregnancy affect the musculoskeletal system at rest and during exercise. Weight gain is the most obvious [14]. The characteristics of exercise prescription should be considered in every physical activity framework regardless of its purpose (basic health, recreational pursuits, or competitive activities) [15].

Nevertheless, this chapter will be mainly based on energy and nutritional requirements of special groups of pregnant exercisers and pregnant athletes such as (1) athletes practicing aesthetic sports, weight competing sports, and sports of long duration, (2) pregnant exerciser women who restrict or prohibit certain dietary practices or the consumption of important sources of energy and nutrients, (3) adolescent pregnant exercisers, and (4) other pregnant exerciser women in high-risk categories. Also dietary intakes before, during, and after physical exercise will be analyzed, and unhealthy behaviors such as the consumption of alcohol, smoking, caffeine, and/or non-nutritive sweeteners and the lack of sleep will be discussed.

11.2 Special Groups of Pregnant Exercisers and Pregnant Athletes

Some pregnant women should be carefully screened and closely supervised by sport and health professionals as they are more sensitive for an inadequate nutritional status during pregnancy and/or for the development of an insufficient or an excessive body weight (Table 11.1) [16].

Special groups of pregnant exercisers and athletes are as follows.

Table 11.1 Special groups of pregnant exercisers and athletes

Special groups of pregnant exercisers and athletes
Pregnant athletes practicing aesthetic sports, weight competing sports, and long duration sports
Pregnant women who restrict or prohibit certain dietary practices
Pregnant adolescents
Pregnant women carrying more than one fetus
Women with multiple pregnancies
Women who are high cigarette smokers, heavy alcohol consumers, and drug abusers (*less frequent*)

11.2.1 Pregnant Athletes Practicing Aesthetic Sports, Weight Competing Sports, and Sports of Long Duration

Athletes practicing aesthetic sports (e.g., any gymnastics' discipline, ballet, artistic skating), weight competing sports (e.g., canoeing, judo), and long duration sports (e.g., marathons) normally exhibit lean bodies and a reduced body weight and often present an inadequate energy intake in accordance with their exercise energy expenditure. Thus, physiological functions, daily activities, and athletic performance can be compromised as these athletes may not achieve adequate amounts of energy available for their daily activities and training demands [17]. Furthermore, they have increased needs for energy and nutrients in prepregnancy, during pregnancy, and postpregnancy in relation to their pairs (i.e., pregnant women nonathletes) (Fig. 11.1).

Energy availability has been defined as the amount of energy intake minus total energy expenditure normalized to fat-free mass [18, 19], where total energy expenditure is divided into basal metabolic rate, diet-induced thermogenesis, and activity energy expenditure [20]. Due to higher metabolic rate and energy expenditure in the synthesis of protein and fat in new tissues in pregnant women, total energy expenditure is higher than in nonpregnant ones (Fig. 11.2).

In addition, low energy availability is defined as energy availability below 45 kcal/kg fat-free mass/day [21]. A threshold below 30 kcal/kg fat-free mass/day is associated with amenorrhea and is considered the lowest energy threshold of energy availability for women [17, 19].

As in short term, energy availability is required to improve exercisers' and athletes' health, including the prevention of injury, and in the long term, sustained low energy availability may predispose female exercisers and athletes to various health hazards, such as irregular menstruation, infertility, and osteoporosis [17, 18]; when we are discussing on pregnant exercisers or athletes, tight supervision is required. Therefore, nutritional supervision through the evaluation of energy needs and energy expenditure is crucial. The application of a food frequency questionnaire and a 7-day food diary may be helpful measures along with others related to

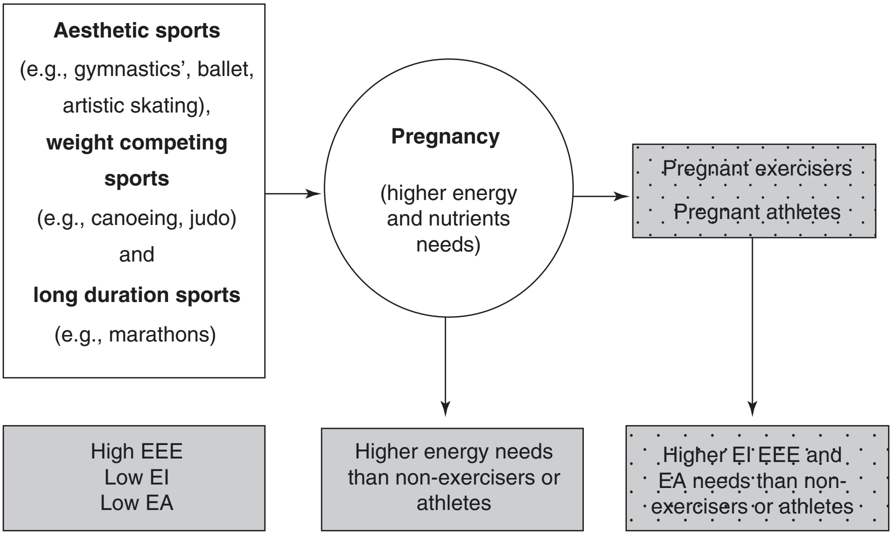

Fig. 11.1 Increased energy needs of pregnant athletes compared to nonathletes (*EEE* exercise energy expenditure, *EI* energy intake, *EA* energy availability)

anthropometry (e.g., body weight, body mass index) in assessing more efficiently the risk of dietary inadequacy in these pregnant women [22].

Although there are no data on the prevalence of eating disorders in pregnant exercisers and athletes, it is well-known that pregnant athletes, with an eating disorder, and their offspring are at particular risk [16, 23].

In fact, the prevalence of eating disorders is higher among athletes (20–22%) than nonathletes (3–9%), with a high frequency in aesthetic (42%), sports with weight categories (30%), and weight-sensitive sports such as endurance (24%) [24–29]. For the aforementioned female competitive athletes, energy restriction is common in order to reduce body weight [17]. In addition, they train intensively from very young ages and maintain that training regime during adolescence and early adulthood, which is normally characterized by a strict control of energy input in combination with a high energy output and reduced levels of body weight and body mass index for age. Exactly, a reported mortality rate between 4% and 10% was reported for those with a severe eating disorder [30].

Pregnant women with anorexia or bulimia are at risk to develop anemia, hyperemesis gravidarum, preterm birth, spontaneous abortion, cesarean section, and postpartum depression [31–33]. Their neonates are at risk for low birth weight, small head [34, 35], and developmental and emotional disturbances [35, 36] such as anxiety, depression, and substance abuse [31, 36]. Additional complications for pregnant women with bulimia involve elevated risk for hypertension, vaginal bleeding, fetal abnormalities, low Apgar scores, breech delivery, and stillbirth [31, 37].

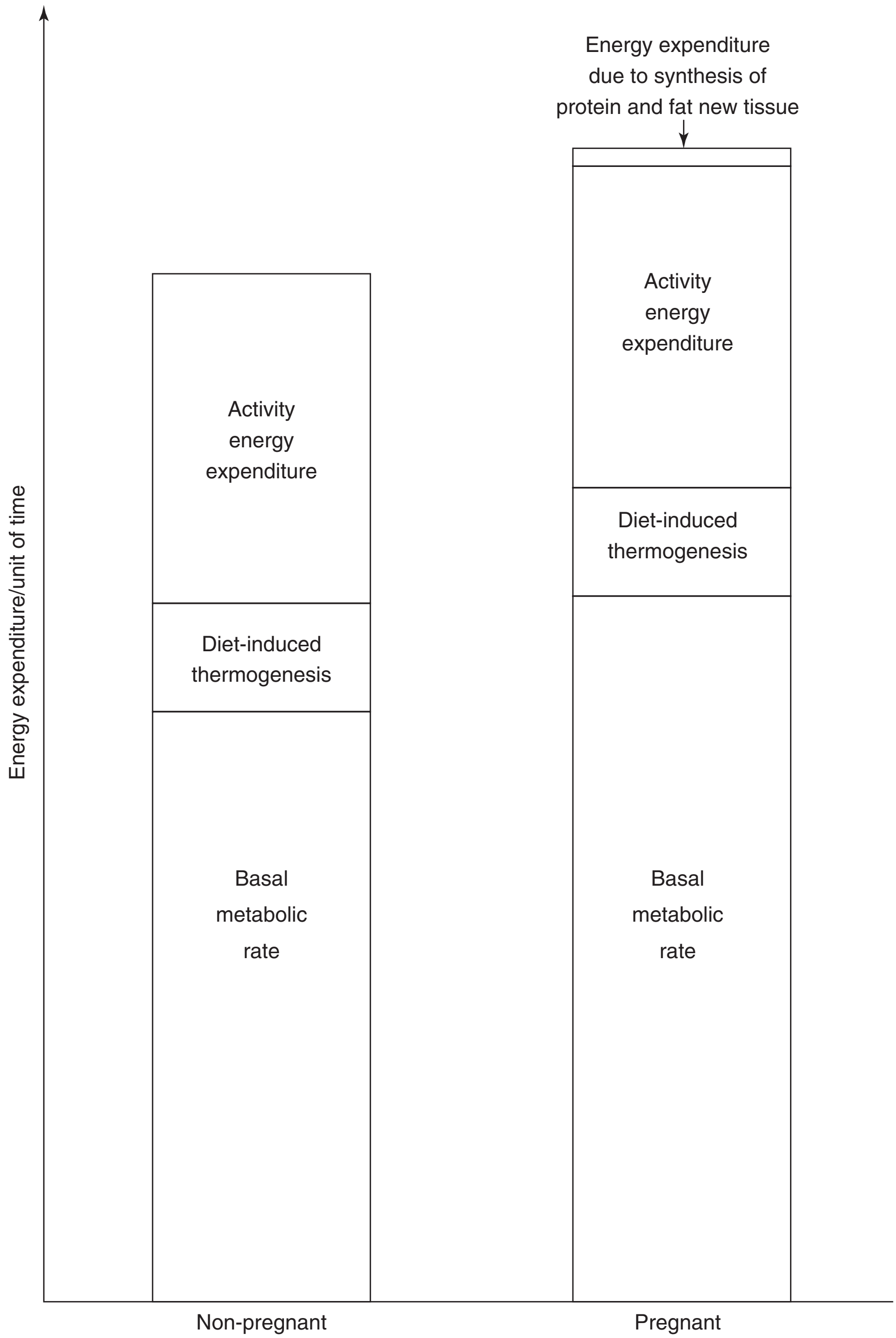

Fig. 11.2 Partitioning of total energy expenditure in nonpregnancy vs pregnancy [20]

11.2.2 Pregnant Exerciser Women Who Restrict or Prohibit Certain Dietary Practices or the Consumption of Important Sources of Energy and Nutrients

Some pregnant exerciser women restrict or prohibit certain dietary practices or the consumption of energy and nutrients, such as all animal foods (proteins) or milk (calcium, vitamin D); thus, these women are at high risk of inadequate nutrient intakes. In such cases based on a poor diet quality and if a better food selection is not possible, selective supplementation is recommended by the IM [22].

11.2.3 Adolescent Pregnant Exercisers

Adolescent pregnant exercisers should be carefully supervised, because adolescence is a period of life that diet is likely to be inadequate for dietary intakes, especially for energy intake and some micronutrients, such as calcium, iron, zinc, riboflavin, folic acid, and vitamins A, D, and B-6. In addition, these young pregnant females are crossing a very demanding period of their own growth and development associated with increased energy needs for the growth and development of the fetus [38]. Therefore, it is recommended for pregnant adolescents to strive for weight gains toward the upper end of the ranges for women with similar weights for height [22].

11.2.4 Pregnant Exerciser Women in High-Risk Categories

Pregnant exerciser women in high-risk categories such as exerciser women carrying more than one fetus, with multiple pregnancies, and who are high cigarette smokers, heavy alcohol consumers, and drug abusers are normally at high risk of delivering prematurely with low body weight and with newborn's malformations [39].

According to the mentioned subcommittee, special groups of pregnant women should daily take a multivitamin-mineral preparation containing several nutrients beginning in the second trimester as follows: iron = 30 mg/day, vitamin B-6 = 2 mg/day, zinc = 15 mg/day, folate = 300 μg/day, copper = 2 mg/day, vitamin C = 50 mg/day, calcium = 250 mg/day, and vitamin D = 5 μg/day. To improve the absorption of these minerals and vitamins, this supplement should be taken between meals or at bedtime [22].

11.3 Energy and Nutritional Requirements for the Pregnant Exerciser and Athlete

During pregnancy, energy and nutrient requirements are normally increased in order to support increased maternal metabolism changes, blood volume and red cell expansion, and the delivery of energy and nutrients for the fetus development [6, 16, 40].

The additional energy need for a pregnant woman with a mean gestational weight gain of 12 kg is estimated to be [13]:

- 325 MJ (77,700 kcal) in total and 375 kJ/day (90 kcal/day) for the first trimester of pregnancy
- 1200 kJ/day (287 kcal/day) for the second trimester
- 1950 kJ/day (466 kcal/day) for the third trimester

However, a pregnant exerciser or athlete who continues to train during pregnancy may have total energy expenditure quite high; this will depend on the type, intensity, frequency, and duration of the activities performed [23]. Because of the type (high intensity, prolonged, and frequent) of training done by elite athletes, it is likely that weight gain will be less for both mother and fetus than for sedentary women [15].

In accordance with the Institute of Medicine and the National Research Council recommendations [22], an important strategy should be adopted by the pregnant woman that is monitoring her energy intake by comparing her weight gain and body mass index (Table 11.2).

The practice of a healthy nutritional intake must be reached by an adequate energy availability, including key micronutrients, especially iron, folate, zinc, calcium, vitamin D, and essential fatty acids that promote red blood cell production, enzyme activity, bone development, and brain development [6].

For a reference 19-year-old active woman, the estimated average energy requirements, such as 2740 kcal/day and 2852 kcal/day, are recommended for the second and the third trimester of pregnancy, respectively (Table 11.3), in accordance with the recommended dietary allowance (RDA) from the Food and Nutrition Board/Institute of Medicine (FNB/IM) [41]. An average energy increase of 14–18% (mean of 16%—Fig. 11.3) is estimated to be the recommended during pregnancy. However, the German National Consensus Recommendations on Nutrition and Lifestyle in Pregnancy by the "Healthy Start—Young Family Network" considers the increase

Table 11.2 Recommendations of the Institute of Medicine and the National Council Research (2009) for total weight gain range in singleton pregnancies by prepregnancy body mass index [22]

Prepregnancy BMI (kg/m^2)	Total weight gain (kg)	Total weight gain (lbs)	Weekly weight gain range in the second and third trimester, kg (lbs)
Underweight (<18.5 kg/m^2)	12.5–18.0	28–40	0.44–0.58 (1.0–1.3)
Normal weight (18.5–24.9 kg/m^2)	11.5–16.0	25–35	0.35–0.50 (0.8–1.0)
Overweight (25.0–29.9 kg/m^2)	7.0–11.5	15–25	0.23–0.33 (0.5–0.7)
Obese[a] (>30.0 kg/m^2)	5.0–9.0	11–20	0.17–0.27 (0.4–0.6)

[a]Includes obesity classes I (30–34.9 kg/m^2), II (35–39.9 kg/m^2), and III (>40 kg/m^2)

Table 11.3 Estimated energy and nutrient requirements for a reference 19-year-old active woman according to the Food and Nutrition Board, Institute of Medicine [16, 41, 43–47]

Dietary reference intakes (DRIs)	Nonpregnant	Pregnant
Energy (kcal/day)	2400	2740–2852[a]
Carbohydrate (g/day)	130	175
Protein (g/day)	46	71
Vitamin A (μg/day)	700	770
Vitamin D (μg/day)	5	5
Vitamin E (mg/day)	15	15
Vitamin K (μg/day)	90	90
Thiamin (mg/day)	1.1	1.4
Riboflavin (mg/day)	1.1	1.4
Niacin (mg/day)	14	18
Pantothenic acid (mg/day)	5	6
Biotin (μg/day)	30	30
Vitamin B-6 (mg/day)	1.3	1.9
Folate (μg/day)	400	600
Vitamin B-12 (μg/day)	2.4	2.6
Vitamin C (mg/day)	75	85
Choline (mg/day)	425	450
Sodium (g/day)	1.5	1.5
Potassium (mg/day)	4.7	4.7
Chloride (g/day)	2.3	2.3
Calcium (mg/day)	1000	1000
Phosphorus (mg/day)	700	700
Magnesium (mg/day)	310	350
Iron (mg/day)	18	27
Zinc (mg/day)	8	11
Selenium (μg/day)	55	60
Iodine (μg/day)	150	220
Copper (μg/day)	900	1000
Manganese (mg/day)	1.8	2
Fluoride (mg/day)	3	3
Chromium (μg/day)	25	30
Molybdenum (μg/day)	45	50
Water (L/day)	2.7	3000

[a]The lower value indicates the second trimester, and the highest value indicates the third trimester

of only 10% more for energy intake in the final months of the pregnancy [42], relying on the slight increases in energy needs, as mentioned before.

Regarding micronutrients, energy needs increase much more than for macronutrients (Fig. 11.3). Even prior to conception, an increased average intake of folate, iodine, and iron is recommended [42]. However, only in the beginning of the second trimester, a marked increase in vitamins and minerals is observed, as can be seen in Table 11.3 and in Fig. 11.3.

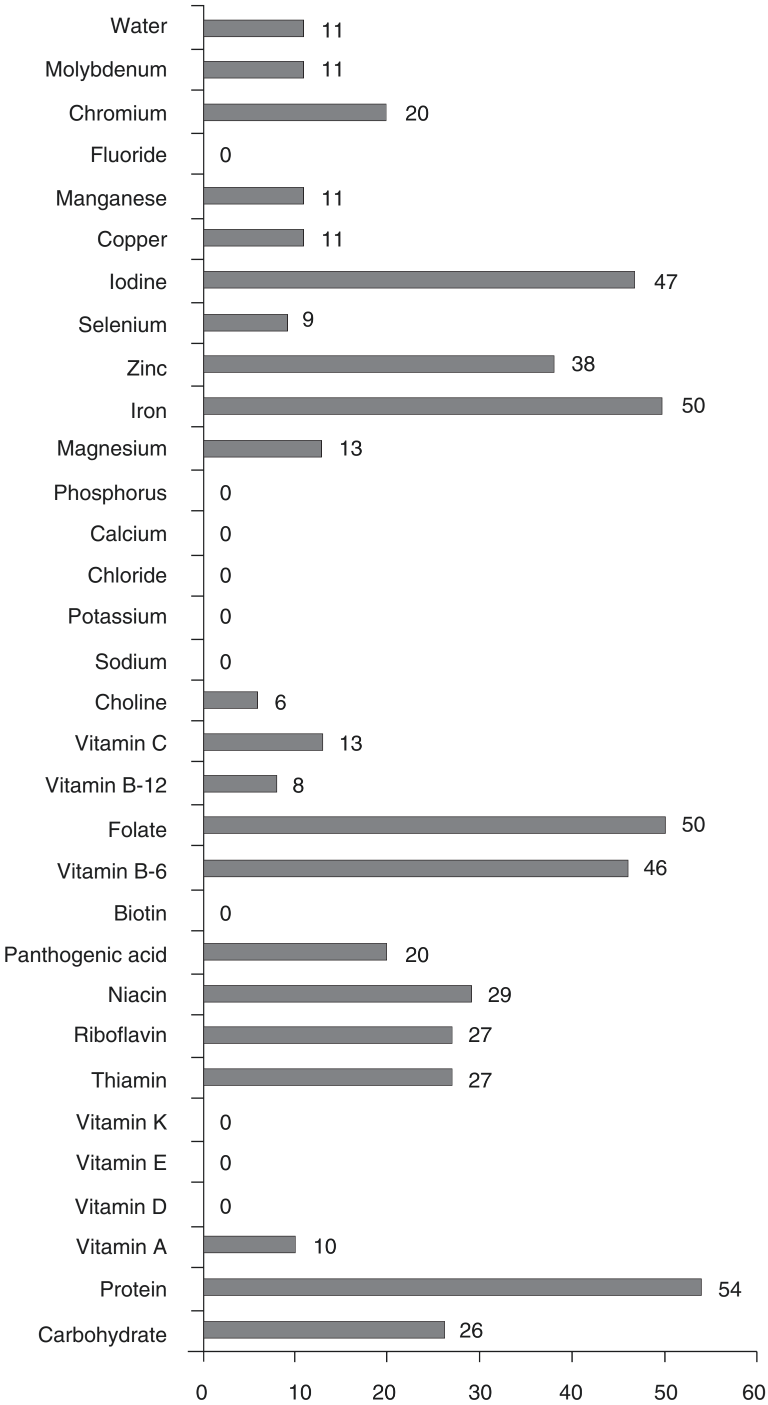

Fig. 11.3 Percentage of increase in DRIs from nonpregnancy to pregnancy in accordance with the Food and Nutrition Board, Institute of Medicine [41, 43–47]

Although the recommended dietary allowances (RDA) for vitamins D, E, and K, biotin, sodium, potassium, chloride, calcium, phosphorus, and fluoride are not increased during pregnancy, estimated energy (as mentioned before), protein, specific vitamin (vitamin A, thiamin, niacin, pantothenic acid, vitamin B-6, folate, vitamin B-12, vitamin C), and mineral (choline, magnesium, iron, zinc, selenium, iodine, copper, manganese, chromium, and molybdenum) requirements are increased in the second and the third trimesters (Fig. 11.3). In relation to fiber intake, the FNB/IM recommends an average intake for total fiber of 28 g/day for a pregnant woman (14 g/1.000 kcal × 1.978 kcal/1.000 kcal/day), slightly higher than the estimated for a nonpregnant woman (25 g/day) [41]. For water intake (from beverages, foods, and drinking water), the FNB/IM recommends an increase from 2.7 L for nonpregnant women to 3.0 L for pregnant women in order to meet hydration needs [47].

11.4 Diet and Physical Exercise

Despite the fact that pregnancy adversely affects the performance, most elite athletes prefer to continue to train during pregnancy. The relatively high-intensity, long duration, and frequent workout schedules of most competitive athletes may place them at greater risk of thermoregulatory complications during pregnancy [16]. Particular attention should be paid to the diet and hydration during and between these exercise sessions. For pregnant exerciser and athlete, the main ergogenic aid will be the manipulation of diet and hydration.

An ergogenic aid is any training technique, mechanical device, nutritional practice, pharmacological method, or psychological technique that can improve exercise performance capacity and/or enhance training adaptations [48].

Supplementation in pregnancy can be interesting, because many women do not comply with the recommendations of some nutrients, vitamins, or minerals through exclusive feeding. However, it is important that the food is supervised by an expert and that it is of quality to ensure complete safety for the fetus. Nutritional needs and manipulation of diet and hydration are similar to nonpregnant female athletes [49]. In Fig. 11.4, the nutritional needs are explained according to the intensity of the exercise practiced [50].

11.4.1 Daily Requirements by Activity

Daily macronutrient requirements are dependent on the intensity of the physical exercise as follows [50]:

- Carbohydrates

  Depending on the intensity of exercise, the daily requirement of carbohydrates increases:

  Light-intensity exercise: 3–5 g/kg/day

  Moderate-intensity exercise (1 h/day): 5–7 g/kg/day

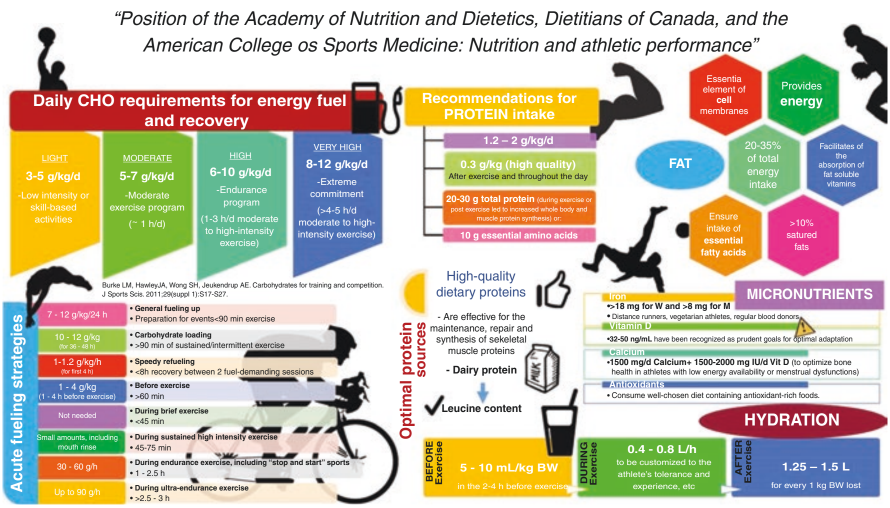

Fig. 11.4 Infographic of the position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine about nutrition and athletic performance [50]

High-intensity exercise (1–3 h/day moderate- to high-intensity exercise): 6–10 g/kg/day

Very high-intensity exercise (>4–5 h/day moderate- to high-intensity exercise): 8–12 g/kg/day

- Protein

  Daily protein intake goals should be met with a meal plan providing a regular spread of moderate amounts of high-quality protein across the day.

  The dietary protein is necessary to support metabolic adaptation and repair and for protein turnover ranges from 1.2 to 2.0 g/kg/day.

- Fat

  Fat intakes that accommodate dietary goals typically range from 20 to 35% of total energy intake.

11.4.2 Dietary Intake Before Physical Exercise

According to the International Society of Sports Nutrition, the daily ingestion of high-carbohydrate meals (65%) is recommended to maintain muscle glycogen, while increased ingestion rates are employed (70%) in 5–7 days leading up to competition as a means of maximizing muscle and liver glycogen stores and in order to sustain blood glucose during exercise [49].

In order to get good muscle glycogen stores, it is necessary to follow a carbohydrate-rich diet (600–1000 g or 8–10 g/kg/day) [49]. The carbohydrate and protein levels before doing exercise depend on the duration and the fitness level, but general guidelines recommend the ingestion of 1–2 g/carbohydrates/

kg of body weight and 0.15–0.25 g/protein/kg of body weight 3–4 h before competition [49].

The recommendation to maintain euhydration before exercise is to consume a fluid volume equivalent to 5–10 ml/kg of body weight in 2–4 h before exercise [50].

11.4.3 Dietary Intake During Physical Exercise

As exercise duration increases beyond 60 min, exogenous sources of carbohydrates become important to maintain blood glucose and muscle glycogen stores. This carbohydrate source should supply 30–60 g/carbohydrates/hour and can typically be delivered by drinking 1–2 cups of a 6–8% carbohydrate solution (8–16 fluid ounces) every 10–15 min [51].

Because exogenous carbohydrate oxidation rates from single carbohydrates do not exceed 1.0–1.1 g/min, it has been recommended to ensure a carbohydrate intake of 60–70 g/h. A higher carbohydrate intake may result in gastrointestinal problems; a lower intake may result in a suboptimal carbohydrate delivery [51].

The fluid intake should be 0.4–0.8 L/h, although it should be adapted to the tolerance and experience of the athletes [50].

In terms of protein intake, 0.05–0.08 g/kg of body weight in activities or workouts lasting more than 1.5 h is recommended during exercise.

In addition, the relatively high-intensity, long duration, and frequent workout schedules of most competitive athletes may place them at greater risk of thermoregulatory complications during pregnancy. Particular attention should be paid to maintaining proper hydration during and between these exercise sessions. Fluid balance during an exercise session can be monitored by weighing before and after the session. Any loss of weight is a fluid loss that should be made up before the next exercise session (1 lb. weight loss ≈ 1 pint of fluid). In addition, the consumption of so-called energy drinks is not recommended, because they normally present high amounts of caffeine [42].

11.4.4 Dietary Intake After Physical Exercise

Following the exercise or training, is recommended the intake of carbohydrates along with proteins. 0.8–1–1.2 g/kg of carbohydrates must be ingested together with 0.25–0.4 g/kg of proteins of high quality.

The muscle adaptation to training can be maximized by ingesting 0.3 g/kg/BW to high quality after key exercise sessions and every 3–5 h [52].

Effective rehydration requires the intake of a great volume of fluid (1.25–1.5 L fluid for every 1 kg of body weight lost). Fluid balance during an exercise session can be monitored by weighing before and after the session. Any loss of weight is a fluid loss that should be made up before the next exercise session (1 lb. weight loss ≈1 pint of fluid).

11.5 Unhealthy Habits to Avoid

11.5.1 Alcohol, Smoking, Caffeine, and Non-nutritive Sweeteners

Generally, the fetal development is the most susceptible period of exposure to two modifiable lifestyle factors, such as alcohol and tobacco.

The consumption of alcohol during pregnancy promotes a range of effects in exposed children, including hyperactivity and attention problems, learning and memory deficits, and problems with social and emotional development.

The most serious outcome of maternal drinking during pregnancy is the fetal alcohol syndrome. Although it seems clear that heavy alcohol consumption during pregnancy can produce fetal alcohol syndrome, the consequences at low-to-moderate levels on children's neurodevelopment are much less obvious. Safe levels of alcohol consumption during pregnancy have not yet been established, so it is recommended to avoid alcohol consumption during pregnancy [53].

On the other hand, according to the data from epidemiological studies, we can suppose that about 20–30% of women actually smoke during pregnancy and about half of the non-smoking pregnant women are exposed to passive smoking [53].

The results from population-based birth cohort (Generation R Study) reflected that children of mothers who continued smoking during pregnancy had a higher risk of behavioral problems at 18 months compared to the children of mothers who never smoke with adjustment for age and gender ($p < 0.05$). According to recently published analysis, based on the data from prospective Polish Mother and Child Cohort, with assessment of exposure based on biomarker measurements (three times in pregnancy and in children at 1 and 2 years of age), cotinine level in saliva collected during pregnancy was significantly associated with decreased motor abilities at 24 months of age ($p = 0.02$) and not with cognitive and language achievements after controlling for variety of confounders [53]. For these reasons, tobacco consumption should be avoided either actively or passively.

As for caffeine consumption during pregnancy, intake of ≥6 units/day during pregnancy is related with impaired fetal weight and length growth [54].

Pregnant women have slower caffeine metabolism, with 1.5–3.5 times longer half-life needed to eliminate caffeine, compared to nonpregnant women [55].

The fetal growth characteristics associated with length or skeleton appear to be more affected from the first trimester onward. Pregnant women should be advised not to consume ≥6 units of caffeine (>540 mg) per day during pregnancy [54].

On the other hand, the American Congress of Obstetricians and Gynecologists states that moderate consumption of caffeine (<200 mg/day) during pregnancy is not a major risk factor for miscarriage or premature birth [56].

Finally is the consumption of sweeteners during pregnancy. The nutritional environment during embryonic, fetal, and neonatal development plays a very important role in the offspring's risk of developing diseases later in life. Non-nutritive sweeteners furnish the sweet taste without increasing the energy supply. Animal studies showed that long-term consumption, particularly of aspartame, starting during the perigestational period, may predispose the offspring to develop obesity and metabolic syndrome later in life [57].

Human extrapolation should be performed very cautiously, as well-designed clinical studies that evaluate the metabolic effects of non-nutritive sweeteners in humans are still lacking. In turn, the adverse effects associated with non-nutritive sweeteners found in animal studies suggest that its use in the human diet as an alternative to nutritive sweeteners during pregnancy should be carefully examined before recommending or not using them [57].

11.5.2 Lack of Sleep

Daily sleep requirements are increased as early as the first trimester of pregnancy, as well as daytime sleepiness in this period of the woman's life cycle [58–64]. In pregnant women, insufficient sleep in quantity and quality may result from sleep disturbances, such as insomnia, restless legs syndrome, and sleep apnea [65].

Restless legs syndrome is two to three times more prevalent in pregnant women than in the general population [66], characterized by an unpleasant sensation leading to sudden movement of the legs, often associated with pain, which hinders the onset of sleep. The scientific literature demonstrates an association between sleep disturbances and negative consequences of pregnancy [67–69], namely, a high risk of preeclampsia, cesarean delivery, and depressive symptomatology [70–72]. The peak incidence occurs in the third trimester, and in most cases the symptoms disappear 1 month after giving birth [66, 73]. These symptoms can be relieved by the movement of the legs, such as walking or kicking. It is probably due to anomalies in the neurotransmitter dopamine [28].

In pregnant women, sleep apnea is associated with overweight and obesity. The breathing is momentarily interrupted and may be accompanied by the typical snoring. Therefore, pregnant women may experience excessive drowsiness during the day, as their sleep may not have been remedial [28]. Since interruption of regular breathing or airway obstruction during sleep may represent serious health complications, symptoms of sleep apnea should be evaluated and monitored during pregnancy [65].

11.6 Conclusion

As pregnancy progresses, several changes occur that will prevent the exerciser or athlete from attaining the same performance levels as before pregnancy. Weight gain, by itself and in the presence of laxity of joints and ligaments and change in the center of gravity, will cause unavoidable limitations in most sporting activities. The ability to stop and start or to change direction will progressively decrease. Any attempts to substitute compensatory movements for finely tuned skill movements result in inefficient movement, decrease in competitive ability, and increase in the risk of injury. Performance in sports in which endurance is important may be adversely affected by the physiological anemia commonly associated with the increased blood volume of pregnancy.

Despite the fact that pregnancy adversely affects performance in the competitive athlete, most elite athletes prefer to continue to train during pregnancy.

In fact, pregnant athletes tend to maintain a more strenuous training schedule throughout pregnancy and to resume high-intensity postpartum training sooner. The concerns of the pregnant, competitive athlete fall into two general categories: the effects of pregnancy on competitive ability and the effects of strenuous training and competition on pregnancy, particularly the fetus. Such athletes would certainly require closer obstetric and nutritional supervision than the routine prenatal care. Additional testing and intervention should occur as clinically indicated.

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