Physical Activity and Pregnancy

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Introduction

Regular physical activity during pregnancy benefits both maternal and infant health [1]. Regardless of the physiological changes women undergo during pregnancy, pregnant women benefit from physical activity just as much as nonpregnant women [2]. The complexity of assessing physical activity during pregnancy hampers the determination of the optimal amount of recreational physical activity for pregnant women [3] and has led to broad physical activity guidelines being proposed for pregnant women. Concurrently, pregnancy is characterised by a reduction in physical activity [4] resulting in discrepancies between physical activity during pregnancy and the guidelines set by various institutional and governmental entities [5–12].

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Physiological Adaptations to Pregnancy

The duration of a pregnancy averages 266 days (38 weeks) after ovulation, or 280 days (40 weeks) after the first day of the last menstrual cycle. This period equals 10 lunar months, or just over 9 calendar months [13]. Physiological changes during pregnancy are divided into a series of stages and sub-stages, and the entire process is then subdivided into three relatively equal trimesters [14].

All maternal physiological systems adapt to the demands of pregnancy; however, the quality, degree and timing of the adaptation varies from one individual to the next and from one organ system to another [15–16]. The adaptations are mostly mediated due to the effects of progesterone and oestrogen that are produced, predominantly by the ovary in the first 12 weeks of pregnancy and thereafter by the placenta [15]. These adaptations enable the foetus and placenta to grow and prepare the mother and baby for parturition [15, 17].

Physiological changes, as a result of pregnancy, represent a serious challenge to all body systems [17]. While these adaptations do not pose major risks for healthy women, the normal physiological changes of pregnancy can place significant strain on already compromised systems, threatening the lives of both the mother and the foetus during parturition [17].

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Cardiovascular Adaptations During Pregnancy

Profound physiological changes occur in the cardiovascular system during pregnancy [17]. Circulating blood volume increases in order to meet the demands of the developing foetus and placenta. During pregnancy, there are major alterations in blood volume, constituents of cells and coagulation factors [16, 17]. A substantial part of maternal weight gain during pregnancy results from fluid accumulation, specifically plasma volume [16]. This increase in plasma volume supplies the necessary nutrients to the uterus and the placenta and ensures the removal of waste products from the uterus and placenta [14]. The increase in the plasma volume is to counter the decrease in the low pressure circulatory system that resulted due to the increase in vascular dilatation. Overall blood pressure decreases too, more specifically diastolic blood pressure to a greater extent than systolic blood pressure [14]. Blood pressure decreases despite an increase in blood volume and cardiac output, due to a decrease in systemic and pulmonary vascular resistance [18]. In addition to the previously mentioned changes, change to the cardiovascular system includes an increase in cardiac output, the product of heart rate and stroke volume [14, 19]. Initially, the increase in cardiac output is mediated by the increase in stroke volume. As pregnancy progresses, an increase in heart rate becomes the dominant factor to increase the cardiac output [18].

Respiratory Changes During Pregnancy

Numerous changes occur in the maternal respiratory system during pregnancy to ensure sufficient oxygen supply to the placenta for increased foetal energy demands and for foetal physiology [15–17]. The net physiologic change in the respiratory system is a lowering of the maternal PCO_2 to facilitate effective exchange of CO_2 from the foetus to the mother [16, 17]. The oxy-haemoglobin dissociation curves of foetal haemoglobin and adult haemoglobin allow the foetus to extract oxygen effectively from the maternal circulation [16]. The effects are mediated by hormonal factors that influence the respiratory centre, specifically progesterone [20]. An increase in progesterone stimulates the respiratory centre to increase minute volume, lowers the threshold of carbon dioxide concentrations [20] and may also decrease airway resistance, facilitating a greater airflow during maternal respiration [21, 22].

Musculoskeletal Changes During Pregnancy

Hormonal changes, specifically, changes in progesterone and relaxin levels, lead to increased joint laxity and hyper-mobility [23], which could potentially raise the risk of injury during exercise in pregnancy [10]. Increased body weight, as a result of foetal growth, increases the forces imposed on the joints such as the hips and knees [24]. Since the abdomen expands anterior during foetal growth, the centre of gravity shifts during pregnancy, resulting in postural adjustments, specifically an extension of the lumbar spine [14], which realigns the body mass above the base of support [25]. Elongation and decreased tone of the abdominal muscles may ensue because of the prolonged maintenance of the abovementioned position [14]. The combination of weight gain, altered postural alignment and ligamentous laxity causes changes in proprioception and postural balance in pregnant women [26]. The postural changes associated with pregnancy result in pregnant women adapting their stance and gait with a longer double limb support time and changes in the angles of hip, knee and ankles, suggesting an adaptation in locomotion to become more efficient [27] that might also influence energy expenditure of gait during pregnancy.

Endocrine Changes During Pregnancy

Since the development of the foetal origin of disease in later life hypotheses (described later in this chapter), plenty of research focused on the intrauterine environment, specifically with regard to hormonal changes during gestation as summarised by Kuijper et al. [28] in a systematic review that found both endogenous and maternal hormones to influence the foetus. Foetal development and sustained essential physiological functions for both mother and foetus are mediated by an increase in the release of specific hormones [29] such as oestrogen, progesterone, human chorionic gonadotropin, prolactin, adrenocorticotropic hormone, thyroid-stimulating hormone, cortisol and thyroid hormones [30]. The mass of cells that forms on the ovaries, the corpus luteum, is the main source of pregnancy-sustaining hormones during the first 6–8 weeks of gestation [31]. As previously mentioned, the majority of hormonal changes in pregnancy are related to the activity of the placenta [30]. The placenta takes over the role of the corpus luteum later in the pregnancy. The changes to hormones during pregnancy and their effects include:

- Oestrogen, which stimulates glandular tissue and ducts in the breast and increases prostaglandin and oxytocin production [13].
- Progesterone, which mediates vital physiological function during pregnancy, including an increased mobility of the joints [13].
- Relaxin, which functions synergistically with progesterone to decrease uterine activity during pregnancy and to suppress oxytocin release [14]. Relaxin also affects the connective tissue to increase the mobility of the joints, in a similar way to progesterone [26].
- Cortisol secretion, which increases from the second trimester of pregnancy to meet the body's extra metabolic workload [30].
- Human chorionic gonadotropin levels increase, which is linked to changes in appetite, sleep patterns and food tolerance in the first trimester [30].
- Thyroid hormones, both T_3 and T_4, increase, causing the basal metabolic rate to increase during pregnancy [32].

In summary, the changes observed in the physiological systems during pregnancy (Fig. 16.1) simulate the adaptations observed in nonpregnant women who perform regular aerobic exercise to a large degree.

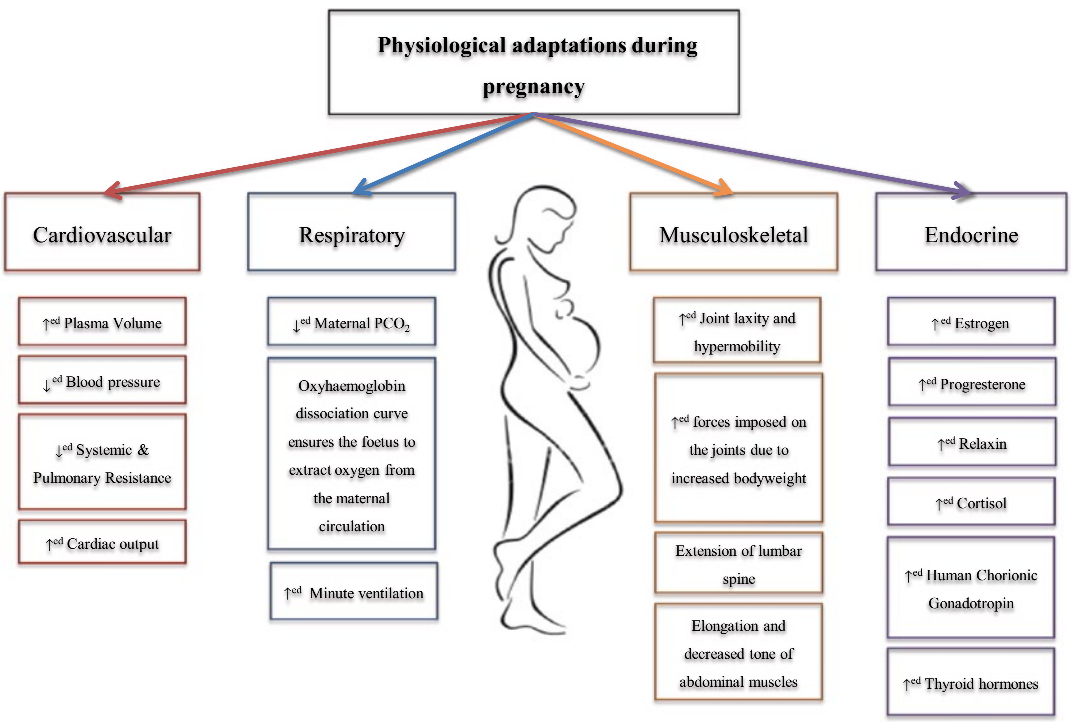

Fig. 16.1 Summary of the physiological adaptations during pregnancy

Metabolic Adaptations to Pregnancy

Energy Intake During Pregnancy

The physiological changes that occur during pregnancy cause an increased demand for dietary energy as a result of increased oxygen consumption, respiration, circulation and renal function of the foetus during development [33]. From conception to birth, all the growth of the foetus is possible because of the nutrients the mother consumes [34]. The nutrient needs during pregnancy and lactation are higher than any other time in a woman's life [34]. This high nutrient demand during pregnancy is met with an increased energy intake, as well as help from the mother's body that maximises absorption and minimises energy expenditure [34].

The energy needs of pregnant women exceed those of nonpregnant women by an additional 340 kilocalories per day during the second trimester and extra 450 kilocalories per day during the third trimester [34]. The additional kilocalories represent 15–20% more food than before pregnancy for an average 2000-kilocalorie daily intake. Ample carbohydrates are essential for fuel to the foetal brain, which ensures that the protein needed for growth is catabolised and used to synthesise glucose [34]. The extra energy demands of pregnancy can be met by an increase in food intake or by the mobilisation of energy fat stores of the mother, particularly those mothers with sufficient energy reserves [35].

The additional energy requirements during pregnancy can be described as the energy needed for maternal tissue and foetal growth, as well as the energy required for the rise in basal metabolic rate and the changes in physical activity [35]. Energy requirements during pregnancy remain controversial because of conflicting data on maternal fat deposition and putative reductions in the mother's physical activity as the pregnancy advances [36].

Energy Expenditure During Pregnancy

Total daily energy expenditure (TDEE) consists of three general factors: resting metabolic rate, thermogenic effect of feeding and physical activity [34, 37]. TDEE for the nonpregnant healthy woman is calculated as the energy expended on resting metabolic rate (60–75%), thermogenic effect of feeding (10%) and physical activity (25–30%). TDEE increases during pregnancy because of tissue growth, an elevated basal metabolic rate and the increased energy costs of moving a heavier body [38].

Resting metabolic rate (RMR) accounts for all the metabolic activities in the human body [34]. Human metabolism involves all the body's chemical reactions of biomolecules that cause anabolism and catabolism. RMR varies dramatically from person to person and for the same individual with a change in circumstances or physical condition (with pregnancy being an extreme physiological condition) [34]. Pregnancy is a dynamic, anabolic state where the human body obtains energy for growth and maintenance [39].

The enhanced work of pregnancy raises the RMR dramatically and demands extra energy [40, 41]. This is calculated by Prentice et al. [42] as 20% in late pregnancy. Forty percent of this variability is explained by the percentage of total body fat before pregnancy and the gain in body weight during pregnancy [35, 41]. Body fat gain accounts for about 55.5 ± 20% of total weight gain during pregnancy [43]. According to Löf et al. [41], factors that are responsible for the variability in RMR response during pregnancy differ in the earlier and later trimesters of pregnancy. Most of the total body fat mass is deposited during the second trimester, with little change taking place in the first and third [44]. Chamberlain and Popkin [33] developed a theoretical model to estimate energy requirements during pregnancy (Fig. 16.2) [45], assuming an average gestational weight gain (GWG) of 12.5 kg (≈0.925 kg protein, ≈3.8 kg fat, and ≈7.8 kg water), which is associated with an increase in RMR [41].

The thermogenic effect of food is attributed to the digestion process and the energy cost of storage of the exogenous macronutrient is proportional to the food energy that is consumed [34]. This diet-induced thermogenesis seems to be unaltered [36, 42, 46–49] or even reduced [44, 50, 51] during pregnancy.

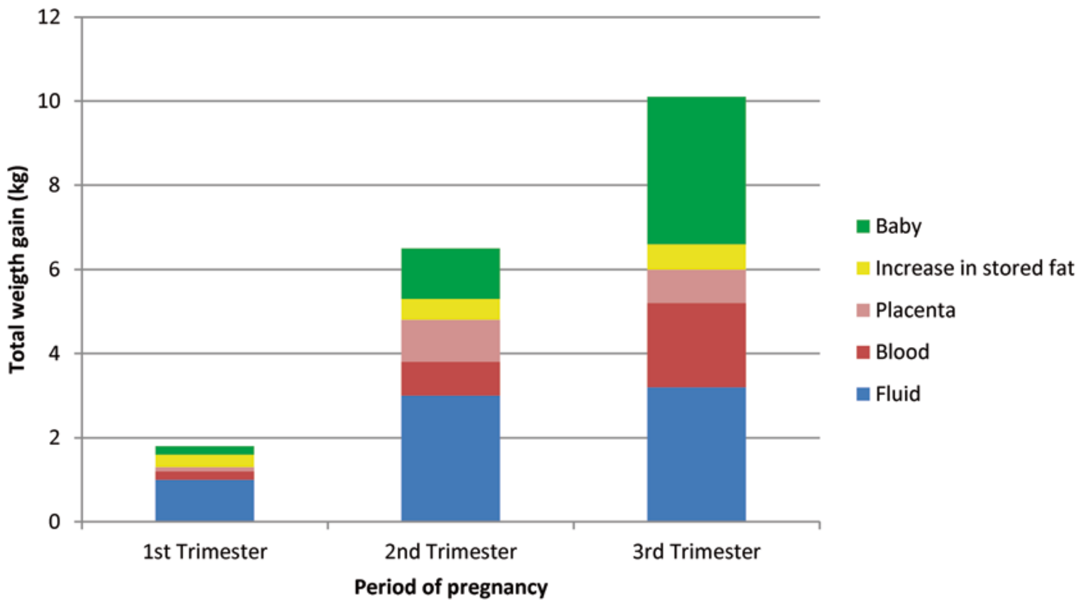

Fig. 16.2 Estimated factors contributing to weight gain during pregnancy. (Based on data from [45])

The most varying factor that determines total energy expenditure is physical activity and is dependent on three factors: muscle mass, body weight and level of activity [34]. The interaction between physical activity and energy metabolism is complex. For example, pregnant women may reduce physical activity energy expenditure by selecting less demanding activities or reducing the pace of activity, although the actual cost might be higher, because of moving a heavier body [38]. However, all pregnant women might not reduce their physical activity because of the knowledge they have of the health benefits of regular physical activity during pregnancy. Over the past 2 years, more studies have focused on the energy expenditure during pregnancy, especially in the wake of the rapid increase in obesity, globally. The measurement of total energy expenditure during pregnancy is controversial, mainly because of conflicting data on the extent of reduction in physical activity as pregnancy advances [35] and the collection of physical activity information with self-report questionnaires.

The energy cost that is attributed to physical activity during pregnancy is generally lower [40, 52–55] and tends to decrease as pregnancy advances [56–60]. Studies show that pregnant Scottish [61] and Dutch [60] women had a slight decrease in absolute energy cost of physical activity, observed in activity diary studies, as their pregnancy advanced. The same results were found in British women by Prentice et al. [42] by means of whole body indirect calorimetry methodology. However, Melzer et al. [35] found this decrease in active energy expenditure insignificant in pregnant women in Sweden and America, but when expressed as per unit of body weight to account for weight differences, this result became significant. Other studies from Sweden and the UK report similar decreases in active energy expenditure per kilogram in the pregnant compared to the nonpregnant state [42, 54]. Preliminary findings of the **H**abitual **A**ctivity **P**atterns during **P**regnanc**Y** (HAPPY)-study in Potchefstroom, South Africa, indicate a 25 % reduction in activity energy expenditure from the first to the third trimester of pregnancy. The study included participants from white, black and coloured ethnic groups as well as low-, middle- and high socioeconomic groups [62]. The physical activity levels (PAL) reported can be classified as low activity to sedentary behaviour from the first to the third trimester of pregnancy.

Reasons for this decrease in physical activity are explained in the following section. However, physical activity cannot be observed in isolation when activity energy expenditure is discussed because the energy intake is also important in the energy balance. More details regarding behavioural changes in activity patterns are discussed in the following section.

To better understand the associations between energy intake, energy storage and energy expenditure during pregnancy, studies should be carried out during free-living conditions applying the most objective and reliable methodology [38]. The correct measuring tool is essential to quantify physical activity during pregnancy.

Measurement of Physical Activity During Pregnancy

Critical appraisal of the physical activity during pregnancy and the influence of recreational or habitual physical activity on birth outcomes and maternal health are dependent on valid and reliable objective measurements of physical activity [3]. The relationship between physical activity and birth outcomes is likely to be modest, therefore it is essential to measure recreational physical activity accurately to minimise the possibility that no effect is observed because of a measurement error [3]. The majority of information on physical activity in the pregnant and nonpregnant population is based on subjective physical activity questionnaire-collected data. The current guidelines for physical activity are therefore also based on the research based on the subjective data. Changes in technology have given rise to the development of more objective instruments to determine habitual physical activity, not only in the general population but also in pregnancy.

Subjective Physical Activity Measurements

A great variety of physical activity questionnaires have been developed and validated over the past 20 years. The accuracy of self-reporting questionnaires is influenced by the subjective nature of the term "intensity of physical activity" [63]. Physical activity questionnaires emphasise participation in moderate to vigorous sports while not including household or childcare activity [64]. Indeed, women spend considerable time and energy in moderate intensity activities related to household chores, their job and family care [65]. Interestingly, the accuracy of short- and long-term recollections of physical activity patterns by pregnant women is not known [66]. According to Poudevigne and O'Conner [66] there is a lack of knowledge regarding how accurately women can recall their physical activity patterns during pregnancy.

Direct measurements of the metabolic cost of energy expenditure among pregnant women, as opposed to relying upon values collected among nonpregnant populations, will objectively define the intensity of recreational activity among pregnant women [3]. For this purpose, doubly-labelled water and indirect calorimetry [67, 68] are used to measure physical activity, but because of the costs, invasiveness and technical sophistication of these methods, their suitability for the general population decreases.

In large samples and population-based studies, questionnaires have been the instrument of choice. Hermann et al. [69] determined the validity of two questionnaires, namely the International Physical Activity Questionnaire (IPAQ) [70, 71] and the Global Physical Activity Questionnaire version 2 (GPAQ) [72]. The GPAQ shows short- and long-term retest reliability and modest validity [69], although it has not been validated in the pregnant population. Specifically during pregnancy, four validated questionnaires are currently being used to determine physical activity [73–76]. A validated, self-administered questionnaire, the Pregnancy Physical Activity Questionnaire (PPAQ) has been used to assess the physical activity levels of pregnant women [74]. Categories in this questionnaire include: household/care-giving, occupational, sport/exercise, transportation and inactivity [77] and asks women to estimate the duration and frequency of time spent per activity during the current trimester of pregnancy. The reliability of the PPAQ for total physical activity was strong ($r=0.78$), with the highest reliability for moderate intensity activity ($r=0.82$). With regards to activity type, the highest reliability was found for occupational activity ($r=0.93$), followed by household/caregiving ($r=0.86$) and sports/exercise ($r=0.83$). The validity of the PPAQ was determined against accelerometry (ActiGraph). The overall correlations between the PPAQ and average counts per minute were within the range of values observed for the published cut points ($r=0.27$ for total activity), while validity coefficients for vigorous activity ($r=0.37$) and sports/exercise ($r=0.48$) were higher using average counts per minute. PPAQ provides an easy method of assessing physical activity patterns in women with uncomplicated pregnancies [77].

Objective Physical Activity Measurements

Both accelerometers [55, 78] and heart rate monitors [79] have been used to measure daily physical activity accurately. However, when these devices are used separately, they have disadvantages [80]. Heart rate is influenced by temperature, humidity, fatigue and emotional stress. [81]. Additional challenges are the loss of data from signal interruptions and delayed heart rate responses [82, 83]. Accelerometers on the other hand are not waterproof and cannot monitor activities in water [80]. Also, static physical activity, such as weight lifting, generates less body movement but requires energy expenditure, which can be problematic when accelerometers are used [84, 85].

To continually measure free-living physical activity, a combination of the abovementioned accelerometers and heart rate monitors are used and could provide more accurate activity profiles by overcoming individual sources of error [84, 86–89]. One such device that combines heart rate and accelerometry is the ActiHeart® (CamNTech, UK) [80], which was first used by Melzer et al. [35] to measure changes in resting and activity-related energy expenditure during pregnancy. The device is currently the only commercially available device that combines acceleration and heart rate, therefore increasing the practical applicability to improve energy estimates compared to traditional acceleration devices [90]. ActiHeart® is a 10 g, waterproof, self-contained logging device that allows activity to be measured synchronously with heart rate at between 15–60 s epochs [91]. The device is worn on the chest and consists of two electrodes that are connected by a short lead and clip onto two standard electrocardiograph (ECG) pads. Free-living data, as assessed by the ActiHeart® and calculated according to branched models, is essential to determine behavioural changes in activity patterns in pregnant women [35]. The ActiHeart® device has shown accurate estimates of energy expenditure versus indirect calorimetry over a wide range of activities (varying from sedentary behaviours to vigorous physical activity) in men and nonpregnant women, although it is not validated specifically for pregnant women [35]. Brage et al. [92] conclude that the ActiHeart® is a reliable and valid tool for the measurement of movement and heart rate in humans at rest and during walking and running. Overall, the ActiHeart® is reliable in measuring and categorising intensities of physical activity [80] in addition to increased monitor-wear compliance in adolescents [93] (Fig. 16.3).

The complexity of assessing physical activity in general, and in particular, during pregnancy, a demanding period characterised by changing physiology, hampers the determination of the optimal dose of recreational physical activity for pregnant women [3]. Because of the well-documented advantages of regular exercise in non-

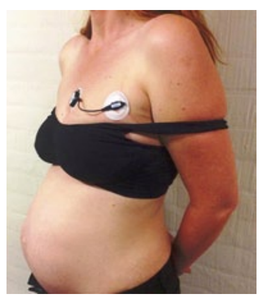

Fig. 16.3 Combined heart rate and accelerometer device (ActiHeart®, CamNtech, UK) placement for the measurement of habitual activity energy expenditure in pregnancy

pregnant women, similar findings are expected during pregnancy. A lack of measuring instruments limits studies on the direct effect of physical activity levels on the growth of the foetus and maternal and foetal birth outcomes. The results are that health professionals have been very conservative in the volume (intensity x duration) and frequency of exercise and physical activity that are recommended to pregnant women. These guidelines have therefore impacted directly on habitual activity patterns during pregnancy.

Physical Activity Patterns During Pregnancy

The physical activity patterns of pregnant women are poorly described [66]. Maternal physical activity tends to decrease during pregnancy because of the minor discomforts that are associated with pregnancy, such as leg cramps, swelling, fatigue, shortness of breath [94], difficulties in movement related to a larger body mass [2] and, sometimes, because of the perception that physical activity may be damaging to the foetus [95, 96].

Physical activity patterns vary across the duration of pregnancy and are generally at a lower level when compared to pre-pregnancy [3, 97]. Prospective studies indicate that recreational, occupational and overall physical activity declines during pregnancy [52, 55]. Physical activity is usually constrained in the first trimester because of nausea, vomiting and profound fatigue [8, 66]. These symptoms usually decrease in the second trimester. Physical limitations—like uterine enlargement and changes in weight distribution [66]— also lead to a decrease in physical activity in the third trimester [8]. Reductions in physical activity, especially in the third trimester, might also be a method to meet the increased energy demands of pregnancy [98]. Physical activity often decreases the most during the third trimester of pregnancy. This decrease in physical activity has sometimes been referred to as the "nesting effect", as pregnant women prepare their home for the arrival of a new baby [66].

Psychological changes, such as a declining body image and depression may make physical activity less attractive during pregnancy [99]. In contrast to this, some of the barriers to physical activity during pregnancy, such as depression and fatigue, can be attenuated by regular exercise [66]. Exercise intensity decreases as many women cease vigorous sport activities when pregnant [100–102]. Evidence indicates that the primary mode of physical activity by pregnant women is low intensity walking [103, 104]. There is a shift in the nature of the activities pregnant women usually perform, to activities that are less vigorous, more comfortable or perceived as safer, like walking and swimming and less bicycling [66, 105, 106]. Work-related physical activity also decreases as pregnancy proceeds [66].

A study done by Löf [38] found that pregnant women, compared with nonpregnant controls, spend less time (1.5 h/24 h) standing and performing moderate activities and more time (1.5 h/24 h) on sedentary activities such as sitting and reclining. Additionally, absolute active energy expenditure decreased by 18 % [38]. The PAL was also significantly lower than the corresponding value for nonpregnant controls per 24-h period [38]. However, as stated by Prentice et al. [42], the use of PAL on pregnant women is not advisable because even if active energy expenditure (total energy expenditure—basal metabolic rate) is unchanged, PAL will still decrease as basal metabolic rate increases during pregnancy. These findings correspond with an American study that confirmed a decrease in active energy expenditure by 13 % as recorded with activity records [40]. However, another study on healthy Swedish women indicated no major effect of pregnancy on activity patterns or on active energy expenditure [54] (Fig. 16.4).

While all of the abovementioned factors contribute to the decreased pattern of physical activity during pregnancy, the strongest predictor of physical activity during pregnancy is the level of physical activity during the year prior to pregnancy [107, 108]. If pregnant women were active as teenagers, they were 13 times more likely to engage in high intensity physical activity during pregnancy as compared to sedentary teens [107]. Highly active women may be more aware of the health benefits of exercise and may have more confidence in their ability to choose an appropriate mode and intensity of exercise [66]. As with

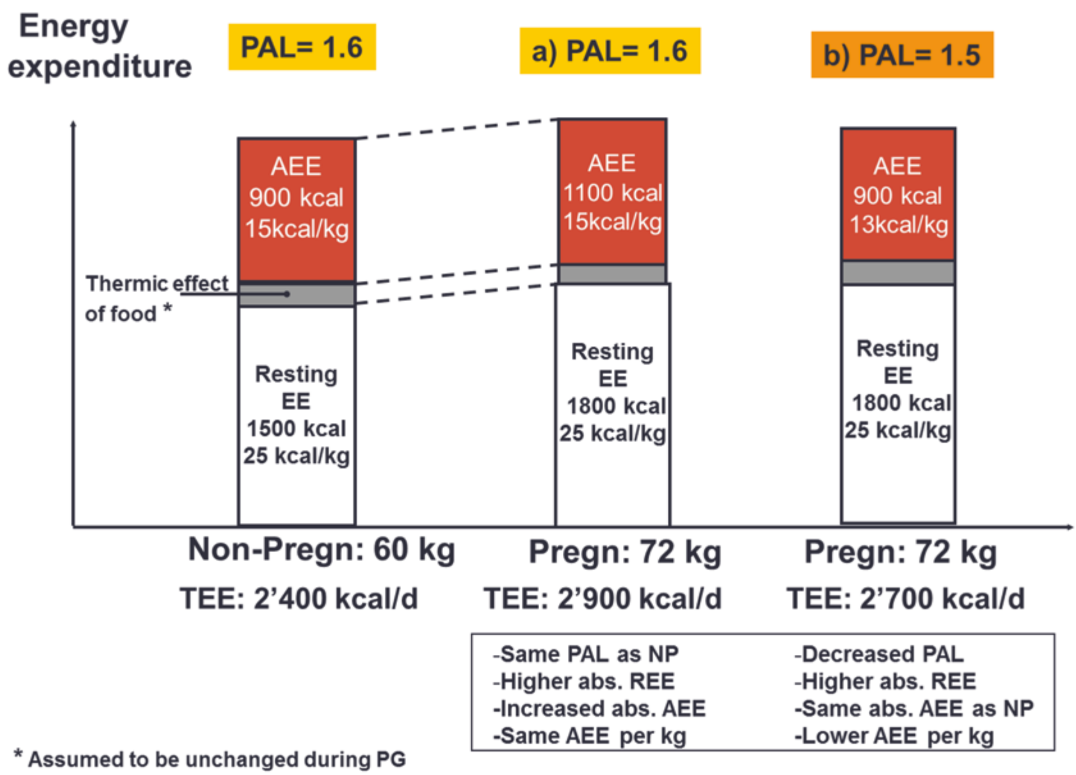

Fig. 16.4 Energy expenditure for nonpregnant versus pregnant women at different physical activity levels. *PAL* physical activity level, *AEE* activity energy expenditure, *EE* energy expenditure, *TEE* total energy expenditure, *NP* nonpregnant; *REE* resting energy expenditure, *kcal* kilocalories, *kcal/d* kilocalories per day, *kg* kilogram

women who were sedentary before pregnancy, some started becoming physically active when they were pregnant, according to a few studies [97, 100, 108, 109]. This indicates that these women consider their pregnancy to be a chance to change their lifestyle [100]. Few studies document longitudinal changes in physical activity during all three trimesters [102, 110, 111]. It is expected that the majority of pregnant women would have low levels of physical activity since PALs of the general nonpregnant population are globally reported to be low.

Very limited research exists pertaining to the physical activity patterns of South African women [112]. Results from a single South African study, determining physical activity subjectively during pregnancy [112], found no change in PALs between the second and third trimester. This contradicts previously mentioned studies that found a decline in physical activity as pregnancy progressed. This contradiction can be explained by the fact that the patients in the study were recruited from a gynaecologist who advocated exercise during pregnancy [112].

Hegaard et al. [100] found that women with a higher body mass index (BMI; more than 25 kg/m^2) decreased their physical activity during pregnancy more than pregnant women with a normal weight (BMI 18.5–24.99 kg/m^2). Changes in physical activity during pregnancy are extremely detrimental because this decrease results in an even higher risk of gestational diabetes, pre-eclampsia or preterm delivery than in women who continued their normal level of physical activity [113–115].

The most extreme type of physical inactivity is bed rest, which is recommended by obstetrics and gynaecology physicians in 20 % of all pregnancies [66]. Bed rest is recommended in the hope of preventing or treating a wide variety of conditions, including spontaneous abortion, preterm labour, foetal growth retardation, oedema and pre-eclampsia [116]. Little evidence exists regarding the effectiveness of bed rest on the treatment of these conditions [117]. The adverse effects of bed rest may be even more detrimental than the conditions it is meant to prevent or treat, like decreased sex steroids, insulin resistance, systemic inflammation, mood disturbances and even progressive bone and muscle loss compromising the ability to perform tasks of daily living [118]. Additionally, Poudevigne and O'Conner [66] state that a combination of biological, psychological, social and environmental factors interacts to contribute to changes in physical activity during pregnancy.

Physical activity in the postpartum period is usually decreased, because of the added fatigue of delivery and newborn care [8]. However, less is known about physical activity during the postpartum period and in the change in activity from pregnancy to postpartum [119]. Data from the HAPPY-study that objectively determined physical activity indicate the activity counts in a sample of 70 women decreased by 20% from the third trimester to 3 months postpartum [62]. According to Pereira et al. [102], walking as a physical activity modality might remain unchanged from pre-pregnancy to postpartum. Usually care-giving physical activity in the postpartum period constitutes the largest proportion of total physical activity [119].

In summary, a reduction in physical activity during pregnancy augments the need to promote regular physical activity of pregnant women as a necessary part of their lifestyle due to the minimal risk and numerous short- and long-term benefits for both the mother and the baby. Education about the benefits of regular physical activity during pregnancy must be included in the planning and implementation of health promotion programmes by medical personnel and physical education staff [120].

Benefits of Regular Physical Activity During Pregnancy

Physical activity is a major determinant of lifelong health [121, 122] and has been associated with reduced morbidity and mortality [123–125] by serving as a primary preventive behaviour for several chronic health conditions including coronary heart disease [126–128], cancer [128], type 2 diabetes [129], [130], stroke [131], metabolic syndrome [132] and osteoporosis [133].

Maternal benefits of physical activity appear to be both physical and psychological in nature [10]. Physical benefits during pregnancy include shorter labour and a lower incidence of operative abdominal and vaginal deliveries and acute foetal distress [2, 128, 134–136]. Benefits for pregnant women also include improved cardiovascular function [2], reduced incidence of muscle cramps and lower limb oedema [137, 138], attenuation of gestational diabetes mellitus [139, 140] and gestational hypertension [24].

Physical activity does not only have physical benefits but also improves psychological health and provides wellbeing benefits [105, 141, 142]. An increased level of physical activity is known to have a protective effect against insomnia, stress, anxiety and depression [143–146], relieve job strain [147] and provide mood stability [66, 148] as well as increased perceived levels of energy during the day [149]. These benefits carry over to the postpartum period [149] and do not compromise infant breast milk acceptance of infant growth [150].

Kalisiak and Spitznagle [151] reviewed clinically controlled trials that demonstrate that there is a moderate amount of evidence proving that exercise during pregnancy in healthy females has positive effects on both the mother and the foetus. While many studies conclude a positive relationship between physical activity and pregnancy outcome, the majority of the studies applied subjective questionnaires to determine the relationships. Therefore, accurate and objective methods to measure levels of physical activity are important when defining an appropriate relationship between physical activity and health outcomes for both the mother and foetus [90].

Recent meta-analyses of randomised control trails determining the effect of structured and supervised exercise during pregnancy report that pregnant women who exercised gained significantly less weight (−1.13 kg) than women in the control group. The birth weight was however not significantly reduced in the exercise group compared to the control group [152].

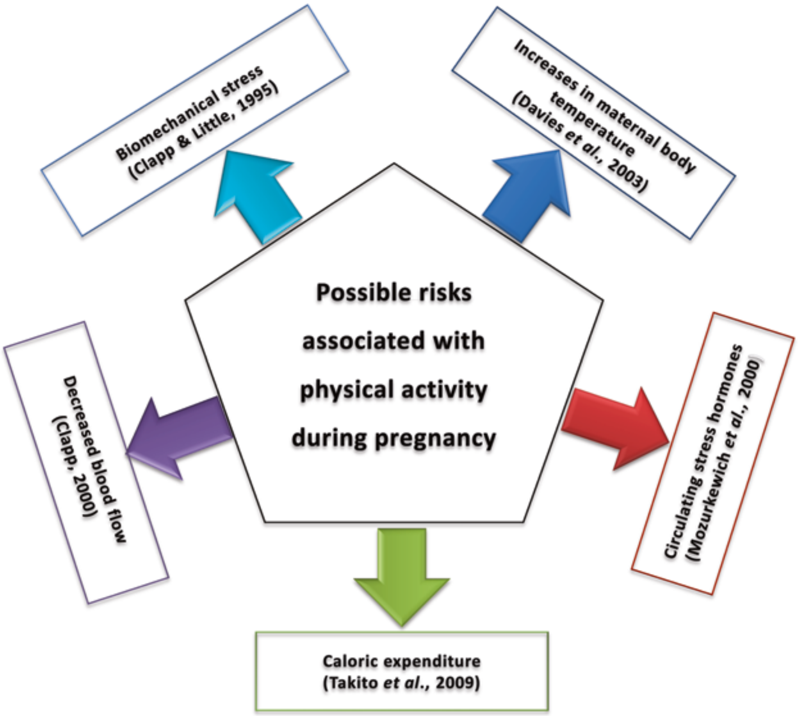

Fig. 16.5 Possible risks associated with physical activity during pregnancy. (Courtesy of Andries Fourie van Oort, M.Sc.)

Risks Associated with Physical Activity During Pregnancy

Physical activity was discouraged until the early twentieth century on the basis of theoretical concerns about exercise-induced injury and adverse foetal and maternal outcomes [31, 144]. These concerns were based on the potentially detrimental effects of exercising on the mother and the foetus, secondary to increases in maternal body temperature, circulating stress hormones, caloric expenditure, decreased blood flow and biomechanical stress [153, 154] as seen in Fig. 16.5 [155].

Biological mechanisms that might contribute to reduced birth weight and length of gestation were theorised by [156]. They suggest that these effects are mediated by the sympathetic nervous system and may also be associated with the release of prostaglandins into the maternal circulation. Physical strain may lead to the release of catecholamines, which may increase maternal blood pressure and uterine contractility and decrease placental function [157].

Another concern of physical training during pregnancy is the subsequent teratogenic effect of hyperthermia in the first trimester [7, 155, 158]. However, this has not been shown to occur in studies of exercising women [8], because an increase in minute ventilation and skin blood flow augment heat dissipation and somewhat inhibit the potential hyperthermic effects of exercise [159]. Even so, exercising while pregnant should preferably take place in a well-ventilated and temperature-controlled environment [7].

The theoretical risk of foetal hypoxia is another concern for the exercising pregnant woman. It was once believed that the demands of exercising muscles divert blood flow from the uteroplacental unit [10]. However, compensatory changes with exercise, such as raised maternal haematocrit and oxygen extraction, appear to prevent the impairment of foetal oxygenation [135, 160]. Takito et al. [161] found that maintaining specific standing postures for a prolonged period could potentially reduce uteroplacental blood flow and lead to decreased foetal growth. Decreased visceral blood flow is suggested to cause potential adverse outcomes, such as congenital malformation, growth retardation, premature labour, brain damage, difficult labour, haemorrhage and maternal musculoskeletal injury [153].

Takito et al. [161] identified high total energy expenditure to potentially be associated with low birth weight, preterm birth and intrauterine growth restriction under the supposition that higher caloric expenditures could withhold energy from the foetus. The risk of maternal musculoskeletal injury due to changes in posture and centre of gravity or fetoplacental injury caused by blunt trauma or stress effects from sudden motions is also a concern [162].

Recommendations of physical activity during pregnancy before the twentieth century were overly conservative [162–171]. Recently, the guidelines have evolved as more reliable research has emerged [14]. The American College of Obstetricians and Gynaecologists (ACOG) found no scientific support that normal pregnant women should limit their exposure to physical activity based on the risks to the foetus and/or mother. However, some studies found that higher daily physical activity is inversely associated with foetal growth [172] and birth weight [173].

Campbell and Mottola [174] found that excessive physical exercise, at a frequency greater than 5 days a week, resulted in a low birth weight. However, their results also showed an equally harmful effect on foetal growth in the group of women who exercised less than two times per week. Magann et al. [175] supported the above-mentioned results and found that less energy expenditure, at work and during leisure time, was associated with an increased risk of preterm birth and low birth weight (< 10th and < 3rd percentile).

The risk–benefit balance of physical activity during pregnancy needs to be assessed. During pregnancy, the risk of a sedentary lifestyle may be more detrimental than an active one [7], since a sedentary lifestyle includes loss of muscular and cardiovascular fitness, excessive weight gain, raised risk of gestational diabetes or pre-eclampsia, development of varicose veins and an increased risk of physical complaints such as dyspnoea, lower back pain and poor psychological adjustment [115, 139, 176]. According to Takito et al. [161], both excessive and insufficient physical activity impact negatively on pregnancy outcomes. Physical activity, done at an appropriate level for the physical condition of the woman, is beneficial to foetal growth, with the extremes being inactivity/sedentarism and a prolonged duration of vigorous intensities, which are potentially harmful to the supply of oxygen for adequate foetal growth [160]. However, women with complicated pregnancies have been discouraged from participating in exercise activities for fear of impacting the underlying disorder or maternal or foetal outcomes [8]. Some publications indicate that high levels of strenuous, high-intensity activity may result in preterm labour in susceptible individuals as well as babies with a low birth weight [177–179].

Absolute contraindications to exercise in pregnancy include haemodynamically significant heart disease, restrictive lung disease, incompetent lung disease, multiple gestation at risk for premature labour (≥ triplets), persistent second- or third-trimester bleeding, placenta praevia after 26 weeks' gestation, ruptured membranes, preterm labour, pre-eclampsia, uncontrolled type-1 diabetes and thyroid disease or other serious systemic disorders like chronic bronchitis and uncontrolled seizures [8]. Relative contraindications to exercise include anaemia (defined by the World Health Organization as < 19 g/dL in pregnant women), unevaluated maternal cardiac arrhythmia, extreme morbid obesity and extreme underweight (BMI 8] (Table 16.1).

However, pregnant women should be advised that adverse pregnancy or neonatal outcomes are not increased for exercising pregnant women [7, 180–186], and maternal and infant health can even be enhanced [144, 180, 187–191]. Table 16.2 provides evidence regarding the effects of physical activity on foetal growth and birth outcomes.

Table 16.1 Absolute and relative contraindicators for exercise during pregnancy. (Reprinted from [5]. With permission from Elsevier)

Relative contraindicators	Absolute contraindicators
Severe anaemia	Haemodynamically significant heart disease
Unevaluated maternal cardiac dysrhythmia	Restrictive lung disease
Chronic bronchitis	Incompetent cervix/cerclage
Poorly controlled type 1 diabetes mellitus	Multiple gestation at risk for premature labour
Extreme morbid obesity	Persistent second- or third-trimester bleeding
Extreme underweight	Placenta praevia after 26 weeks of gestation
History of extremely sedentary lifestyle	Premature labour during current pregnancy
Heavy smoker	Ruptured membranes
Poorly controlled hypertension	Pre-eclampsia/pregnancy-induced hypertension
Orthopaedic limitations	
Poorly controlled seizure disorder	
Poorly controlled hyperthyroidism	
Intrauterine growth restriction in current pregnancy	

Table 16.2 Mapping the evidence: Physical activity and foetal growth. (Randomised controlled trials)

Author	Year	Title	Study design	Method	Foetal growth	Outcome
Alderman et al. [192]	1998	Maternal physical activity in pregnancy and infant size for gestational age	Control: women recruited for an epidemiological investigation of risk factors for craniosynostosis Experimental: mothers were identified by random sampling of Colorado live births records for 1979–1988 matched to birth defect registry cases on month and year of birth	Interviews with the adapted Coronary Artery Risk Development in Young Adult Study (CARDIA) Physical activity history (PAH), which classifies activities into 13 groups based on intensity	Birth weight from birth records. Gestational age was reviewed from medical records of the neonatal exam, interview data from the mother and birth records	Maternal physical activity decreased the risk of large-for-gestational-age infants
Bell et al. [193]	2000	Antenatal exercise and birth weight	Experimental: continued strenuous exercise >=5 times per week from 24 weeks Control: strenuous exercise reduced to <=3 times per week from 24 weeks	Exercise diaries, with details of the baby, labour and delivery	Birth weight and birth rate	Increased mean birth weight
Clapp et al. [194]	2000	Beginning regular exercise in early pregnancy: effect on fetoplacental growth	Experimental: 20 min of aerobic exercise, 3–4 times per week, beginning at 8–9 weeks and continuing until delivery Control: no aerobic exercise	Indirect calorimetry	Gestational weight gain, mid-trimester placental growth rate, placental volume, birth weight, length, ponderal index, head circumference, preterm birth, infant lean mass, fat mass, % fat	Significant, balanced increase in fetoplacental growth in normal pregnancy

Table 16.2 (continued)

Author	Year	Title	Study design	Method	Foetal growth	Outcome
Clapp et al. [195]	2002	Continuing regular exercise during pregnancy: effect of exercise volume on fetoplacental growth	Experimental: 60 min weight-bearing exercise, 5 days per week from 8 to 20 weeks, then reduced to 20 min, 5 times per week from 24 weeks to delivery ('Hi-Lo" group) opposite pattern ('Lo-Hi' group)	Indirect calorimetry	Placental growth rate, birth weight and placental volume at term	Reduced fetoplacental growth. Proportionally greater increase in fat mass than in lean body mass
			Control: intermediate intensity, constant pattern (40 min, 5 days per week, from 8 weeks to delivery)			
Haakstad et al. [196]	2011	Exercise in pregnant women and birth weight: a randomised controlled trial	Experimental group: nulliparous pregnant women (N=52) encouraged to participate in supervised aerobic dance and strength training; 60 min, twice per week; 12 weeks, plus 30 min of self-imposed physical activity on the non-supervised week-days	Questionnaire measured physical activity and sedentary behaviour	Labour and delivery records (infant birth weight, length, head circumference, gestational age at time of delivery and Apgar scores at 1 and 5 min after birth)	Aerobic-dance exercise appeared to be safe and was not associated with any reduction in newborn birth weight, preterm birth rate or neonatal wellbeing
			Control group: (N=53)			
Marquez-Sterling et al. [197]	2000	Physical and psychological changes with vigorous exercise in sedentary primigravidae	Experimental: 1 h aerobic exercise, 3 times per week, for 15 weeks	Questionnaires	Physical fitness, gestational weight gain, birth weight, 5-min Apgar score, caesarean section and body image	Low birth weight in experimental group
			Control: no aerobic exercise during pregnancy			
Prevedel et al. [198]	2003	Maternal and perinatal effects of hydrotherapy in pregnancy	Experimental: aerobic (swimming exercise for 1 h, 3 times per week, for 10 weeks	Maximal oxygen consumption, stroke volume and cardiac output	Physical fitness, foetal heart rate before and after exercise (acute exercise effect) not included in review	Hydrotherapy assisted metabolic and cardiovascular maternal adaptation to pregnancy and did not cause prematurity or weight loss in newborns
			Control: normal activity without aerobic exercise			

Guidelines for Physical Activity During Pregnancy

The ACOG [5] recommends that healthy pregnant women exercise at moderate intensity for at least 30 min, most days of the week [24] while the American College of Sports Medicine [7] encourages an accumulation of 30 min or more of moderate physical activity per day on most, if not all, days of the week. Yet, another recommendation set forth by the US Department of Health and Human Service states in the document "2008 Physical Activity Guidelines for Americans" that pregnant women should engage in a minimum

Table 16.3 A summary of physical activity guidelines during pregnancy as prescribed by various organisations

Body prescribing guidelines	Guideline
ACOG [5]	Healthy pregnant women should exercise at moderate intensity for at least 30 min, most days of the week
ACSM [6]	Encourages pregnant women to accumulate 30 min or more of moderate physical activity per day on most, if not all, days of the week
US Department of Health and Human Services [12]	Pregnant women should engage in a minimum of 150 min of moderate-intensity aerobic activity a week, even if they were not physically active prior to pregnancy
Sports Medicine Australia [11]	Moderate exercise as determined with the Borg scale
Davies et al. [8]	All women without contraindications should be encouraged to participate in aerobic and strength-conditioning exercises as part of a healthy lifestyle during their pregnancy
RCOG [10]	Exercise program should be individualised based on previous physical activity level. Sedentary pregnant women should start with 15 min continuous exercise 3 times per week and increase to 30 min 4–5 times a week
Holan et at. [9]	Sedentary women should be moderately active during pregnancy and gradually increase their activity (up to 30 min per day)
Barsky et al. [7]	In low-risk pregnancies, women should be encouraged to participate in aerobic and strength-conditioning training at a moderate intensity on most or all days of the week

of 150 min of moderate-intensity aerobic activity a week, even if they were not physically active prior to pregnancy [12]. Recommendations in Australia [11], Canada [8], the UK [10] and Norway [9] are similar to the abovementioned American [120]. A recent South African Position Statement [7] supports the guidelines set out by the ACOG [5], the Society of Obstetricians and Gynaecologists of Canada (SOGC) and the Canadian Society of Exercise Physiology [8], but focuses on exercise and does not give guidelines regarding general physical activity during pregnancy (Table 16.3).

The question remains whether pregnant women adhere to these guidelines. Due to the uncertainty regarding the benefits and risks of exercise during pregnancy [199], the adherence of pregnant women to exercise is not reflective of the recommended ACOG guidelines [55, 104, 200]. Additionally, pregnant women often receive mixed messages from friends, family and even their doctors about exercise during pregnancy [199]. While scientific data support the safety of exercise during pregnancy, this knowledge is not always communicated to pregnant women. According to Price et al. [199], exercise must be prescribed to pregnant women in a similar way as the prescription of medicine. In addition, more reliable quantitative-determined data are warranted to provide an evidence-based exercise regimen for pregnant women.

The recommendations for physical activity for pregnant women, as presented in Table 16.3, are similar to the guidelines for nonpregnant women. The only exception is the intensity of the activity. In the guidelines, “moderate activity” is given as the intensity, but the definition for moderate-intensity activity is not defined. When the presented guidelines are compared to the guidelines for maintaining weight after weight loss, which is 60–90 min of activity, it is understandable that women do not comply with the guidelines due to the inherent discrepancies. Finally, the guideline for heart rate should be clarified in consideration with the fitness level of the pregnant women and previous exercise experience and level of fitness prior to pregnancy.

Birth Outcomes

Foetal Growth Parameters and Confounders Thereof

Monitoring the growth of the foetus is a major purpose of antenatal care [201]. The overall term “foetal growth parameters” includes: head and abdominal circumference, femur length, ponderal index (weight in grams x100 divided by length in cubic centimetres), placental weight and expected birth weight [202]. While birth weight is a crude measurement of foetal growth, the measurement of head size and length at birth gives an insight into the timing of growth retardation during intrauterine life [203].

Birth Weight

Although birth weight is not the most objective measurement of foetal growth, it is important with regards to public health [3]. Birth weight is an amalgam of multiple determinants and is a proxy for the many different processes that occur in the months preceding delivery [204]. Birth weight is associated with a broad range of short- and long-term maternal complications (e.g. pre-eclampsia, premature labour), foetal complications (e.g. stillbirth, malformations), neonatal complications (e.g. respiratory distress, infant mortality) and long-term complications (e.g. behavioural disorders, cerebral palsy) [205, 206].

Foetuses delivered with a lower birth weight than expected might become healthy, thriving infants, while others are small because their growth in utero was impaired and have an increased risk for perinatal morbidity and mortality [207, 208]. The cut-off for small-for-gestational-age is a birth weight below the tenth percentile [209]. Low birth weight and foetal growth impairment may be multifactorial in origin, therefore it is vital to have knowledge of possible associations between specific risk factors, pre- and postnatal growth patterns and specific adult health parameters like smoking and physical activity habits [210].

Over the last decade, a new paradigm evolved from the notion that environmental factors in early life and in utero can have profound influences on lifelong health [204]. Reduced foetal growth might also be the origin of cardiovascular disease later in life through programming in foetal life and infancy [203].

Theory of Foetal Origins

Time in the womb can be seen as a critical window during which maturation must be achieved, because failure of maturation is to some extent irrecoverable [203]. The maternal environment influences these critical stages of early life and leads to long-term changes in the body's structure, physiology or metabolism—this is called programming [211, 212]. Relationships between foetal experiences and later risk for adult chronic disease, including cardiovascular disease and its risk factors, cancer, osteoporosis, diabetes, neuropsychiatric outcomes and respiratory diseases, have been demonstrated by a large number of studies [213–216]. The abovementioned relationship, the foetal origins hypothesis, was first proposed by the British epidemiologist David Barker as the "thrifty gene hypothesis" [217]. The foetal origin hypothesis was developed by linking records of births in the early twentieth century with health in later life from the Hertfordshire records [203, 217–225].

The theory of foetal origins suggests that associations with body size at birth underestimate the influence of intrauterine development on later disease. Prevention of coronary heart disease and non-insulin-dependent diabetes may be related to the choices of the mother. Therefore, chronic disorders that manifest later in life may be related to poverty (malnourished mothers give birth to malnourished infants with low birth weight) and prosperity (exposure of an infant with low body weight phenotype to a high caloric diet) [226] In this way, both a low and high birth weight is associated with negative outcomes in later life, showing a U-shaped relationship as observed by Rich-Edwards et al. [227]. Newborns that are small-for-gestational-age tend to preserve body fat at the expense of lean body mass [228], whereas large newborns may also have relatively increased body fat. Hammani et al. [229] suggest that associations between foetal growth and later adiposity are complex. The findings that a low and high birth weight is a strong predictor of diabetes and cardiovascular disease in later life has led to continuing debate about the significance of nature and nurture [230].

Environmental Pollution

Environmental air pollution has been shown to have associations with a low birth weight and its determinants, preterm delivery and intrauterine growth restriction [231–238]. Exposure to an air pollutant like carbon monoxide could lead to decreased oxygen delivery to tissues, including the foetus [239]. Inhaling air pollution particles may lead to increased blood viscosity, which may have an adverse effect on placental function, thereby restricting foetal growth [233]. However, the effect of air pollution on foetal growth is smaller than the effect of high-risk behaviours [239].

Lifestyle

Tobacco smoking, alcohol consumption and illicit drug abuse are increasing among women of childbearing age [240]. Intrauterine growth restriction and low birth weight are the most consistent effect of these high-risk behaviours [240]. Maternal smoking during pregnancy is an extremely important, modifiable risk factor that is associated with adverse perinatal outcomes [241–243], such as intrauterine growth retardation [243, 244], low birth weight [245–248], preterm and very preterm delivery [249], ectopic pregnancy [250], placental pathologies [251] and a significant higher risk of perinatal and infant mortality [252–255]. Specifically, smoking has negative effects on multiple foetal growth parameters including body weight, femur length, limb length, total length, head circumference, chest circumference and abdominal circumference [256–259]. According to Hernandéz-Martínez et al. [261], maternal smoking during pregnancy is also related to cognitive, emotional, temperamental and behavioural problems throughout the child's life.

The effects of smoking could be mediated by the direct toxic effect on the foetus, leading to metabolic alterations, as well as by mechanisms resulting in decreased oxygen delivery [255]. Cigarette smoke contains more than 2500 chemicals and some of these are harmful to the developing foetus and cause adverse pregnancy outcomes [261, 262]. Carbon monoxide readily crosses the placental barrier by passive diffusion, causing a fourfold increase in the level of carboxyhaemoglobin in umbilical cord blood, which inhibits the release of oxygen into foetal tissues [263–266]. This chronic hypoxia alters the physiological development of organs and tissues [261, 267]. Therefore, cigarette smoking during pregnancy is a strong dose-dependent risk factor for small-for-gestational-age [268, 269]. Second-hand smoke showed a similar relationship, according to Horta et al. [248].

Cigarette smoking may confound the relationship between birth weight and later body size [204]. Multiple studies have demonstrated a clear inverse relationship between maternal smoking and childhood weight [270, 271], although [272] suggest an increased risk of obesity later in life among offspring of mothers who smoked during pregnancy. [255] analysed body composition and found that lean body mass was more affected than body fat, and proportional body distribution of subcutaneous fat was not affected in infants from mothers who smoked during pregnancy.

Alcohol consumption during pregnancy has been associated with various pregnancy complications such as miscarriage [273], stillbirth [274] and other multiple birth defects [275–279] such as foetal alcohol syndrome [280, 281] and an increased risk of low birth weight [282, 283].

Drug abuse during pregnancy may lead to complications for the foetus, the newborn and later during childhood [240]. Cannabis, cocaine and heroin specifically have been studied in relation to their effects on foetal growth [240, 284], and findings have proposed that cannabis abuse during pregnancy decreases foetal growth, but this has not been confirmed in follow-up studies [285–287]. Poor pregnancy outcomes, including premature birth and abnormalities of behavioural testing in the offspring, have been associated with cocaine use during pregnancy [240]. Associations with heroin use during pregnancy and an increased incidence of pregnancy complications, including premature delivery, premature rupture of the membranes, intrauterine foetal growth retardation and perinatal mortality have also been confirmed [240].

Another confounder between birth weight and later adiposity may be social and economic factors [204]. Vagero et al. [289] found that babies born to women with a lower social status had lower birth weights. As such, neighbourhood factors that have been associated with an increased risk for a low birth weight include a negative perception of the neighbourhood [290], an average income [291, 292], economic hardship, low housing costs [293] and, interestingly, neighbourhood crime rates [294]. How these factors relate to birth weight remains speculation, but there have been explanations that focus on the stress-related hormonal factors and birth outcomes through biological mechanisms [295–299], whereas others researched the association with maternal health behaviours, such as smoking [300–302]. Although environmental factors play an important role in determining foetal growth, genetics must also be considered.

Genetics

Both genetic and environmental factors are important determinants of foetal growth [230, 303, 304]. As stated by Tower and Baker [305], the growth potential of any foetus is likely to be genetically determined. As an example, Knight et al. [304] found that paternal height is an important, independent determinant of foetal linear growth. Knight et al. [304] concludes that skeletal size is regulated by genetic information, while the adiposity of the newborn is reflected by the maternal intrauterine environment. Another example is that offspring birth weight has a strong association with parental adiposity [306, 307]. Therefore, the associations of maternal and paternal birth weight with offspring birth weight suggest genetic or intergenerational environmental influences [204, 308, 309].

Foetal growth restriction is a complex trait for which no single susceptibility gene can be identified [305]. There are between 100 and 200 imprinted genes and there is increasing evidence that many are involved in pre- and postnatal growth [310]. When the normal imprint is disrupted, malformations in the development of the foetus occur [310]. Vaessen et al. [230] postulate that the Insulin-like Growth Factor-1 (IGF-1) gene imprint disruption may lead to low circulating IGF-1 concentrations, reduced height in adulthood, diminished insulin secreting capacity and a high risk of type-2 diabetes and myocardial infarction. Although genetically established expression of IGF-1 and insulin are important determinants of growth during the foetal period, they do not play a major role in the regulation of body weight in postnatal life [230]. Additionally, the postnatal environment that includes adverse eating and activity habits shared by family members may also lead to a higher birth weight and higher adiposity later in life. Other genetic and environmental factors such as diet and physical activity have more relevant effects on the regulation of weight [230]. A summary of the interactions can be seen in Fig. 16.6 that has been composed from the existing literature.

Labour

Natural birth seems to be the best conclusion of the pregnancy for both the mother and the baby [311] and should therefore be seen as a major goal for all pregnant women [120]. Other methods of childbirth, including a caesarean section, should only be used when justified by the circumstances [120]. From a public health perspective, there is concern regarding the increased rate of caesarean sections during the last decade because this procedure is not risk-free [312]. One possible explanation for this recent rise in caesarean sections includes a rise in maternal obesity [313]. However, this rise cannot be attributed entirely to a worsening of maternal or foetal risk factors [314–316]. Therefore, caesarean sections may be not justified medically, exposing women and babies to surgical risks without proved benefit [317, 318]. Reducing rates of caesarean sections should be a public health priority [312].

In recent years, prenatal physical activity has increasingly been recommended to promote natural birth [99, 120, 134, 165, 319]. Regular physical activity during pregnancy may have other beneficial effects on multiple aspects of the course and outcome of labour and delivery [120] including a shorter delivery [134, 320–323], less frequent need for anaesthesia [134, 324], a lower rate of induction of labour [134, 320], amniotomy [134], episiotomy and perineum lacerations [134, 321, 325] and improved neonatal outcome

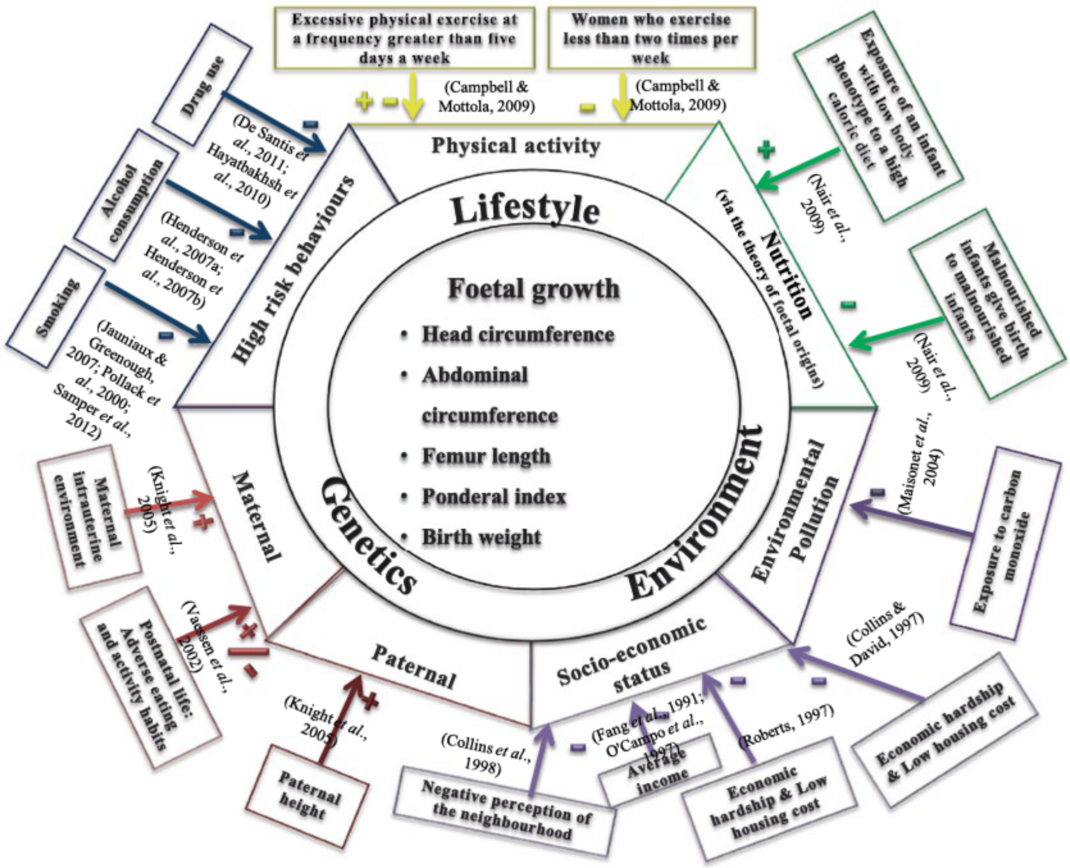

Fig. 16.6 Multifactorial influences on foetal growth. + positive influence/effect, − negative influence/effect

directly after birth [134]. Based on these findings, it is clear that physical activity during pregnancy has physiological benefits on labour. However, as stated by Guskowska [326], pregnant women often experience fear about labour and delivery, which is undoubtedly detrimental. Physical activity might produce anti-anxiety effects that will help to reduce labour anxiety [326].

To conclude, Ghodsi et al. [322] state that physical activity can result in shorter labour, fewer medical interventions, less exhaustion during labour and might also reduce the fear associated with giving birth. Encouraging pregnant women to be physically active could represent a low-cost, low-risk approach to reduce the number of caesarean deliveries [312].

Body Composition at Birth Related to Disease in Later Life

Early environmental influences, as early as in the womb, have long-term effects on body composition and musculoskeletal development as evidenced by the prevalence of obesity, sarcopenia and osteoporosis in later life [327]. This phenomenon is explained by means of foetal programming as previously mentioned, and more specifically, to the body composition of the baby, referred to as developmental plasticity [327]. Developmental plasticity is defined as the ability of a single genotype to produce more than one alternative form of structure, physiological state or behaviour in response to early environmental conditions [327].

During embryonic life, bone and muscle develop from the mesoderm layer, differentiate during the first trimester into dermatomes containing bone and muscle cell precursors [327]. Muscle development starts between 6 and 8 weeks of gestation and progresses until about 18 weeks [328]. Adipose cell formation is determined much later, the critical period varying from 30 weeks of gestation to the first year of postnatal life [329]. These major phases of the developing of muscle and fat are important, because of the high vulnerability of foetal programming occurring during this period of rapid cell division, the so-called critical periods [330].

A low birth weight has implications on fat, muscle and bone distribution in later life [327]. An association between low birth weight and increased adult central distribution of fat exists and has been evident in a couple of studies [327, 331, 332]. Reduced muscle mass and strength have also been implicated due to small size at birth [327]. These abovementioned effects are mediated by mechanisms that include a direct effect on cell number, altered stem cell function and resetting of regulatory hormonal axis [327].

Overall, evidence indicates that a higher birth weight is associated with increased risk of adiposity in childhood and adulthood, as reflected by BMI [204]. According to findings from Silverman et al. [333], increased adiposity was apparent at birth and progressively after the age of 4 years, but not from ages 1 to 3 years. Numerous studies have found direct associations between a higher birth weight and a higher adult BMI [227, 271, 334–339]. Specifically, the magnitude ranges from 0.5 to 0.7 kg/m^2 for each 1-kg increment in birth weight [339, 340].

Maternal Weight Gain During Pregnancy

Women often express concern about weight gain during pregnancy; however, it is important to remember that during pregnancy, all women gain weight due to foetal and maternal health. This weight gain also corresponds directly with foetal birth weight, which is a strong precursor of the health and development of the infant [34]. However, desirable weight gain also depends on BMI before pregnancy. Siega-Riz et al. [341] recommend GWG ranges for women on the basis of BMI as outlined in Table 16.4. The recommended ranges are derived from the observed weight gains of women delivering full-term, healthy infants without complications [40]. The total amount of weight gained in normal-term pregnancies varies considerably between women [41]. Studies show that about one third of mothers in the USA gain more or less the recommended weight; however, there is a lack in current research regarding the effects of physical activity on weight gain during pregnancy in the South African context [112]. One cross-sectional South African study found physically active pregnant women tend to gain less weight than relatively inactive pregnant women [112]. The findings are also supported by a recent meta-analysis from Domenjoz et al. [152] who reported a 1.3 kg less weight gain in women participating in physical activity compared to a non-active control group.

Weight gain during pregnancy is an important factor to consider to determine long-term obesity [342] and predict other health risks such as pre-eclampsia and adverse birth outcomes [343]. Women are usually very self-conscious or concerned about weight gain during pregnancy

Table 16.4 Recomm gestational weight gain ranges for women on the basis of body mass index. (Adapted from [342]. With permission from Elsevier)

Body mass classification	Body mass index (kg/m^2)	Recommended weight gain range (kg)
Low	<19.8	12.5–18
Normal	19.8–26.0	11.5–16
Overweight	26.0–29.0	7.0–11.5
Obese	≥29.0	6

[344]. Brunette et al. [112] conclude that leading a moderately active lifestyle during pregnancy can have definite weight-control benefits, therefore women should be advised to be physically active during their pregnancies to reap the benefits and possibly to prevent the development of postnatal obesity. On the other hand, adopting a sedentary lifestyle, a common trend among pregnant women, results in women gaining weight above the recommended weight gain ranges [345].

Physical Activity in Infertility-Related Conditions

Polycystic Ovarian Syndrome

The most common endocrinopathy affecting women of reproductive age are polycystic ovarian syndrome (PCOS). The condition affects between 4–12 % [346, 347] of women in America. Various diagnostic criteria are used, with the most common being an increase in insulin resistance compared to non-PCOS women independent of obesity [348]. Women suffering from PCOS experience reduced fertility, morphological changes of the ovaries and increased abdominal visceral fat [349]. Although the link between insulin resistance and infertility have not been completely resolved, various studies have indicated in the general population that regular physical activity increases insulin sensitivity, reducing insulin resistance. Researchers were therefore prompted to investigate the effect of physical activity on insulin resistance of women suffering from PCOS. A systematic review including premenopausal women diagnosed with PCOS who were exposed to between 12–24 weeks of exercise reported an improvement of between 23–30 % in fasting insulin [350]. When the effect of diet alone and diet combined with exercise was analysed, an overall improvement in ovulation and/or menstrual cycle was reported in 49 % of the participants. No difference between diet only and diet plus exercise intervention groups were found. The findings from the review suggest that regular physical activity may improve ovulation rates independent of dietary restrictions and changes in body fat. The physical activity interventions seem to enhance the insulin sensitivity which restores the reproductive function.

Amenorrhea

Amenorrhea is considered the most severe form of menstrual abnormality that causes infertility and is reported to be present in 1–44 % of female athletes [351]. The prevalence tends to be higher in athletes of sports where a very low BMI is required or in sports with a large strength component [352]. The mechanism through which exercise disturbs the menstrual cycle is described as a disruption of the hypothalamic–pituitary–ovarian axis. The consequence is that the hypothalamic pulsatile release of gonadotropin-releasing hormone (GnRH) is supressed, which consequently reduces the release of gonadotropins follicle-stimulating hormones (FSH) and luteinizing hormone (LH). An anovulatory and hypoestrogenic state results as a lack of ovarian stimulation [353].

Results from a population-based study in Norway during the mid-1980s with a follow-up one decade later focussing on infertility indicated that an increase in frequency, duration or intensity of physical activity was related to an increase in difficulty conceiving. A 3.2-fold greater chance of being infertile was reported for women exercising most days of the week. Independent of age, smoking and BMI, the risk of infertility increased 2.3 times when exercising to exhaustion [354].

Although regular physical activity and exercise is highly beneficial for most women, adverse effects related to fertility can and do occur. Current evidence indicates that the mechanism appears to be via an energy deficit that is created through a high intensity training program with a concomitant deficit in energy intake [355]. The energy deficit results in a catabolic state, shutting down the reproductive system in order to maintain health.

Summary

Early environmental influences, as early as in the womb, have long-term effects on an individual's health. The maternal environment influences critical stages of early life and leads to long-term changes in the body's structure, physiology and metabolism. A healthy lifestyle during pregnancy, which includes regular physical activity, no smoking and alcohol consumption, is essential. The physical and psychological benefits of regular physical activity during pregnancy are plentiful. Regular physical activity not only provides maternal benefits (decreased GWG, reduced risk of gestational diabetes and pre-eclampsia) but also foetal benefits (decreased risk for small- or large-for-gestational-age) and improved birth outcomes (lower incidence of operative abdominal and vaginal deliveries and a shorter labour period).

Physical activity tends to decrease as pregnancy progresses despite these known benefits. Although scientific data supports the safety of physical activity during pregnancy, this knowledge is not always communicated to pregnant women. The lack of objective and quantitative research regarding physical activity and pregnancy might have led to these uncertainties. Determining physical activity during pregnancy remains problematic due to methodological difficulties. However, the combined heart rate and accelerometer available on the market is a valid and reliable tool for the measurement of physical activity. Free-living data can be assessed and is essential to determine behavioural changes in activity patterns during pregnancy. Accurately determining physical activity will minimise possible inaccuracies of subjectively determined habitual activity patterns by means of questionnaires and could provide better insights into the effect of these patterns on foetal growth.

Determining the influence of habitual physical activity on foetal growth is difficult. Multiple determinants influence foetal growth and these factors have thoroughly been researched. One exception is the influence of habitual physical activity on foetal growth, possibly because of a relatively small relationship. Regular physical activities tend to decrease the risk of small- and large-for-gestational-age. Regular physical activity, in addition, also appears to have advantages for women suffering from infertility due to PCOS, since the restoration of insulin sensitivity improves ovulation rates.

Various institutional and governmental entities have set guidelines specifically for physical activity during pregnancy, but few women follow these guidelines because of uncertainty of the benefits and risks associated with physical activity during pregnancy. These guidelines are not based on longitudinal studies on pregnant women and might be unnecessarily conservative. Future research needs to be aimed at objectively determining the habitual physical activity patterns during pregnancy, as well as guiding governmental organisations to set specific physical activity guidelines and educating women about these guidelines. In addition, the safety of regular physical activity during pregnancy must also be addressed with doctors and health workers.

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