

Physical Activity and Pregnancy

Cardiovascular Adaptations, Recommendations and Pregnancy Outcomes

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Abstract

Regular physical activity is associated with improved physiological, metabolic and psychological parameters, and with reduced risk of morbidity and mortality. Current recommendations aimed at improving the health and well-being of nonpregnant subjects advise that an accumulation of ≥ 30 minutes of moderate physical activity should occur on most, if not all, days of the week.

Regardless of the specific physiological changes induced by pregnancy, which are primarily developed to meet the increased metabolic demands of mother and fetus, pregnant women benefit from regular physical activity the same way as nonpregnant subjects.

Changes in submaximal oxygen uptake ($\dot{V}O_2$) during pregnancy depend on the type of exercise performed. During maternal rest or submaximal weight-bearing exercise (e.g. walking, stepping, treadmill exercise), absolute

maternal $\dot{V}O_2$ is significantly increased compared with the nonpregnant state. The magnitude of change is approximately proportional to maternal weight gain.

When pregnant women perform submaximal weight-supported exercise on land (e.g. level cycling), the findings are contradictory. Some studies reported significantly increased absolute $\dot{V}O_2$, while many others reported unchanged or only slightly increased absolute $\dot{V}O_2$ compared with the nonpregnant state. The latter findings may be explained by the fact that the metabolic demand of cycle exercise is largely independent of the maternal body mass, resulting in no absolute $\dot{V}O_2$ alteration.

Few studies that directly measured changes in maternal maximal $\dot{V}O_2$ ($\dot{V}O_{2max}$) showed no difference in the absolute $\dot{V}O_{2max}$ between pregnant and nonpregnant subjects in cycling, swimming or weight-bearing exercise. Efficiency of work during exercise appears to be unchanged during pregnancy in non-weight-bearing exercise. During weight-bearing exercise, the work efficiency was shown to be improved in athletic women who continue exercising and those who stop exercising during pregnancy. When adjusted for weight gain, the increased efficiency is maintained throughout the pregnancy, with the improvement being greater in exercising women.

Regular physical activity has been proven to result in marked benefits for mother and fetus. Maternal benefits include improved cardiovascular function, limited pregnancy weight gain, decreased musculoskeletal discomfort, reduced incidence of muscle cramps and lower limb oedema, mood stability, attenuation of gestational diabetes mellitus and gestational hypertension. Fetal benefits include decreased fat mass, improved stress tolerance, and advanced neurobehavioural maturation. In addition, few studies that have directly examined the effects of physical activity on labour and delivery indicate that, for women with normal pregnancies, physical activity is accompanied with shorter labour and decreased incidence of operative delivery.

However, a substantial proportion of women stop exercising after they discover they are pregnant, and only few begin participating in exercise activities during pregnancy. The adoption or continuation of a sedentary lifestyle during pregnancy may contribute to the development of certain disorders such as hypertension, maternal and childhood obesity, gestational diabetes, dyspnoea, and pre-eclampsia. In view of the global epidemic of sedentary behaviour and obesity-related pathology, prenatal physical activity was shown to be useful for the prevention and treatment of these conditions. Further studies with larger sample sizes are required to confirm the association between physical activity and outcomes of labour and delivery.

Regular physical activity is associated with improved physiological, metabolic and psychological parameters, and with reduced risk of morbidity and mortality from diseases such as cardiovascular disease, hypertension, diabetes mellitus, obesity, osteoporosis, sarcopenia, cognitive disorders and some forms of cancer.^[1] Current recommendations aimed at improving

the health and well-being of nonpregnant subjects advise that an accumulation of 30 minutes or more of moderate physical activity should occur on most, if not all, days of the week.^[2]

Regardless of the specific physiological changes induced by pregnancy, which are primarily developed to meet increased metabolic demands of mother and fetus, pregnant women benefit

from regular physical activity the same way as nonpregnant subjects.^[3] However, a substantial proportion of women stop exercising and decrease their general physical activity level after they discover they are pregnant, and only few begin participating in exercise or sport activities during pregnancy.^[4] The adoption or continuation of a sedentary lifestyle during pregnancy may contribute to development of certain disorders such as hypertension, maternal and childhood obesity, gestational diabetes, dyspnoea and pre-eclampsia.^[3] In view of the global epidemic of sedentary behaviour and obesity-related pathology, prenatal physical activity has been shown to be useful for the prevention and treatment of these conditions.^[5]

A systematic literature review was conducted on physical activity and pregnancy. The search included articles published in MEDLINE and ISI Web of Science databases. Keywords used were: 'physical activity' OR 'physical exercise', 'pregnancy' OR 'gestation', 'pregnancy outcomes', 'labour', 'cardiovascular adaptations', 'heart rate', 'training', 'detraining', 'physical activity recommendations' AND 'pregnancy'. In a first round, there were no restrictions to certain years of publication. In a second round, publications published between 2007 and 2009 were specifically reviewed to assure inclusion of any relevant new publication.

The aim of this article was to review the current state of knowledge on (i) the cardiovascular adaptations to physical activity in the pregnant and nonpregnant states; (ii) the compliance of pregnant women with current physical activity recommendations; and (iii) the effects of physical activity on pregnancy outcomes.

1. Cardiovascular Adaptations to Training and Detraining in Pregnant and Nonpregnant States

1.1 Cardiovascular Adaptations to Training

Repeated episodes of physical activity performed over a longer period (i.e. training) cause adaptations in the respiratory, cardiovascular and neuromuscular systems that enable physi-

cally trained persons to exercise for longer at a given absolute exercise intensity, or to exercise at a higher exercise intensity for a given duration.^[6] The adaptations in metabolic and physiological systems depend on the type of exercise overload imposed. Short duration activities demanding high levels of anaerobic metabolism favour the adaptation of the immediate and short-term energy systems, with limited impact on the aerobic system. Regular endurance training, on the other hand, improves overall aerobic capacity.^[7-9]

For public health concerns and in contrast to training for sports-specific improvement, current interest in physical activity participation arises largely from a desire to improve health-related fitness components, primarily cardiorespiratory fitness.^[10] Aerobic training produces significant changes to the cardiovascular system: enlarged left ventricular cavity of the heart; enhanced blood and stroke volume; increased maximum cardiac output (\dot{Q}); and decreased resting and sub-maximal exercise heart rate.^[6] The lower resting and sub-maximum exercise heart rate generally reflect an improved submaximal and maximal oxygen uptake ($\dot{V}O_{2max}$) and a correspondingly higher level of cardiovascular fitness.

1.2 Cardiovascular Adaptations to Detraining

While regular physical activity is accompanied by better cardiovascular fitness, a reduction or cessation of physical activity leads to partial or complete reversal of the physiological adaptations. Inactivity is accompanied by a rapid decline in $\dot{V}O_{2max}$ and blood volume. Consequently, submaximal exercise heart rate increases but insufficiently to counterbalance decreased stroke volume, thus resulting in a reduction of maximal \dot{Q} .^[11] Measurable alterations in physiological functions take place after only a week or two of detraining.^[8] Total loss of training improvements occurs within several months.^[8] As a result, any sudden physical effort imposed on the detrained subjects leads to physiological and metabolic stress, as they are not able to respond to imposed physical exertion as efficiently as trained subjects.

2. Cardiovascular Changes due to Pregnancy

Regardless of training status, women who become pregnant undergo profound cardiovascular system alterations (figure 1). The first haemodynamic change during pregnancy is a rise in heart rate, both at rest and during submaximal work-out. It starts between 2 and 5 weeks of pregnancy and continues well into the third trimester.^[12] On average, the resting heart rate raises 8 beats/min by the eighth week, and reaches an increase of 16 beats/min by the end of pregnancy.^[13] The effect is less evident in supine or lateral positions and more evident during sitting.^[14] The mechanism of the increased heart rate is not yet clearly identified. It may be attributed to chorionic gonadotropin, or to sympathetic reflex adjustments to maintain arterial blood pressure despite reduced peripheral vascular resistance.^[15]

Between 10 and 20 weeks of pregnancy, a notable increase in blood volume takes place due to an increase in both plasma and erythrocytes.^[16,17] This represents a rise of approximately 1500 mL,^[16] of which 1000 mL is plasma volume and 500 mL is erythrocytes.^[18] Since plasma volume amplifies more than red blood cell volume, a relative dilutional anaemia occurs.^[19] Blood volume expansion may be even greater in multifetal gestations.^[18]

Resting \dot{Q} is increased as early as the fifth week of pregnancy as a result of the increased heart

rate, stroke volume and blood volume.^[12,17,20] Resting \dot{Q} increases by 1 L/min at 8 weeks of gestation, which represents >50% of the overall change in pregnancy.^[20] During the third trimester, resting \dot{Q} increases only minimally, primarily because of the increase in heart rate as term approaches.^[21] In multifetal pregnancies, resting maternal \dot{Q} is greater by approximately 20% compared with singleton pregnancies.^[19] \dot{Q} is also affected by the positional changes of the women.^[14] After 20 weeks of gestation, the gravid uterus may obstruct the aorta and inferior vena cava, causing a decrease in uteroplacental blood flow and venous return to the heart,^[9] especially when the woman is in the supine position. The left lateral position quickly relieves compression of the inferior vena cava.^[21] Left uterine displacement also tends to prevent aortocaval compression, although it is less optimal than the left lateral position.^[19]

Blood pressure is not increased in normal pregnancy due to decreased peripheral vascular resistance.^[19] In fact, systolic pressure remains quite stable, whereas diastolic pressure decreases up to 15 mmHg in mid-pregnancy.^[22]

2.1 Cardiovascular Changes during Labour and Delivery

Although \dot{Q} remains relatively constant in the latter half of pregnancy, there is a significant

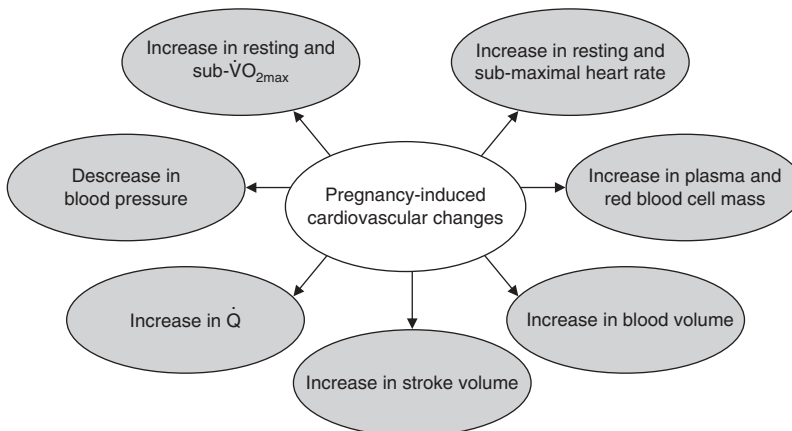


Fig. 1. Pregnancy-induced cardiovascular changes. \dot{Q} = cardiac output; $\dot{V}O_{2max}$ = maximal oxygen uptake.

increase during active labour and immediately after delivery. A study^[12] of normal labour in women without epidural anaesthesia reported an increase in \dot{Q} of 12% and 34% between contractions and at full dilatation, respectively. The increase in \dot{Q} seems to be caused by an increase in heart rate and stroke volume. Such changes are thought to be sympathetically mediated and are likely due to the combined effects of pain, increased metabolic demand and increased venous return during uterine contractions.^[23] Circulating blood volume also increases during contractions by an additional 300–500 mL due to blood auto-transfusion from the placenta.^[24]

The physical effort of normal labour does not impose high energy demands on the parturient. The energy requirement is affected more by the frequency and duration of uterine contractions than by the total duration of labour.^[25] Katz et al. measured energy expenditure of labour in 23 healthy women.^[25] The results showed oxygen uptake ($\dot{V}O_2$) of 0.255 L/min during uterine relaxation (at 4 cm dilatation), 0.338 L/min during contractions (at 4 cm dilatation), and 0.510 L/min at delivery. Thus, the $\dot{V}O_2$, which increases ~20% during normal pregnancy, may increase an additional 60% during the contractions, but remains rather low when compared with the increase observed during physical activity (walking, running, cycling). It is higher in multiparous women than in nulliparous women and is highest in those women with the shortest labour.^[25] If the process of expulsion is prolonged (>30 minutes), the increased demand for oxygen is partially met by anaerobic metabolism causing an increase in maternal blood lactate levels.^[25]

The haemodynamic changes seen during labour and delivery are influenced by anaesthetic and analgesic techniques.^[21] Lumbar epidural anaesthesia during labour reduces maternal adrenaline (epinephrine) levels,^[26] and decreases the work of breathing, $\dot{V}O_2$,^[27,28] fetal heart rate,^[29] maternal \dot{Q} and blood pressure.^[30-32] The haemodynamic changes are also influenced by the position of the parturient. For example, \dot{Q} and stroke volume are significantly decreased in the supine, compared with the lateral, position.^[33]

2.2 Postpartum Cardiovascular Changes

Within the first 15–20 minutes after delivery of the fetus and placenta there is a substantial increase in \dot{Q} , as the blood is no longer diverted to the uteroplacental vascular bed, but rather redirected to the maternal circulation.^[21] By 24 hours after delivery, \dot{Q} is no longer significantly different from pre-labour values,^[34] and fully returns to pre-pregnant values by 2 weeks after delivery. Stroke volume also decreases within 2 weeks, although there is a further small reduction up to 6 months after delivery.^[12]

3. Physical Activity and Pregnancy

Although pregnancy induces an increase in \dot{Q} , stroke volume and heart rate, women who continue aerobic exercise training during pregnancy have lower resting heart rate and higher stroke volume than matched sedentary controls.^[35,36] In addition, aerobically fit women have greater $\dot{V}O_2$ response at a given heart rate compared with their sedentary counterparts.^[36]

3.1 Submaximal Aerobic Capacity during Pregnancy

Changes in submaximal $\dot{V}O_2$ during pregnancy depend on the type of exercise performed. During maternal rest or submaximal weight-bearing exercise (e.g. walking, stepping, treadmill exercise), absolute maternal $\dot{V}O_2$ (L/min) is significantly increased compared with the nonpregnant state.^[37,38] The magnitude of change is approximately proportional to maternal weight gain. At the same speed or grade of walking or running, the values for $\dot{V}O_2$ expressed in mL/kg/min are thus similar or only slightly higher during pregnancy compared with the nonpregnant state.^[37,39-41]

When pregnant women perform submaximal weight-supported exercise on land (e.g. level cycling), where the energy cost of locomotion is not altered by maternal morphological changes, the findings are contradictory. Some studies reported significantly increased absolute $\dot{V}O_2$,^[37,40,42] while many others^[15,35,38,40,43-47] reported unchanged or only slightly increased absolute $\dot{V}O_2$

compared with the nonpregnant state. The latter findings may be explained by the fact that the metabolic demand of cycle exercise is largely independent of the maternal body mass, resulting in no absolute $\dot{V}O_2$ alteration.

3.2 Work Efficiency

Net efficiency of work during exercise, i.e. the slope of the relationship between $\dot{V}O_2$ and work rate, appears to be unchanged during pregnancy in non-weight-bearing exercise (e.g. cycle ergometer testing).^[38,44,48] The efficiency of weight-bearing exercise (e.g. treadmill testing), on the other hand, was shown to be improved in early pregnancy in athletic women who continue exercising and those who stop exercising during pregnancy.^[49,50] The increase in exercise efficiency is obscured after the fifteenth week of pregnancy by pregnancy-associated increases in maternal weight. When adjusted for weight gain, the increased efficiency is maintained throughout the pregnancy, with the improvement being greater in women who continue exercising during pregnancy.^[49]

3.3 Maximum Aerobic Capacity during Pregnancy

$\dot{V}O_{2max}$, as a criterion measure of cardiovascular fitness, is poorly documented in pregnancy. Measuring $\dot{V}O_{2max}$ during gestation holds a theoretical risk of inducing fetal stress due to blood distribution favouring maternal skeletal muscle at the expense of uterine blood flow. For ethical reasons, most studies report estimated values obtained by extrapolating individual submaximal heart rate- $\dot{V}O_2$ curves rather than actual measured values at peak exercise intensity. The few studies (table I) that directly measured changes in maternal $\dot{V}O_{2max}$ showed no difference in the $\dot{V}O_{2max}$ (L/min) between pregnant and nonpregnant subjects in cycling,^[44-47,50-53] swimming or weight-bearing exercise.^[47,50,51,54] Well conditioned women or athletes who maintain a moderate to high level of exercise during and after pregnancy have even shown a small but significant increase in $\dot{V}O_{2max}$ following pregnancy.^[53,54] Thus, pregnancy may have an added

training effect in well conditioned, recreational sports women.

3.4 Maximal Heart Rate during Pregnancy

Although the $\dot{V}O_{2max}$ values do not seem to differ significantly in the pregnant compared with the nonpregnant state, maximal heart rate was reported to be approximately 4 beats/min lower in pregnancy compared with post partum.^[50] The blunted heart rate responses to maximal exercise may be due to reduced sympathoadrenal responses to heavy exertion during pregnancy.^[43]

As a result of the increased resting heart rate and decreased maximal heart rate, heart rate reserve is reduced and heart rate rises to a lesser extent with increasing $\dot{V}O_2$, lowering the slope of the heart rate- $\dot{V}O_2$ relationship during pregnancy compared with the nonpregnant state.^[15,51] However, with the exception of resting heart rate, the change in the heart rate- $\dot{V}O_2$ relationship appears not to be affected significantly by a woman's habitual exercise behaviour throughout pregnancy.^[55]

4. Physical Activity Recommendations during Pregnancy

In the past, recommendations for physical activity were based on cultural and traditional mores rather than scientific evidence. In the 1950s, continuation of household chores and a 1.6 km (1 mile) walk per day, preferably divided into several short sessions, was advised, whereas sports and exercise were discouraged.^[5] In 1985, the American College of Obstetricians and Gynecologists (ACOG) formulated one of the first recommendations for exercising during pregnancy. It was advised that the intensity of exercise should not induce an increase in heart rate above 140 beats/min and that strenuous exercise should not last more than 15 minutes.^[5] Since then, evidence has accumulated on the type, intensity, duration and frequency of exercise beneficial for mother and offspring,^[56] leading to the revision of the guidelines.

Present ACOG recommendations,^[57] and those jointly published by the Society of Obstetricians and Gynecologists of Canada (SOGC) and the

Table 1. Studies reporting actual measured maximal oxygen uptake ($\dot{V}O_{2max}$) in pregnant women

Study (year)	No. of subjects	Measurements	Findings
Heenan et al. ^[44] (2001)	14	$\dot{V}O_2$ (L/min) measurements in pregnant women (35 ± 0.4 wk) and age-matched nonpregnant control group ($n = 14$) while cycling maximally. Low age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnant vs control group
Lotgering et al. ^[50,51] (1991, 1992)	33	$\dot{V}O_2$ measurements (L/min) at 16, 25 and 35 wk of pregnancy and 7 wk post partum at increasing levels of cycling and treadmill exercise until maximum aerobic power was reached. Average age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnancy period vs post partum during cycling and treadmill exercise
McMurray et al. ^[52] (1991)	10	$\dot{V}O_2$ measurements (L/min) at 25–35 wk of pregnancy and 9–11 wk post partum during cycling and swimming maximally. Average age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnancy period vs post partum during cycling. The swim $\dot{V}O_{2max}$ was significantly greater post partum than in the 35th swim trials
Sady et al. ^[45] (1988)	45	$\dot{V}O_2$ (L/min) measurements in pregnant women (26 ± 3 wk) and a nonpregnant control group ($n = 10$) while cycling maximally. Low age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnant vs control group
Sady et al. ^[46] (1989)	45	$\dot{V}O_2$ (L/min) measurements at 26 ± 3 wk of pregnancy and 8 ± 2 wk post partum while cycling maximally. Low age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnancy period vs post partum
Spinnewijn et al. ^[47] (1996)	11	$\dot{V}O_2$ measurements (L/min) at 30–34 wk of pregnancy and 8–12 wk post partum during cycling and swimming maximally. Average age-specific aerobic capacity levels	No significant differences in $\dot{V}O_{2max}$ in pregnancy period vs post partum during bicycle and swimming

$\dot{V}O_2$ = oxygen uptake.

Canadian Society of Exercise Physiology (CSEP),^[58] advise that pregnant women who are free of medical or obstetric complications follow the American College of Sports Medicine–Centers of Disease Control and Prevention (ACSM-CDC) guidelines for physical activity and exercise. According to these guidelines, pregnant women may safely engage in ≥ 30 minutes of moderate physical activity on most, if not all, days of the week.^[57] Moderate physical activity is defined as an activity performed at an intensity of three to six metabolic equivalents (METs), which corresponds to brisk walking at ~ 5 – 7 km/h (3–4 mph).^[59] Previously sedentary women should start with 15 minutes of continuous exercise three times a week, increasing gradually to 30-minute sessions four times a week.^[58] The aim of exercising during pregnancy is to maintain a good condition without trying to reach a peak fitness level.^[58]

Because of the potential risk of certain activities, healthcare professionals should adapt the exercise prescriptions accordingly, prescribing

activities such as walking, swimming, stationary cycling and aquafit rather than gymnastics, horseback riding, skiing, racquet sports or contact sports. The risks of injury associated with falling are increased in latter activities due to increased levels of oestrogen and relaxin, which augment ligamentous laxity and hypermobility.^[54,60] Pelvic support belts and core stability exercise can be used to enable women to remain active in spite of these changes. In addition, muscle conditioning (light weight-lifting in moderate repetitions) is suggested to maintain flexibility and muscle tone, prevent gestational lower back pain, and promote general conditioning.^[61] Abdominal strengthening is difficult to perform due to the development of diastasis recti and associated abdominal muscle weakness.^[58] For that reason, pregnant women should avoid exercising in the supine position after ~ 16 weeks of gestation. Scuba diving is also to be avoided throughout pregnancy, as the fetus is not protected from decompression sickness and gas embolism.^[58]

Exertion at altitudes above 2500 m (8250 feet) is advised only after 4–5 days of exposure and acclimatization to such high altitudes.^[62]

Metabolic responses during exercise in pregnancy are related to the duration and intensity of exercise. Blood glucose of pregnant women decreases at a faster rate and to a significantly lower level post-exercise than in nonpregnant women.^[63] This decrease does not seem to cause hypoglycaemia, even after 40 minutes of moderate walking or aerobic dancing.^[64,65] However, consuming adequate calories and limiting exercise sessions to <45 minutes is advisable.

During the course of pregnancy, thermo-regulation improves as a result of increased blood circulation and sweating. Prolonged exercise in hot, humid conditions should nevertheless be avoided and adequate hydration maintained knowing that maternal core temperature above 39.2°C during the first trimester may be potentially teratogenic (neural tube defects).^[66] At present, the limited data that are available from studies on exercising pregnant women suggest that women do generally not exercise at levels that cause significant hyperthermia.^[67,68]

4.1 Recommended Heart Rate Target Zones for Aerobic Exercise in Pregnancy

As a result of the reduced maximal heart rate reserve during pregnancy, modified heart rate target zones for aerobic exercise are proposed for each age decade (table II). The proposed modification is based on lowering the top end of the zone by 5 beats/min, thus reducing its range from 20 to 15 beats/min.^[61] The heart rate target range represents ~60–80% of aerobic capacity of a pregnant woman.

Table II. Modified heart rate target zones for aerobic exercise in pregnancy (reproduced from Davies et al.,^[58] with permission from the Society of Obstetricians and Gynaecologists of Canada)

Maternal age (years)	Heart rate target zone (beats/min)	Heart rate target zone (beats/10 sec)
<20	140–155	23–26
20–29	135–150	22–25
30–39	130–145	21–24
≥40	125–140	20–23

If the heart rate is chosen to be used solely as an indicator of exercise intensity during pregnancy, ratings of perceived exertion (RPE) is recommended to be used in addition to heart rate (table III).^[58] RPE consists of numerical ratings from 6–20.^[69] When multiplied by 10, the RPE ratings would roughly correspond to heart rate observed in healthy young adults. The conventional prescriptive zone for fitness training of healthy adults is 12–16. Pivarnik et al.^[40] have shown that this zone is not significantly altered in pregnancy during weight-supported exercise (e.g. cycling). By contrast, the RPE rises in pregnancy during weight-bearing exercise (e.g. walking) proportionally to increased energy expenditure due to maternal weight gain. For that reason, a target zone of 12–14 is identified as the recommended RPE range in pregnancy.

5. Compliance with Physical Activity Recommendations during Pregnancy

Individual physical activity varies greatly during pregnancy, and is determined by socioeconomic and cultural factors specific to the population. Activity-induced energy expenditure is generally low in gestation^[70–75] and tends to decrease as pregnancy advances.^[76–83] The decrease in physical activity during pregnancy is probably attributed to difficulties of movement related to larger body mass and discomfort from pregnancy-induced morphological and physiological changes. Reductions also occur as a result of behaviour changes with respect to the type of activity and in the pace or intensity at which it is carried out.^[84,85]

Studies reviewing retrospective and prospective data on physical activity during pregnancy concluded that women decrease physical activity intensity and duration as pregnancy progresses and shift toward performing less intense, more comfortable modes of activity with lower risks of maternal and fetal injury.^[83,86–88] Pregnant women who ran or jogged before pregnancy were reported to be no longer involved in these modes of exercise but to have shifted toward swimming, walking or gardening. A similar trend can be observed regarding occupational activities. Women

Table III. Borg's rating of perceived exertion^a (reproduced from Davies et al.,^[58] with permission from the Society of Obstetricians and Gynaecologists of Canada)

Borg's rating of perceived exertion	
6	
7	Very, very light
8	
9	Somewhat light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

a A rating of 12–14 is appropriate for most pregnant women.

with physically strenuous professions are more likely to stop working during the last trimester of pregnancy than women working in less physically demanding occupations.^[83]

The decrease in activity-related energy expenditure during pregnancy can be observed in both the developed and the developing world. Compared with nonpregnant women, energy expended on physical activity during pregnancy is decreasing, on average, by 233 kcal/day (20%) at 30 weeks in Sweden,^[76] 201 kcal/day (22%) at 25 weeks and 240 kcal/day (23%) at 35 weeks in Colombia,^[89] and 103 kcal/day (13%) at 38 weeks in Switzerland.^[90]

As a result, few women reach the recommended physical activity (≥ 30 minutes of moderate physical activity on most, if not all, days of the week) during pregnancy. In the US, only 16% of pregnant women comply with the physical activity recommendations, compared with 26% of nonpregnant women.^[91] Even healthy, otherwise active women decrease physical activity due to pregnancy. For example, 70% of women living in Switzerland complied with the recommendations during pregnancy compared with 89% in the nonpregnant state.^[92]

6. Effects of Physical Activity on Pregnancy Outcomes

The influence of physical activity on pregnancy outcomes is widely debated. Traditionally, pregnant women were advised to reduce their levels of physical activity. This advice was based on concerns that exercise would affect pregnancy outcomes by raising core body temperature, by increasing the risk of maternal musculoskeletal injury due to changes in posture, centre of gravity and ligamentous laxity, and by moving transport of oxygen and nutrients to maternal skeletal muscle rather than to the developing fetus.^[58]

In the meantime, research has provided a significant amount of new information about how a pregnant woman and her fetus respond to regular engagement in moderate physical activity.^[93] New investigations have shown no adverse maternal or neonatal outcomes, no abnormal fetal growth and no increase in early pregnancy loss or late pregnancy complications.^[58]

On the contrary, regular physical activity has proven to result in marked benefits for mother and fetus. Maternal benefits include improved cardiovascular function, limited pregnancy weight gain,^[94] decreased musculoskeletal discomfort,^[5] reduced incidence of muscle cramps and lower limb oedema,^[60] mood stability^[83,95] and attenuation of gestational diabetes and gestational hypertension.^[96] Fetal benefits include decreased fat mass, improved stress tolerance, and advanced neurobehavioural maturation.^[97]

The most common fetal response to maternal exercise is alteration in fetal heart rate. The fetal heart rate was reported to increase in the immediate post-exercise period, and to be correlated with both duration and intensity of maternal exercise.^[15,98] Increases in maternal core temperature and maternal-fetal transfer of catecholamines have been reported as causes of post-exercise fetal tachycardia.^[99] Transient decrease in fetal heart rate was also reported during mild or moderate intensity exercise or in studies involving high intensity maternal exertion.^[98,99] Reduced uterine blood flow caused by a rapid post-exercise fall in \dot{Q} was postulated as a cause of the bradycardia, although firm physiological bases

for these changes are still lacking.^[99] Despite the overall alterations of fetal heart rate due to maternal exercise, no abnormal birth outcomes have been noted in healthy women undergoing a normal pregnancy.^[99]

Only a few studies so far have directly examined the effects of physical activity on labour and delivery. One of them was performed by Clapp^[100] on 131 well conditioned recreational athletes. Those who continued to exercise at or above 50% of their pre-pregnancy performance level throughout pregnancy had a lower incidence of operative abdominal and vaginal deliveries and fewer fetuses with acute fetal distress in labour. Erdelyi^[101] reported that among 172 Hungarian athletes, the frequency of caesarean section was almost 50% lower than in a control group of 184 non-athletes.

Even sporadic exercisers, who participated in a structured exercise programme for at least 1 hour, twice weekly for a minimum of 12 weeks during pregnancy, were more likely to have a spontaneous vaginal delivery than their non-exercising counterparts.^[102] Hall and Kaufmann^[103] studied 845 pregnant women who were given the option to participate in exercise programmes designed specifically for pregnant women. They reported that the incidence of caesarean delivery was 6.7% in the high-exercise group (women who completed 64 exercise sessions [range 60–99] during pregnancy), compared with 28.1% in the sedentary group (0.8 sessions [range 0–10] during pregnancy) [$p < 0.0001$]. Melzer et al.^[92] studied the effects the recommended levels of ≥ 30 minutes of moderate physical activity per day on pregnancy outcomes in 44 healthy Swiss women. Active women had a lower risk of operative delivery compared with inactive women (odds ratio = 3.67; 95% CI 1.02, 13.1). Adjustment for parity, maternal weight gain and infant weight strengthened the association between lack of physical activity and operative delivery (adjusted odds ratio = 7.65; 95% CI 1.27, 45.84).

Prior studies showed a strong correlation between length of labour and physical fitness.^[100–102,104,105] Penttinen and Erkkola,^[106] on the other hand, found no significant differences in labour parameters between athletes and controls. Many other studies^[103,106–108] also reported

no significant difference in labour duration between recreationally active women and their controls. Lastly, maternal exercise has been reported to increase,^[103,109,110] decrease^[100] or have no effect^[88,102,111,112] on newborn birthweight.

The inconsistent results on the effects of exercise on the newborn's birthweight may be due to the differences in type, timing, frequency and duration of the exercise regimen imposed (table IV). Clapp et al.^[113] demonstrated that women who begin a regular, moderate regimen of weight-bearing exercise (treadmill, step aerobic or stair stepper) in early pregnancy (for 20 minutes 3–5 times per week) gave birth to larger newborn birthweights compared with non-exercising mothers. Other studies further indicated that women who stayed active throughout the pregnancy also experienced improved fetal growth.^[103,109,110] Physical activity during pregnancy may thus be an important mechanism for improving placental functional capacity, circulation and gas exchange, which in turn increases nutrient delivery and overall growth rate of the fetus.^[109,113]

Nevertheless, weight-bearing exercise was shown to influence fetal growth in both a time-dependent and exercise volume-dependent fashion.^[114] Women who increased the volume of their moderate weight-bearing exercise (treadmill, step aerobic or stair stepper) in late pregnancy (20 minutes 3–5 times per week through week 20, gradually increasing to 60 minutes 5 days per week by week 24 and maintaining that regimen until delivery) experienced a significantly lower newborn birthweight than those women who maintained the high volume of exercise in early pregnancy and then decreased it by two-thirds in late pregnancy.^[114] For women who exercised to term, the drop in infant weight was attributed mainly to differences in newborn fat mass. Clapp and Capeless^[115] concluded that most of the variability in birthweight (40%) can be explained by the relative level of weight-supported exercise performance in the last 5 months of pregnancy. Other studies have been unable to demonstrate decreased birthweight in women who continue exercising but at reduced levels, or in those performing weight-supported exercise (cycling) and/or weight-lifting exercise.^[103,107]

Table IV. Effect of a structured exercise programme during pregnancy on a newborn's birthweight

Study (year)	Number of subjects	Exercise mode	Newborn birthweight
Beckmann and Beckmann ^[102] (1990)	50 exercise group; 50 control group	Exercise group participated in a non-endurance strength training programme for at least 1 h, 2×/wk, for a minimum of 12 wk during pregnancy	No statistical difference in birthweight between exercise and control group (3.69±0.3 vs 3.65±0.3 kg)
Clapp ^[100] (1990)	87 exercise group (runners, aerobic dancers); 44 control group (runners, aerobic dancers who stopped exercising during pregnancy)	Exercise at ≥50% of preconception level (preconception level: running, 14–68 km/wk, 51–83% $\dot{V}O_{2max}$; aerobics, 3–11 sessions/wk, 25–30 min at 54–90% $\dot{V}O_{2max}$)	Exercise group had heavier babies than those born to control group women (3.78±0.4 vs 3.37±0.3 kg; p=0.01)
Clapp et al. ^[97] (1999)	34 exercise group; 31 control group	Throughout pregnancy: running, aerobics, swimming or stair-climbing, 3×/wk, >20 min, >55% $\dot{V}O_{2max}$	Control group had heavier babies than those born to exercise group women (3.64±0.05 vs 3.44±0.1 kg; p=0.01)
Clapp et al. ^[113] (2000)	22 exercise group; 24 control group	Weight-bearing exercise (treadmill, step aerobics or stair stepper) from the 8th wk of pregnancy, 20 min, 3–5×/wk at 55–60% pre-pregnancy $\dot{V}O_{2max}$	Exercising mothers had heavier babies than those born to control women (3.75±0.8 vs 3.49±0.7 kg; p=0.05)
Clapp et al. ^[114] (2002)	26 L-H; 24 M-M; 25 H-L	From the 8th wk of pregnancy, at 55–60% $\dot{V}O_{2max}$: L-H, 20 min, 5×/wk through wk 20, increasing to 60 min 5×/wk by wk 24 and maintaining that level until delivery; M-M, 40 min, 5×/wk; H-L, 60 min, 5×/wk through wk 20, decreasing to 20 min, 5×/wk by wk 24 and maintaining that level until delivery	H-L group had heavier babies compared with the M-M and H-L groups (3.90±0.1 vs 3.44±0.1 vs 3.34±0.1 kg; p<0.001)
Collings et al. ^[107] (1983)	20 exercise group; 12 control group	During the 2nd and 3rd trimester of pregnancy: aerobic exercise 3×/wk, >25 min, 65–70% $\dot{V}O_{2max}$	Exercise group had no significantly heavier babies from those born to control group women (3.60±0.4 vs 3.35±0.4 kg)
Hall and Kaufmann ^[103] (1987)	393 control group (average 0.8 sessions); 82 low level exercise group (15 sessions); 309 medium level exercise group (32 sessions); 61 high level exercise group (64 sessions)	Throughout pregnancy, exercise session consisted of 3 components: warm-up (5 min treadmill at 5–6 km/h, or 5 min bicycle at 50 W) + 5×/wk, 45 min weight-lifting + bicycle ergometer (~85% of maximal HR but <140 beats/min)	High exercise group had 151 g heavier babies than those born to control group women (3510 vs 3359 g; p=0.06)
Kardel and Kase ^[112] (1998)	21 MEG; 21 HEG	From 20th wk of pregnancy, 3-part programme: 1. Muscle strength: MEG and HEG: 5×/wk, 72 min 2. Interval aerobic (HR = 170–180 beats/min): MEG, 1st day 15 sec exercise, 15 sec rest for 10 min, 2 times with 5 min break between; HEG, the same as MEG with 15 min rest 3. Endurance aerobic (HR 120–140 beats/min): MEG and HEG, 2×/wk, 90 min	No statistical difference in birthweight between MEG and HEG group (3.59±0.5 vs 3.65±0.5 kg)

HEG = high intensity exercise group; H-L = high-low exercise group; HR = heart rate; L-H = low-high exercise group; MEG = medium intensity exercise group; M-M = moderate-moderate exercise group; $\dot{V}O_{2max}$ = maximal oxygen uptake.

7. Conclusions

Various physiological modifications arise during pregnancy, labour and delivery in order to

meet the increased metabolic demands of mother and fetus. Despite the pregnancy-induced physiological changes, moderate physical activity during normal pregnancy appears to be beneficial

and should be encouraged. Unfortunately, energy expended on physical activity often decreases as pregnancy advances, which may have negative consequences on mother and infant, including maternal cardiovascular fitness and capacity to sustain efforts required during labour and delivery. Further studies with larger sample sizes are required to confirm the association between physical activity and outcomes of labour and delivery.

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