Literature Review

Exercising While Pregnant

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Current literature on exercise and pregnancy was reviewed. Normal anatomic and physiological changes of pregnancy are briefly outlined. Benefits of maternal exercise experienced by the mother and fetus have been reported by some researchers. Other researchers have documented respiratory and cardiovascular changes peculiar to exercise during pregnancy. Effects on the fetus are also discussed. Guidelines for exercise during pregnancy are discussed with recommendations for health professionals caring for pregnant women. It is concluded that exercise during pregnancy can be safe if common sense is used and guidelines are followed.

With an increase in the number of women participating in regular exercise, more women are asking about continuing, or even initiating, activities while pregnant. While some women asking this question are professional athletes partaking in a high level of activity, the majority are recreational athletes concerned about their health and the health of the fetus. Studies have identified various maternal and fetal responses to exercise; however, further study is needed in many areas before conclusions can be reached concerning the amount, level, and type of exercise which is safe and perhaps beneficial for both mother and fetus. This paper is designed to review the current literature on the maternal and fetal effects of exercise during pregnancy, with recommendations for the pregnant woman who wishes to exercise.

REVIEW OF THE LITERATURE

Normal Anatomic and Physiologic Changes during Gestation which Affect the Ability to Exercise

Posture, Center of Gravity, and Body Weight

The weight gain of 20–35 lbs during an average, normal pregnancy causes shifts in the mother's posture and center of gravity. The protruding abdomen would cause a forward shift of the center of gravity were it not for the body compensating with an increase in the lumbar lordosis and forward tilt of the pelvis (1), thus shifting the center of gravity back over the pelvis to prevent falling forward. Increased thoracic kyphosis and forward head posture may result to compensate for the lumbar lordosis and increased breast mass (13). The instability of this new posture results in a wide-based, "waddling" gait. Such rapid changes in posture often cause low back discomfort and make tasks such as walking, turning, lifting, stooping, and throwing more difficult (11).

Increased Body Fluid

The average woman gains approximately 8.5 liters of water during pregnancy (1, 11). While some of the fluid gain is found in the maternal blood, tissue, and products of conception, a portion is believed to be distributed in the ground substance of the connective tissue visible as pitting ankle edema in some pregnant women (1). This extra fluid doses not shield the pregnant woman from dehydration associated with physical activity (11). The byproducts of increased metabolism in pregnancy result in increased heat and waste production. Subcutaneous fat stored during pregnancy acts as an insulator, reducing the conduction method of heat dissipation (1). The increased fluid needs of pregnancy combined with the increased fluid need of exercise make it essential for the pregnant athlete to consume extra fluids.

Energy Expenditure

An estimated increase of 80,000 kcal in dietary intake over the 40 weeks of pregnancy is necessary to support growing fetal and maternal

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tissues (1, 19). Due to increased weight and metabolism, it is theorized that a pregnant woman would use as much or more energy than a nonpregnant one for daily activities (11). Basal metabolic rate per kilogram body weight was found to increase progressively with increased gestational age (Table 1). However, Lawrence et al. (19) found no increase in energy cost of resting in pregnant versus nonpregnant women and only slight increases in the energy cost of walking, with no change in the energy cost of walking when the increased body weight was accounted for.

The exact energy cost of pregnancy varies from one individual to the next, depending on body size, physiological characteristics, and activity level. If dietary intake is inadequate to meet the needs of the mother and fetus, protein will be catabolized (1). Healthy weight gain is the best assurance that calorie requirements are being met (1).

TABLE 1

*Changes in basal metabolic rate (BMR) with advancing gestational age**

Gestational Age	BMR/kg Body Weight
	cal/kg/min
Postpartum (control)	12.2 ± 2.5
20–28 weeks	14.9 ± 1.6
29–36 weeks	15.3 ± 1.1

* Adapted from Blackburn & Calloway (4).

TABLE 2

Cardiovascular responses during pregnancy

Cardiac hypertrophy (1, 22)
Increased cardiac output 30–40% (1, 9, 22)
Increased heart rate 4–20 bpm (1, 22)
Increased stroke volume 30% (1, 22)
Increased end diastolic volume 70–80 ml (1, 21, 22)
Increased total blood volume 40–50% (1, 20, 21, 22)
Increased plasma volume 50% (1)
Increased red blood cell volume 20% (1)
Increased venous pressure to lower extremities (22)
Decreased total peripheral resistance (22)
Decreased arteriovenous oxygen difference (1, 3, 22)
Decreased arterial blood pressure (22)
Decreased hematocrit 40% (1)

Respiratory Changes

Early in pregnancy, increased levels of progesterone cause a reduced threshold for pCO_2 and an increased sensitivity to any increase in pCO_2 (1, 23). This stimulates an increase in tidal volume and minute volume ventilation of up to 40% during normal pregnancy (1). Since there is little increase in vital capacity, these volumes are increased by a decrease in expiratory reserve volume of 200 ml and a decrease in residual volume of 300 ml.

In addition, anatomical changes occur. The diaphragm rises 4 inches, the lower ribs flare outward, and the subcostal angle widens. These changes account for the 15–20% increase in basal oxygen consumption during normal pregnancy (1, 23).

Additional respiratory stress during pregnancy, such as exercise, is not a problem as the system has the capacity to increase 10-fold (1). However, these changes do cause the gravid woman to experience heightened awareness of the desire to breathe (23), and breathlessness on exertion (1, 23).

Cardiovascular Changes

The cardiovascular changes during pregnancy are summarized in Table 2. These parameters vary according to gestational age and position of the mother.

Stroke volume increases in early pregnancy then decreases to near prepregnancy levels at term (4, 23), whereas heart rate increases progressively until about 32 weeks gestation, then decreases slightly until term (4). Cardiac output gradually increases (1, 4, 11), reaching a maximum at 20–24 weeks gestation (21). Varying results have been documented regarding the changes in cardiac output at term (22). This area requires further study. Arteriovenous oxygen difference [$(a\text{-}v)O_2$ diff] decreases in early and midpregnancy but again increases in the third trimester to near prepregnancy levels (1, 3, 4, 23).

The supine position interferes with venous return to the heart and reduces end diastolic volume and cardiac output (1, 23). The uterus also impedes flow through the iliac veins in the sitting or standing position but less than in supine (1). Blood pressure in supine or standing is lower than in sidelying, especially near term (23).

Benefits of Maternal Exercise during Pregnancy

Several researchers (14, 18, 21, 25), having studied the effects of exercise during pregnancy, cannot support any adverse effect on the mother or the fetus. Evidence has been found to support possible positive effects of exercising while pregnant.

Effects during Pregnancy

Increased physical work capacity has been reported by several authors (14, 18, 25) in women who participate in aerobic exercise during pregnancy. Strength training (17) can decrease physical discomfort and compensate for postural

changes (13). Subjectively, self-image was improved (13).

Limited studies on the effect of exercise on weight gain during pregnancy have been reported. One female athlete who jogged regularly throughout pregnancy gained 18.7 lbs and weighed 3.5 lbs less postpartum than prepregnancy (14). Kulpa et al. (18) reported a 6.4 lb greater mean weight gain in exercising multiparous women compared to controls. There was no difference in weight gain between exercising and control primiparous women. No significant difference in fetal weight was reported between groups. Body fat of female athletes has been reported to be 50% less than in the general population (26). Since the underweight and overweight individuals are known to present special problems during pregnancy (24), limiting weight gain during pregnancy may be a benefit or risk of exercise, or may have no effects. Conclusions about exercise and weight gain during pregnancy cannot be made until this subject is studied in more detail. Risks of limited weight gain during pregnancy are discussed later in this paper.

Effects during Delivery and Postpartum

Researchers have reported reduced duration of labor (1, 25), decreased rate of Cesarean section (13), decreased length of hospital stay (13), and subjectively easier labor (13) in women who exercised throughout pregnancy. In addition, women who exercised recuperated more quickly postpartum (11, 13). Although studies of decreased infant birth weight have been reported in pregnant runners, Hall et al. (13) and Collings et al. (10) actually reported increased infant birth weight in women who exercised on a bicycle ergometer. Further studies are needed to determine the relationship between weightbearing and nonweightbearing exercise and fetal birth weight.

Effects of Exercise on the Mother's Body

Respiratory Effects

The effects of exercise on the respiratory system are most influenced by gestational age and intensity of exercise. In one highly fit runner observed throughout pregnancy, O_2 consumption increased linearly from 60% in the third month to 70% in the eighth month (14). Kulpa et al. (18) reported a training effect in women who exercised at 75% $\dot{V}O_2$max during pregnancy when compared to a control group of women who limited activity throughout pregnancy (18). Blackburn and Calloway (4) reported increased $\dot{V}O_2$ (expressed in ml/kg/min), as pregnancy progressed for cycling at 300 or 400 kpm, and for walking 3 mph on level and 5% grade. However, with exercise intensity of walking 3 mph on 10% grade, $\dot{V}O_2$ increased only until 36 weeks gestation, then decreased slightly in the last month of pregnancy. Collings et al. (10) noted an 18% improvement compared to a 40% decline in $\dot{V}O_2$ when comparing exercising verses nonexercising pregnant women (10).

Several authors have documented increased ventilation (V_E) in exercising women with increased gestational age (3, 14). Artal et al. (3) also documented a greater increase in ventilation in pregnant women than in controls. These authors also documented an increase in the ventilatory equivalent for oxygen ($V_E/\dot{V}O_2$) with increased gestational age (3, 14). Although $V_E/\dot{V}O_2$ was higher in pregnant subjects than in controls, the difference was not statistically significant (3).

As mentioned earlier, tidal volume at rest is increased in pregnant women over controls (1, 3). The increase in tidal volume during exercise is about the same for the same amount of work in pregnant women versus controls (3). At higher workloads, the increase in tidal volume is slightly less for pregnant women (3).

In summary, oxygen consumption, ventilation, and tidal volume have been shown to adapt sufficiently to the combined stress of exercise and pregnancy for levels up to 70–75% $\dot{V}O_2$max. Further studies are needed to draw conclusions regarding the respiratory responses at exercise levels higher than 70–75% $\dot{V}O_2$max. Until further studies are conducted, exercising at levels higher than this is not recommended while pregnant.

Cardiovascular Effects

The cardiovascular changes occurring during exercise while pregnant are summarized in Table 3. Although heart rate was shown to increase progressively with submaximal and maximal exercise in sheep (20), Blackburn and Calloway (4) and Artal and Wiswell (1) report a decrease in heart rate with maximal exercise in human subjects. Cardiac output may follow this same pattern (1). Heart rate recovery to pre-exercise levels was longer with increased gestational age (14), but stroke volume recovered more quickly in late gestation (22). In sheep experiments, $(a\text{-}v)O_2$ difference was increased with exercise (20) but no change has been reported in studies on human subjects (1).

As with respiratory responses, cardiovascular adaptations to exercise while pregnant may be limited at maximal intensity levels. In addition, adaptations may be decreased with advancing gestational age. It has been suggested that venous pooling of blood in the lower extremities may be responsible for decreased cardiovascular ad-

TABLE 3

Acute cardiovascular changes with maternal exercise during pregnancy

Study	Level of Exercise	HR		HR Recovery	SV	Q	
		Submaximal	Maximal			Submaximal	Maximal
		bpm			*ml*	*ml/min/kg*	
Lotgering (20) (sheep experiments)	70–100% $\dot{V}O_2$max	↑	↑			↑	↑
Morton (22)	60–70% age predicted maximal HR	↑		>9 minutes	↑	↑	
Hutchinson (14)	61–70% $\dot{V}O_2$max	↑		2 minutes 2nd trimester 13 minutes 3rd trimester			
Blackburn (4)	Varied VO_2max not recorded	↑	↓				
Artal (1)	Varied	↑	↓		↑	↑	↓

aptations in late pregnancy, due to the enlarged uterus compromising circulation (22). It is suggested that women gradually decrease their workout time and intensity as pregnancy advances.

Since uterine blood flow affects the fetus, changes in uterine blood flow during exercise will be discussed with fetal responses.

Body Weight and Body Fat

Studies reporting direct correlations between exercise and body weight/body fat gained during pregnancy are limited. However, weight gain is directly related to the birth weight of the fetus. Among factors known to influence birth weight, prenatal weight gain accounts for the largest proportion of variation in term infants and second largest proportion among infants of all gestational ages (6).

Some effects of low or high weight gain during pregnancy are listed in Table 4. In one study, Asian mothers producing light babies put on significantly less fat during the second trimester as measured by triceps skinfold (28). Anthropometric measurements to monitor body fat as well as body weight measurements may prove beneficial for the exercising mother-to-be. If body weight gain is less than 15% (24) or skinfold measurements are decreasing with increasing gestational age (28), decreasing exercise intensity and/or increasing calorie intake may be necessary. Further studies in this area are needed.

TABLE 4

*Effects of weight gain during pregnancy**

Low Weight Gain	High Weight Gain
↑ Vaginal bleeding	↑ Hypertension
↓ Fetal birth weight	↑ Duration of second stage of labor
	↑ Cesarean sections
	↑ Fetal birth weight
	↑ Incidence of pre-eclampsia
	↑ Perinatal mortality

* Adapted from Brown et al. (6) and Shepard et al. (24).

Effects of Exercise on the Uterus and Fetus

Fetal Heart Rate

The effect of exercise on fetal heart rate is summarized in Table 5. Although some instances of fetal bradycardia have been reported, most studies report fetal tachycardia. Mode of exercise did not affect the results. Increase in fetal heart rate was similar for mild, moderate, and strenuous exercise (2).

It is interesting to note that in both studies reporting fetal bradycardia, the fetal heart rate fell within the initial 30 sec of exercise, remained at this level throughout exercise, and returned to pre-exercise levels within 1–3 minutes post-exercise, followed by a period of fetal tachycardia (2, 17).

In all studies but one (10) reporting fetal tachycardia, the fetal heart rate was measured after exercise (7, 9, 27). The fetal heart rate was recorded during and after exercise in the two studies reporting fetal bradycardia (2, 17). Due to the rapid increase in fetal heart rate post-exercise, the lack of fetal heart rate recordings during exercise may explain some of the different results.

Factors which may be related to accelerated fetal heart rate following maternal exercise include fetal arousal, placental transfer of elevated maternal catecholamines, increased maternal and fetal temperature or reduction of uterine blood flow (9, 10). In addition, it has been suggested that fetal tachycardia post-exercise may be a compensation to fetal bradycardia during exercise (10, 17).

Fetal bradycardia may be caused by a sustained vagal reflex secondary to major blood volume shifts in both mother and fetus (2), cord

TABLE 5

Fetal heart rate response to exercise

Study	No. Participants	No. Bradycardia	No. Tachycardia	Type of Exercise*
Artal et al. (2)	45	5	40	W
Veille et al. (27)	17	0	17	R, B
Clapp (7)	6	0	6	R
Collings and Curet (9)	25	0	25	W, R, B
Jovanovic et al. (17)	6	6	0	B
Collings et al. (10)	20	0	20	B

*W, Walking; R, running; B, bicycling.

compression (2), or anticipation of the change in placental perfusion pressure (17). Fetal bradycardia maintains systolic perfusion pressure of fetal tissue in the face of decreased placental blood flow, and tissue perfusion is thought to be maintained through increased O_2 extraction.

Uterine Blood Flow, Hyperthermia, and Fetal Hypoxia

Two conditions which may occur during maternal exercise—decreased uterine blood flow and hyperthermia—are of great concern because of the possibility of fetal hypoxia. Lotgering (20) reported progressive decreases in uterine blood flow in sheep experiments. Uterine blood flow decreased with longer and more intense exercise. Uterine blood flow gradually increased after exercise, returning to normal values within 20 minutes.

In humans, uterine blood flow can be compromised as blood flow is redistributed to working muscles away from the visceral organs (2, 26), as occurs during exercise in the general population. Another mechanism which may decrease uterine blood flow is the increased levels of catecholamines during exercise (2, 13). Intravenous administration of norepinephrine in term patients stimulates uterine activity, but no increased activity was noted after exercise in a study on pregnant exercisers done by Veille (27), and fetal activity and breathing were unchanged as a result of maternal exercise in another study (16). The effect of exercise on uterine blood flow remains uncertain, but the birth of healthy, normal, term infants (16) suggests the ability of the fetus to withstand this stress. Since physical conditioning can decrease the catecholamines response to exercise, it may be beneficial to condition the expectant mother before the stress of labor and delivery (13).

In Lotgering's sheep studies (20), maternal temperature increased as much as 1.5° C with strenuous exercise and required more than an hour to return to pre-exercise levels. Fetal temperature rose 1.3° C, and remained significantly elevated even after 1 hour of recovery.

Studies by Clapp et al. (8) and Jones et al. (16) recorded increased maternal rectal temperatures of 0.4–1.0° C. Surprisingly, the lower results occurred with later gestational age (8). This could be accounted for partially, but not completely, by the decrease in exercise intensity (8, 16). It is suggested that the efficiency of heat dissipation may be increased during pregnancy as it is with both training and heat acclimatization (8), although sweat production did not change throughout pregnancy (16). There was no change in vaginal temperature either at rest or after exercise, in any trimester during pregnancy, suggesting that heat was not stored in significant amounts in the region of the fetus during maternal exercise (16).

The mother's thermoregulatory mechanisms appear capable of dissipating the heat produced during moderate exercise (12), but the experiments on sheep (20) suggest the need for further study of thermoregulatory responses during strenuous exercise. The ethical issue of subjecting pregnant women to strenuous exercise which raises core temperature above 39° C limits our knowledge of the thermoregulatory response.

Guidelines for Exercise during Pregnancy

In 1985, the American College of Obstetricians and Gynecologists (ACOG) published Guidelines for Exercise During Pregnancy and Postpartum (Table 6). The guidelines were designed with the average woman in mind, exercising alone. Maternal and fetal safety are of primary concern. Some have criticized the guidelines because they do not sufficiently tax the woman who is accustomed to regular strenuous exercise prepregnancy (12). Data suggests no adverse effects of exercise in women who are conditioned to such activity before pregnancy (15).

In the same year, Edward C. Maeder also published guidelines for pregnant patients. These are listed in Table 7. While some of the guidelines are similar to those of the ACOG Guidelines, Maeder's guidelines allow flexibility for the aerobically conditioned woman. In addition, Maeder gives recommendations for the health professional managing the pregnant patient who wishes

TABLE 6

*American College of Obstetricians and Gynecologists Guidelines For Exercise During Pregnancy and Postpartum**

1. Regular exercise (at least three times per week) is preferable to intermittent activity. Competitive activities should be discouraged.
2. Vigorous exercise should not be performed in hot, humid weather or during a period of febrile illness.
3. Ballistic movements (jerky, bouncy motions) should be avoided. Exercise should be done on a wooden floor or a tightly carpeted surface to reduce shock and provide a sure footing.
4. Deep flexion or extension of joints should be avoided because of connective tissue laxity. Activities that require jumping, jarring motions, or rapid changes in direction should be avoided because of joint instability.
5. Vigorous exercise should be preceded by a five-minute period of muscle warm-up. This can be accomplished by slow walking or stationary cycling with low resistance.
6. Vigorous exercise should be followed by a period of gradually declining activity that includes gentle stationary stretching. Because connective tissue laxity increases the risk of joint injury, stretches should not be taken to the point of maximum resistance.
7. Heart rate should be measured at times of peak activity. Target heart rates and limits established in consultation with the physician should not be exceeded.
8. Care should be taken to gradually rise from the floor to avoid orthostatic hypotension. Some form of activity involving the legs should be continued for a brief period.
9. Liquids should be taken liberally before and after exercise to prevent dehydration. If necessary, activity should be interrupted to replenish fluids.
10. Women who have led sedentary life-styles should begin with physical activity of very low intensity and advance activity levels very gradually.
11. Activity should be stopped and the physician consulted if any unusual symptoms appear.

PREGNANCY ONLY

1. Maternal heart rate should not exceed 140 beats/minutes.
2. Strenuous activities should not exceed 15 minutes in duration.
3. No exercise should be performed in the supine position after the fourth month of gestation is completed.
4. Exercises that employ the Valsalva maneuver should be avoided.
5. Calorie intake should be adequate to meet not only the extra energy needs of pregnancy, but also of the exercise performed.
6. Maternal core temperature should not exceed 38°C.

* Reprinted with permission from American College of Obstetricians and Gynecologists Exercise During Pregnancy and the Postnatal period (ACOG Home Exercise Programs). Washington DC, ACOG, 1985, p 4.

TABLE 7

*Exercise Guidelines for Pregnant Patients**

1. Do not suddenly increase the amount of exercise undertaken.
2. Do not exceed the amount of exercise normally undertaken before pregnancy.
3. Eliminate sports in which the risk of injury is high, i.e., water skiing.
4. Late in pregnancy, avoid excessive aerobic exercise, i.e., long-distance running.
5. Avoid exercises that require lying on the back.
6. Avoid activities where balance is of major importance.
7. In the latter part of pregnancy, avoid activities likely to cause joint strains.
8. Avoid changing positions quickly (to prevent dizziness).
9. Wear good supportive footwear and adequate breast support while exercising.
10. Do not exercise to the point of exhaustion or severe breathlessness.
11. Remember the importance of good nutrition when undertaking an exercise program.
12. Monitor pulse rate and keep within the recommended target zone.

* Reprinted with permission from Maeder (21).

to continue exercising. These guidelines are:

— Identify the high-risk obstetric patient. At present, strenuous exercise cannot be advised for women at high risk.
— Evaluate the patients previous exercise or fitness status.
— Caution the patient to avoid hyperthermia, especially in the first trimester.
— Monitor uterine activity to detect uterine hypoxia (21).

Intensity of exercise may be an important factor in exercise prescription (10). Although ex-

ercise up to 70% $\dot{V}O_2$max has been shown to produce normal healthy infants (9), this level of exercise cannot be recommended until more research is performed. Due to the higher $\dot{V}O_2$max observed during weightbearing activities, the speed of activities such as jogging should be progressively decreased as pregnancy progresses (14). Women who participate in "aerobics" classes should decrease the intensity of activity as pregnancy progresses.

Certain activities must be avoided during pregnancy, even if the mother is accustomed to such activities. Sports recommended and discouraged during pregnancy are listed in Table 8. Those sports discouraged are all potentially harmful to mother and/or fetus.

Because of the progressive nature of the physical changes of pregnancy, the obstetrician needs to re-evaluate the exercise prescription at regular intervals throughout the pregnancy (13). Many medical conditions are contraindications to exercise during pregnancy (1, 5). Any disturbance of fetal growth (5) or signs of fetal distress (1) are contraindications to exercise.

There is a need for structured exercise programs where the pregnant women can be supervised by qualified medical personnel. The combined efforts of obstetricians, physical therapists, and exercise physiologists is recommended to develop individualized exercise prescriptions, monitor maternal and fetal responses, and continue researching the responses to exercise during pregnancy.

SUMMARY

The stress of pregnancy necessitates changes in every system of the mother's body. The stress of exercise affects some of the same systems, particularly the respiratory and cardiovascular systems. The combined stress of exercise and pregnancy on the mother has been discussed.

It has been demonstrated that the fetus may be affected by the exercising mother. Changes in fetal heart rate, uterine blood flow, and maternal and fetal temperature as well as the possibility of hypoxia to the fetus have been reviewed.

Although studies on exercise during pregnancy have been limited, the results have been favorable. Little, if any, negative effects on the mother and fetus have been documented. Some studies have suggested improved fetal outcomes when the mother exercises throughout pregnancy. Large scale experiments are necessary before conclusions can be drawn. Moderate exercise appears to be safe during pregnancy, as long as common sense is used and guidelines are followed.

TABLE 8

Sports during pregnancy•

Recommended	Discouraged
Swimming	Diving (scuba & diving board)
† Running/jogging	Water skiing
Walking	Mountain climbing
† Tennis	Raquetball
Biking	All contact sports
Ballroom dancing	Horseback riding

• Adapted from Diddle (11).

† These activities should only be performed if accustomed to activity before pregnancy.

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