Impact of Physical Activity during Pregnancy and Postpartum on Chronic Disease Risk

ABSTRACT

Research over the past 20 years has focused on the safety of physical activity during pregnancy. Guidelines for health care providers and pregnant/postpartum women have been developed from the results of these studies. The overwhelming results of most studies have shown few negative effects on the pregnancy of a healthy gravida, but rather, be beneficial to the maternal-fetal unit. Recently, researchers have begun to consider the role of maternal physical activity in a more traditional chronic disease prevention model, for both mother and offspring. To address the key issues related to the role of physical activity during pregnancy and postpartum on chronic disease risk, the American College of Sports Medicine convened a Scientific Roundtable at Michigan State University in East Lansing, MI. Topics included preeclampsia, gestational diabetes, breastfeeding and weight loss, musculoskeletal disorders, mental health, and offspring health and development. **Key Words:** DIABETES, EXERCISE, HYPERTENSION, OBESITY, WOMEN

EXPERT PANEL

James M. Pivarnik (Chair)
Heather O. Chambliss
James F. Clapp
Sheila A. Dugan
Maureen C. Hatch
Cheryl A. Lovelady
Michelle F. Mottola
Michelle A. Williams

INTRODUCTION

Prior to 1970, less than 300,000 girls participated in high school sports in the U.S. Following the Title IX Education Act of 1972, there was a dramatic increase in sports opportunities for girls, and by the end of the 20th century, the number participating in school-sponsored sports exceeded 2.6 million (121). Many high school athletes wish to continue their physical activity programs during childbearing years, and seek information regarding the safety of remaining physically active during pregnancy and postpartum. Unfortunately, in the early years following Title IX, little information was available.

In 1985, the American College of Obstetricians and Gynecologists (ACOG) provided recommendations for exercise during pregnancy that were conservative, based on limited evidence available at that time (4). For example, women were told not to perform intense activity continuously for more than 15 minutes per session, and limit their heart rate to 140 beats·min^{-1}. Following these original ACOG guidelines, research over the past 20 years has focused on the safety, as well as the potential benefit of physical activity performed during the peripartum period. Results from most studies have shown clearly that any effects of physical activity on the maternal-fetal unit are likely to be beneficial (37,83,110,176). Most recently updated ACOG Guidelines, and those jointly published by the Society of Obstetricians and Gynaecologists of Canada and Canadian Society of Exercise Physiologists are proactive, and suggest that virtually all women having a normal pregnancy can benefit from a physical activity program (6,52).

Recently, researchers have begun to consider the role of physical activity in a more traditional chronic disease prevention light, for both mother and offspring. This roundtable was undertaken to discuss current findings, as well as future directions that should be considered when studying the role of physical activity during pregnancy/postpartum on long-term health. Specific topic areas included the role of physical activity on pregnancy induced hypertension, gestational diabetes, musculoskeletal disorders, breastfeeding and weight loss, mental health, and offspring health and development. Our educational objectives for the roundtable were to summarize current research on the role of physical activity during pregnancy and

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postpartum on a woman's health and chronic disease risk, summarize current research on the role of maternal physical activity on growth, development, and chronic disease risk of the offspring, and establish directions for future research on the role of physical activity during pregnancy/postpartum on chronic disease risk.

PHYSICAL ACTIVITY DURING PREGNANCY MAY REDUCE THE OCCURRENCE OF PREECLAMPSIA

In this communication we provide a brief overview of the clinical and public health significance of preeclampsia, and highlight evidence regarding whether physical activity may play a role in its prevention. We will also discuss available data regarding specific details (e.g., duration, type and intensity) of physical activity associated with clinically relevant reductions in the preeclampsia occurrence.

What is Preeclampsia and Why is it Important?

Hypertensive disorders during pregnancy are the second leading cause, after embolism, of maternal mortality in the United States, accounting for approximately 15% of such deaths (165). Hypertension in pregnancy is associated with potentially lethal complications including abruptio placentae, disseminated intravascular coagulation, cerebral hemorrhage, hepatic failure, and acute renal failure (122). Preeclampsia, one of the hypertensive disorders of pregnancy, has an incidence of 3–7%.

Preeclampsia is characterized clinically by maternal high blood pressure, proteinuria and edema. Preeclamptics are more likely than normotensive pregnant women to experience metabolic disturbances similar to those seen in nonpregnant patients with coronary heart disease. Metabolic disturbances consistently associated with preeclampsia include hypertriglyceridemia (65,87), excessive lipid peroxidation (167), antioxidant deficiency (182), insulin resistance (87), sympathetic nervous system overreactivity (147), plasma elevations of proinflammatory cytokines and C-reactive protein (134,170), hyperhomocystinemia (153), hyperleptinemia (124,170), and a thromboxane-prostacyclin imbalance that favors vasoconstriction (168). Moreover, pathologic lesions found in preeclamptic placentas are similar to those seen in atherosclerosis (137). There is considerable overlap between the epidemiology of preeclampsia, essential hypertension and coronary heart disease. Risk factors for the respective disorders include obesity, sedentary lifestyle, history of diabetes, familial history of essential hypertension, depression and anxiety. Women with a history of preeclampsia have increased risk of developing essential hypertension in the years following such pregnancies (97,125,150). For example, Nisell et al. (125) reported that after seven years of follow-up, women with a history of gestational hypertension or preeclampsia experienced an increased risk of developing essential hypertension compared to normotensive controls (37% and 20% vs. 2%, respectively).

Overall, available evidence suggests that the pathophysiological and epidemiological characteristics of preeclamptics are remarkably similar to those seen among men and nonpregnant women with essential hypertension (165,172). However, relatively little research has been conducted to assess the occurrence of the former condition in relation to modifiable risk factors such as physical activity. This is an important area that should be explored further in future studies.

What is the Evidence of Reduced Risk of Preeclampsia with Physical Activity?

To date there are only three published studies that have assessed the occurrence of preeclampsia in relation to maternal recreational physical activity. Over a decade ago, Marcoux et al. performed a case-control study of previously pregnant Canadian women (106). Women who participated regularly in recreational physical activity during the first 20 weeks of pregnancy experienced a 43% reduction in risk of preeclampsia as compared to sedentary women. The investigators also noted that the relative risk of preeclampsia decreased as average time spent performing physical activities increased. Sorensen et al. found that regular participation in recreational physical activity during the first 20 weeks of pregnancy was associated with a 35% reduced risk of preeclampsia (154). The risk of preeclampsia decreased in proportion to exercise intensity and total energy expended during the activities. The authors also documented a possible reduction in risk of preeclampsia in relation to walking and stair climbing, activities that pregnant women perform routinely. Women who climbed stairs regularly experienced a 44% to 69% reduction in risk of preeclampsia, and the reduction was evident among all women, irrespective of their participation in recreational physical activities. In 2004, Saftlas et al. (143) reported results from a nested case-control study of New Haven, CT women that corroborated the previous reports from Montreal and Seattle (105,154).

What Mechanisms are Likely to Account for the Observed Reductions in Preeclampsia Risk in Relation to Maternal Participation in Recreational Physical Activity during Pregnancy?

Evidence from epidemiological, controlled clinical metabolic, and animal studies suggests that physical activity may impact preeclampsia occurrence through a number of biological pathways. Potential intermediate effects include reduced blood pressure, decreased concentrations of proinflammatory cytokines and leptin in peripheral circulation, reduced oxidative stress, and improved plasma lipid and lipoprotein concentrations (21,27,61,81,108,123,180). The following paragraphs include a brief review of the literature, which documents metabolic and other physiologic changes associated with habitual physical activity. Where possible, specific indication is provided regarding whether studies included pregnant women.

Results from observational epidemiological studies and randomized trials have consistently demonstrated an inverse relation between recreational physical activity and blood pressure in nonpregnant (89,108) and pregnant women (180). In a meta-analysis of randomized controlled trials, investigators observed that aerobic exercise performed by nonpregnant women significantly reduced resting systolic and diastolic blood pressures (89). Exercise therapy has also been shown to result in reduced diastolic blood pressures in pregnant women with a history of mild hypertension, gestational hypertension or family history of hypertensive disorders (180).

Recreational physical activity is also associated with improvements in lipid concentrations in men and nonpregnant women. Specific improvements include reduced plasma triglycerides and increased high-density lipoproteins (61). Every aspect of lipid metabolism is dramatically altered during pregnancy. Maternal serum or plasma cholesterol and triglyceride concentrations increase 1.5- and 3-fold, respectively, above nonpregnant levels by the mid-third trimester (132). Pregnancy-associated hyperlipidemia is further exaggerated in women with preeclampsia. Recently, Butler et al. (27) reported that mean triglyceride concentrations were lower (-23.6 mg·dL^{-1}) among women in the highest tertiles of time performing physical activity (>2 h·wk^{-1}) compared to inactive women. Similar reductions were seen in total cholesterol. Linear relationships were observed across levels of physical activity measures for triglyceride and total cholesterol. There was no association between physical activity and HDL-cholesterol (27). These data suggest that habitual physical activity performed during pregnancy may mitigate the pregnancy-associated dyslipidemia commonly noted in preeclampsia.

Moderate intensity physical activity results in decreased concentrations of proinflammatory cytokines and C-reactive protein in peripheral circulation. Clapp and Kiess reported that regular weight-bearing exercise during pregnancy influences alterations in plasma tumor necrosis factor-α during pregnancy (40). Women randomized to the physical activity group experienced a greater attenuation of the proinflammatory cytokine concentrations during pregnancy compared to sedentary women. As late pregnancy is characterized by both an increase in insulin resistance and elevated circulating TNF-α levels, regular weight-bearing exercise during pregnancy may moderate insulin resistance, which is characteristic of preeclampsia (87).

Results from studies of the relationship between physical activity and increased risk of oxidative stress are equivocal (2,141). Evidence suggests that physical activity also results in increased antioxidant enzyme activity. This increase compensates for greater oxidative stress that may be attributable to vigorous physical activity (87). Given the central role of oxidative stress in the pathophysiology of preeclampsia (167), more studies are needed to clarify the relationship between maternal and fetal enzymatic and non-enzymatic antioxidant response to physical activity during pregnancy.

Hyperleptinemia has emerged as a promising clinical risk factor for preeclampsia (123,171). As noted previously, preeclampsia risk is inversely associated with maternal physical activity before and/or during pregnancy (105,143,154). In a study of 879 normotensive, nondiabetic pregnant women, Ning et al. reported that maternal leptin concentration in early pregnancy was inversely related with multiple measures of maternal physical activity (e.g., duration, intensity and total energy expenditure) (123). The authors reported that mean leptin was 5.8 ng·mL^{-1} lower among active vs. inactive women ($P = 0.001$). Mean leptin was approximately 8 ng·mL^{-1} lower ($P < 0.001$) among women in the highest levels (>12.8 h·wk^{-1}) of time performing physical activity and energy expenditure (>70.4 MET·h·wk^{-1}), compared with inactive women. These findings are consistent with previously published observational studies that have evaluated the impact of habitual physical activity on leptin concentrations in men and nonpregnant women (57,68,140). Physical activity may influence plasma leptin concentrations via several postulated biological mechanisms. Some investigators (92,148,161) have noted that exercise-induced sympathetic nervous system modifications result in increased catecholamine concentration, which may attenuate leptin synthesis and release. Alternatively, physical activity may influence plasma leptin concentrations directly through its impact on synthesis. Results from animal and human studies (69,135) support this thesis. Lastly, some investigators postulate that improved insulin sensitivity, secondary to physical activity, may influence leptin synthesis and concentrations, independent of adipose tissue mass (48). Whatever the mechanism, results from animal and human studies using diverse methodologies suggest that physical activity is an independent determinant of leptin concentration in the peripheral circulation.

Finally, recreational physical activity has been linked to improvements in emotional well-being and reductions in stress and anxiety (107). Investigators have shown that pregnant women experiencing anxiety and/or depression are at a threefold increased risk of preeclampsia (95). It is reasonable to speculate that the risk of preeclampsia, particularly those cases attributable to maternal psychosocial stress, may be impacted by the psychophysiological benefits of regular physical activity.

Should PA be Evaluated as a Nonpharmacological Therapy for Women with Hypertension in Pregnancy?

Questions remain unanswered concerning contraindications for recreational physical activity during pregnancy. For instance, although physical activity is often prescribed as a nonpharmacological therapy for mild hypertension in nonpregnant individuals, pregnant women presenting with mild hypertension may be directed to go on bed-rest. The question of whether women with high-normal or slightly elevated blood pressures in early pregnancy should be encouraged to begin a supervised moderate-intensity physical activity regimen, is a good one. Prospective studies, conducted in diverse populations, are needed to address this question.

Summary

Physical activity may reduce the risk of preeclampsia through several relevant physiological and metabolic pathways. Emerging results from small clinical and epidemiological studies in pregnant women offer compelling evidence of both short and long-term benefits of physical activity in pregnancy. These data provide evidence to support the biological plausibility of using recreational physical activity to help prevent preeclampsia in pregnant women. Future studies in this area should also explore the link between physical activity and risk of developing chronic hypertension.

THE ROLE OF MATERNAL PHYSICAL ACTIVITY TO TREAT OR PREVENT GESTATIONAL DIABETES

Introduction

Physical inactivity is a risk factor for obesity and type 2 diabetes, both of which are reaching epidemic proportions (14,99). Obesity and gestational diabetes mellitus (GDM) are closely linked (63,71). The prevalence of GDM in obese women is 17%, and overweight women have a 1.8–6.5 times greater risk of developing GDM than normal weight women (99). In addition, women with GDM are at increased risk for type 2 diabetes later in life (99). Sedentary lifestyle is a risk factor for developing GDM (28) and thus, the common link between obesity and GDM is physical inactivity, with both obesity and GDM as risk factors for type 2 diabetes.

Definition of GDM

GDM is defined as a form of diabetes first diagnosed during pregnancy (7,28). During a normal pregnancy, a series of hormonal events contributes to insulin resistance at the muscle level. An increase in insulin resistance decreases maternal blood glucose uptake by the muscles, ensuring an adequate glucose supply for fetal growth and development (9). If risk factors for GDM are present, pregnancy may tip the balance and abnormally high maternal blood glucose and insulin concentrations may result (58). The cause of GDM is unknown, but may be a combination of genetics and lifestyle, perhaps the cumulative effects of unmodifiable and modifiable risk factors.

Risk Factors for Developing GDM

Unmodifiable risk factors include a history of diabetes in the immediate family, ethnicity, and maternal age (58,78,138,151). Modifiable risk factors for GDM include physical inactivity, obesity/overweight, previous GDM, and a history of macrosomic (> 4000 g) babies (14,85).

Up to 60% of women with GDM will develop type 2 diabetes within 4 years after delivery (88). Risk of developing type 2 diabetes is a function of the number of GDM pregnancies a woman has (181). In addition, there is increased health risk for offspring born to GDM women. These babies are more likely to develop type 1 or 2 diabetes later in life (28). Large babies are at greater risk for obesity, which is a risk factor for diabetes (30).

Effects of GDM on the Fetus

High blood glucose concentration in women diagnosed with GDM is available to the fetus for excessive growth and birth weight, which may result in difficult labor and delivery. The increase in body size usually consists of excessive body fat and the baby is born lethargic. In addition, baby growth is disproportional in that the shoulders grow bigger than the head, leading to difficult delivery through the birth canal, often resulting in a cesarean section delivery. Babies born to women with GDM may also be delivered with very low blood sugars due to high fetal insulin concentrations produced in response to excess maternal glucose diffusing into fetal blood. Once the umbilical cord is cut, the high maternal blood glucose supply is cut off, while the fetal pancreas continues to deliver high concentrations of insulin into the fetal circulation. This results in hypoglycemia at birth, requiring intravenous glucose supply (28).

Diagnosis of GDM

Most pregnant women in the US and Canada are screened for GDM between 24 and 28 weeks gestation (7,28). Screening is a random test in which the woman is given a 50 g glucose load to drink. A blood sample is analyzed 1 h after glucose ingestion. If blood glucose concentration is $\geq 7.8\ \mathrm{mmol \cdot L^{-1}}$, a fasted oral glucose tolerance test is warranted. If the concentration is $\geq 10.3\ \mathrm{mmol \cdot L^{-1}}$, GDM is diagnosed. In Canada, the oral glucose tolerance test (OGTT) is two hours and utilizes a drink containing 75 g of glucose. In the United States, the glucose drink is 100 g and the test is 3 h in length. If two of the blood glucose values are met or exceeded, GDM is diagnosed ((7,28), Table 1A).

GDM—Conventional Management

GDM is managed primarily through energy intake control. The goals are to achieve normal blood glucose levels through

TABLE 1. Comparative tables of glucose concentrations ($\mathrm{mmol \cdot L^{-1}}$) for diagnoses of glucose intolerance and gestational diabetes in Canadian and United States, oral glucose tolerance test (1A) and self-capillary glucose monitoring concentrations to determine course of action for women with gestational diabetes mellitus (1B).

	Canada (75 g)	United States (100 g)
1A		
Fasting	5.3	5.3
One hour	10.6	10.0
Two hours	8.9	8.6
Three hours	—	7.8
1B		
Fasting	5.3	5.8
One hour	7.8	8.6
Two hours	6.7	7.2

good food choices, and to provide sufficient energy and nutrients to meet pregnancy needs (75). Dietary plans usually include smaller, more frequent meals, reducing simple and increasing more complex carbohydrates (28). Management of women with GDM encompasses self-glucose monitoring up to seven times per day. After two weeks of dietary intervention, failure to control capillary glucose concentrations may result in a need for blood glucose management through insulin injections. It is imperative that maternal blood glucose be maintained below target values (Table 1B), either through dietary intervention or diet plus insulin injections. The course of insulin injections depends on how well maternal blood glucose is controlled throughout the day (119). The type and amount of insulin injected is beyond the scope of this paper but depends on medical intervention and management.

Exercise as an Adjunctive Therapy for GDM

Many health professionals who counsel women with GDM recommend clients increase their physical activity. The Canadian Diabetes Association suggests that, "physical activity should be encouraged, with the frequency, type, duration and intensity tailored to individual obstetric risk" (28). The American Diabetes Association suggests, "women without medical or obstetrical contraindications be encouraged to start or continue a program of moderate exercise as part of treatment for GDM" (7). ACOG suggests that, "women with GDM who lead an active lifestyle should be encouraged to continue a program of exercise approved for pregnancy" (5). In fact, research has shown that the most physically active women have the lowest prevalence of GDM (62). However, frequency, intensity, time and type of activity leading to the best possible outcomes for women with GDM have yet to be determined. Thus, exercise remains an adjunctive therapy. When exercise has been evaluated for controlling blood glucose concentrations, or, for delaying or preventing insulin therapy, results have been inconclusive (10,25,86,96). Mixed results could be due to nonrandomization of the subject pool, small sample sizes, not well-controlled or reported exercise intensity, no evaluation of chronic physical activity, difference in exercise modalities, or exercise program compliance issues.

Studies Showing Improvement in Glucose Excursion

Jovanovic-Peterson et al. found a 6-wk arm ergometry exercise program to be successful in normalizing fasted plasma glucose concentrations and glycosylated hemoglobin (A1c) in GDM women randomized to diet therapy plus exercise, compared to diet therapy alone (86). The exercise program consisted of 20 min of arm ergometry, three times per week, at an intensity $\leq$ 50% $\dot{V}O_{2max}$. Bung et al. randomized GDM women into a group with diet and insulin therapy or diet and exercise (25). The exercise program consisted of stationary cycle ergometry (50% $\dot{V}O_{2max}$) for 45 min (three 15-min bouts with two rests), three times per week. Because no differences were found between groups, the authors suggested that exercise might be sufficient therapy for many patients due to an increase in insulin sensitivity (25). Garcia-Patterson et al. also found a positive effect of physical activity on GDM women (70). Those who performed light postprandial walking at 2.25 $km \cdot h^{-1}$ showed decreased glucose excursion. More recently, Brankston et al. randomized GDM women to either diet alone or diet plus circuit-type resistance training groups (20). The number of women requiring insulin did not differ between groups. However, overweight women who exercised were less likely to need insulin compared to overweight women who had diet only interventions. Finally, Avery and Walker showed that, compared to rest, a single 30 min bout of cycle exercise at 35% or 55% of $\dot{V}O_{2max}$ improved glucose excursion (11).

Studies Showing No improvement in Glucose Excursion

Lesser et al. determined the effects of a single bout of stationary cycling for 30 min at 60% $\dot{V}O_{2max}$, on six normal and five GDM gravidas (96). Eating a mixed meal 14 h postexercise did not result in improved glucose excursion in the GDM women (96). In another study, GDM women assigned to a partial home-based exercise program (70% of estimated heart rate max) were compared to GDM women with no structured exercise program (10). Although cardiorespiratory fitness improved in GDM women who exercised, glucose excursion did not differ between groups (10).

Preliminary Work

Since 2004, Davenport et al. have assessed conventional management of women diagnosed with GDM using retrospective chart review of patients from London, Canada (51). After conventional management performed for two weeks after diagnoses, 62% of these women required insulin therapy by 30 weeks gestation. Overweight women were 2.6 times more likely to require insulin therapy than normal weight women. Average prepregnancy BMI of women requiring insulin therapy was 30.6 ± 6.4 $kg \cdot m^{-2}$ (51). This high incidence of insulin use in overweight women demonstrates the need for an alternative therapy. In a pilot study, only 50% of women diagnosed with GDM at 16–20 weeks gestation required insulin therapy if they followed a structured walking program (30% $\dot{V}O_{2peak}$, 3–4 times per week) in addition to conventional management (51). Although these data are preliminary, it appears that early diagnoses in women at risk for GDM (especially overweight women) and the addition of structured physical activity, may have promising results.

Maternal Physical Activity to Prevent GDM

In high-risk groups, GDM is considered a significant initiating factor for type 2 diabetes (62), so prevention is crucial. Unfortunately, few prospective studies have been done in this area. Dyck et al. examined the feasibility of using first trimester exercise to prevent GDM in Aboriginal women (62). Despite incentives, compliance was minimal as the investigators recruited only eight women over two years. The exercise program may have been too strenuous as the women were required to exercise at 70% of age-predicted heart rate maximum. Due to small subject number, the authors were not able to determine whether the program truly prevented GDM, but it was nevertheless important to assess the feasibility of early GDM diagnosis and intervention.

Dempsey et al. studied women who participated in recreational activities using a self-reported questionnaire (53). The authors found that women who were most active within the first 20 weeks of pregnancy had a 48% reduction in GDM. In addition, women who were most active one year prior to pregnancy had a 51% reduction in GDM risk. When both variables were combined, overall GDM risk was reduced by 60%. The authors concluded that even though their physical activity measurement tool was imprecise, the relationship between physical activity and GDM risk reduction was robust (53). These data were confirmed later by the same authors using a prospective cohort design (54).

Preliminary Work

Mottola et al. (117) investigated low-risk pregnant women and showed that mild (30% $\dot{V}O_{2peak}$) cycling performed in late gestation was better than more intense (70% $\dot{V}O_{2peak}$) exercise at promoting glucose tolerance in response to an oral glucose load. Vastus lateralis biopsies showed that GLUT4 (glucose transporters sensitive to insulin) was elevated in the mild compared to more intense exercisers, starting at 16–20 weeks gestation until delivery (116). In a subsequent study, nutritional intake was controlled during pregnancy to approximately 8350 kJ·day^{-1} and included 200 g of carbohydrate per day (113). This combination of nutritional control and mild exercise (30% $\dot{V}O_{2peak}$ on stair climber) was better than mild exercise alone in controlling blood glucose concentrations and preventing excessive weight gain during pregnancy. The blood glucose control remained at two months postpartum. These preliminary studies led to the development of a Nutrition, Exercise and Lifestyle Intervention Program (NELIP) which included mild walking (30% $\dot{V}O_{2peak}$) combined with nutritional control (8350 kJ·d^{-1}; 200 g carbohydrate per day) for women at risk for GDM (152). Preliminary results are encouraging, as women at risk for GDM did not develop this disease while on NELIP (N = 23), excessive weight gain was prevented, and normal glucose tolerance remained at two months postpartum (13). In addition, high-risk women on NELIP maintained an insulin sensitivity index similar to those at low risk for GDM, and none developed the disease (115). Preliminary results suggest that overweight women at risk for GDM can enter a NELIP at 16 weeks gestation to help maintain their insulin sensitivity and glucose excursion, as well as prevent excessive weight gain and GDM. Assessment of glycosylated hemoglobin in these women also showed values well below the diabetic range (114). It may be that mild exercise, regardless of modality (e.g., bike, stair climber or walking), in combination with nutritional control, is key in helping women at risk for GDM regulate blood glucose concentrations and prevent excessive weight gain during pregnancy.

Summary

Researchers have not been able to determine a cost-effective, easily accessible evidence based program with guidelines for frequency, intensity, duration of exercise and type of activity that will produce optimal outcomes for women who are at risk for, or who develop GDM. Exercise is considered a valuable adjunctive therapy, and preliminary results are encouraging. However, until guidelines are available from well-controlled studies, the true effectiveness of a specific structured exercise program remains unknown. If modifiable GDM risk factors such as excessive weight gain and glucose intolerance can be improved by incorporating appropriate nutrition and physical activity intervention, we may help reduce diabetes and obesity epidemics in subsequent generations. Future studies should include the role of physical activity on subsequent type II diabetes incidence in women who were at risk for GDM during pregnancy.

MATERNAL PHYSICAL ACTIVITY AND POSTPARTUM MUSCULOSKELETAL ISSUES

Introduction

Virtually all women experience some degree of musculoskeletal discomfort during pregnancy. Twenty-five percent have symptoms that are at least temporarily disabling. Common pregnancy-related musculoskeletal conditions have been identified. Knowledge of musculoskeletal and neuroanatomy and physiology allows for correct diagnosis, prognosis, and treatment of these disorders. Musculoskeletal adaptations of pregnant women should be considered to insure safe and effective exercise prescriptions and avoid provocation of symptoms or injury. There have been few randomized controlled studies designed to evaluate either acute or chronic maternal musculoskeletal effects of exercise. Much available literature is based on case series and expert opinion derived from clinical practice experience. Further research is needed to establish true evidence-based practice and appropriate interventions.

Low Back Pain

Studies have shown that 50–90% of pregnant women experience some type of back pain during pregnancy (66, 93,127,129). Several investigators have followed women with back pain during pregnancy for months to years after delivery. Factors associated have included severity of pain during pregnancy, history of low back pain prior to pregnancy and advanced maternal age (24,127,129, 130,155,160,162). Back pain is also the most commonly reported reason for missed days of work during pregnancy (128). It is not clear how frequently pain extends postpartum work leave.

Specific causes of back pain during pregnancy are unclear but have been attributed to increased biomechanical strain and altered hormonal influences (93). The sacroiliac joints, located under the dimples on both sides of the upper buttock, are often involved. Increased biomechanical strain should be considered in exercise prescription, especially in individuals performing high impact exercise. Obesity, in relation to maintained maternal weight gain, may also influence chronic musculoskeletal disease risk related to low back pain, and hip and knee osteoarthritis.

Spondylolisthesis, a condition where there is forward slipping of one vertebra on an adjacent vertebra, is secondary to a defect in the posterior elements of the spine. Degenerative spondylolisthesis is most common at the L(lumbar)4-L5 level and more common in women than men. Studies have shown a higher incidence of L4-L5 spondylolisthesis in women who have had children compared to those who have not (142). Therefore, pregnancy may play a role in the development of degenerative spondylolisthesis in susceptible women.

Kihlstrand et al. investigated the effects of water exercise on the incidence and severity of low back pain experienced during pregnancy (90). The authors found that water exercise during the second half of pregnancy resulted in a significant reduction in low back pain intensity. Since severity is correlated with symptom chronicity, exercise interventions that reduce pain intensity may be useful in limiting chronic disability from low back pain. A recently completed randomized control trial showed physical therapy with guided stabilization exercises demonstrated greater positive effect on postpartum pelvic girdle pain compared to a program without stabilization exercises (157).

More research is needed to determine if specific exercise programs that decrease low back and pelvic pain during pregnancy and the postpartum period also reduce chronic pain. In addition, pregnancy and postpartum exercises leading to weight management and diabetes prevention may have the secondary effect of reducing the incidence of chronic neuropathic pain. Further, shortening the active stage of labor may be beneficial in reducing labor and delivery related nerve injuries that can lead to chronic impairments.

Pelvic Floor Muscle Dysfunction and Pregnancy-Related Urinary Incontinence

Review of pregnancy-related urinary incontinence (UI) indicates multifactorial causes (23). Pregnancy-related UI is a debilitating, chronic issue for many women. Issues of labor and delivery are most frequently cited, in particular nerve injury (including lumbar nerve root, lumbosacral plexus, and peripheral nerves, in particular pudendal) and soft tissue injury related to rapid fetal descent and episiotomy. While exercise and physical activity may have no impact on features of labor and delivery related to UI, physical fitness level may have some impact on maternal pushing ability. Prolonged pushing has been associated with nerve injury (178).

Many women are counseled to perform Kegel exercises (voluntarily squeezing the muscles of the pelvic floor) during pregnancy and the postpartum period to restore neuromuscular control to the pelvic floor musculature. Studies have demonstrated reduced postpartum UI in women involved in specific postpartum pelvic floor exercises performed with a vaginal device providing resistance or feedback, likely by increasing strength (79). Kegel exercises alone have not been shown to be helpful in reducing pregnancy-related UI. In another study of risk factors, Burgio et al. showed that nonspecific pelvic floor exercises were not related to reduced UI at 12 months postpartum (26). Pelvic floor muscle training during pregnancy has been shown to prevent urinary incontinence during pregnancy and after delivery when physical therapists provided once per week group training for 12 weeks (112). Therapists instructed patients on pelvic floor muscle exercises and encouraged intensive contractions. Participants also performed the training at home.

Pregnancy Related Abdominopelvic Musculoskeletal Conditions that may be Impacted by Physical Activity/Exercise in Pregnancy

Separation or diastasis of the rectus abdominus muscle from the linea alba, the midline anchor point of the stomach muscles, can occur in pregnancy with an incidence as high as 67% (18). Rectus abdominus muscles originate from the rib cage and diaphragm, and attach on each pubic bone. Although spontaneous reduction usually occurs, separation may continue chronically in some women. Long-term sequelae may include abdominal wall pain, pelvic dysfunction given the distal attachment of the rectus abdominus to the pubic bones, or low back pain given the key role the abdominal muscles play in stabilization. It is not known whether specific physical activity or exercise performed in pregnancy or postpartum can prevent this abdominal muscular separation.

The pubic symphysis is the fibrocartilagenous joint that connects the pelvic ring in the front by joining the right and left pubic tubercles. Pubic symphysis abnormalities can be pregnancy or labor and delivery related. Pubic symphysis dysfunction and regional pain occur as a result of increased motion related to ligamentous laxity. In a recent European study, the authors estimated the prevalence of this condition as 1 in 36 women (131). Mild cases of symphysis inflammation generally respond to rest and ice. Once a woman becomes symptomatic, careful attention to maintaining short arc or symmetric movements of her lower limbs during exercise is critical in limiting symptoms and mechanical stress.

Osteitis pubis is characterized by bony resorption about the symphysis followed by spontaneous reossification of the pubic tubercles (136). The pregnant or postpartum woman has a gradual onset of pubic symphysis pain followed by rapid progression over the course of a few days. Eventually, excruciating pain may radiate down the inside of both thighs and is exacerbated by any movement of the extremities. Prognosis for recovery is invariably good with a self-limited course that lasts from several days to weeks, before gradually subsiding (72,94). Long-term sequelae have not been studied.

Rupture of the symphysis pubis is rare, and refers to a true rupture of the ligaments supporting the symphysis pubis. This is believed to occur as a result of the wedge effect of the forceful descent of the fetal head against the pelvic ring, usually during delivery, creating a separation of more than one centimeter (82). In a case series performed by Cappiello et al., the authors suggested that symphyseal rupture can occur as a result of forceful and excessive abduction of the thighs with labor epidural anesthesia (29). Characteristically, there is a sudden pain in the region of the symphysis pubis, possibly an audible crack, followed by radiation of pain to the back or thighs. A gap may be palpable with associated soft tissue swelling. No studies have addressed whether a woman's physical activity or fitness level is associated with pubis symphysis diastasis.

Musculoskeletal Conditions of the Lower Extremity

The literature on joint and muscle injury is related primarily to injury concomitant with pregnancy. There are no studies correlating acute injury in pregnancy with chronic symptoms. However, women with pregnancy-related ligamentous injuries, such as anterior cruciate ligament tears, are at higher risk of degenerative joint disease of the involved knee, as is any individual with this condition. In addition, transient bone density abnormalities of pregnancy resulting in stress fractures may predispose a woman to chronic bone disease. In a case-control study, approximately 100 postpartum and matched nulliparous controls were surveyed regarding lower extremity pain complaints (164). Postpartum subjects were twice as likely as nulliparas to have symptoms of leg and foot pain, with the majority of pain beginning in the second and third trimesters. The study authors did not find an association between regular exercise and pregnancy-related complaints.

Ligamentous laxity may be associated with lower extremity injury. Blecher et al. documented transient ACL laxity in a pregnant woman in her third trimester and postpartum period after reconstruction performed two months before conception (16). Relaxin-related dissociation of large collagen fibrils was thought to be causative. Differential diagnosis in pregnant and postpartum women with musculoskeletal pain should include other bone, joint and soft tissue structures in addition to ligaments. For instance, the labrum of the hip or meniscus of the knee may be at greater risk of injury in the setting of ligamentous laxity. Flik et al. reviewed two cases of pregnant women presenting with acute locking of the knee; one patient required urgent arthroscopic repair of a torn meniscus (67). Their findings showed history of previous injury in the area, current injury in adjacent areas, or systemic metabolic conditions such as pregnancy related osteoporosis could be associated with an acute musculoskeletal injury in pregnant women. These injuries could then lead to chronic musculoskeletal sequelae, such as joint replacement. Case studies also document sacral and tibial stress fractures in pregnant women related to osteoporosis in addition to rib and vertebral fractures (3,47,144,159). In a case study of a pregnant woman with normal lumbar and femoral bone density, bilateral sacral stress fractures were related to fatigue fracture due to unaccustomed loading in the last trimester (145). This finding might provide insight into whether previously inactive women should avoid third trimester high impact exercise.

Musculoskeletal Conditions of the Upper Extremity

Peripheral nerves are susceptible to injury in the pregnant, laboring and postpartum woman by several mechanisms including compression, traction, ischemia and less commonly, laceration. From a biomechanical perspective, labor and delivery are more likely to compromise the lumbosacral plexus, the web of nerves that forms in the pelvis after the nerve roots exit the spine, and lower extremity peripheral nerves. Activities of daily living and childcare, especially those requiring repetitive or prolonged positioning of the upper limb, are associated with upper extremity peripheral nerve injury. Upper extremity neuropathies (such as median neuropathy at the wrist or carpal tunnel syndrome) can also occur during pregnancy due to peripheral edema.

Hand pain (primarily from carpal tunnel syndrome [CTS]) is the second most frequent musculoskeletal symptom of pregnancy (82). The median nerve can be entrapped at the wrist in the enclosed space formed by the carpal bones and the overlying transverse carpal ligament. CTS typically presents with pain and numbness in the first three digits of the hand, often bilaterally, and is most frequently diagnosed during the third trimester (156). The incidence of CTS varies from 2 to 25% of pregnant women, and is most common in older primiparas (64,163,169). The pain can worsen with repetitive wrist flexion or extension. Peripheral edema has been implicated in pregnancy related CTS. We found no studies addressing the exercise habits of pregnant women with carpal tunnel syndrome. Exercises that require repetitive or prolonged wrist flexion or extension may be causally implicated in CTS while water activities that reduce peripheral edema via hydrostatic pressure may reduce CTS risk. Exercise in normal temperature pool water is advantageous to the pregnant woman. Buoyancy helps unload the joints to ease painful movements.

DeQuervain's tenosynovitis is an inflammatory condition of the thumb tendons that travel on the posterolateral aspect of the wrist. It can develop in pregnancy or during the postpartum period with localized pain along the radial aspect of the wrist. Fluid retention related to hormonal status of pregnancy and lactation is suspected in the pathophysiology. Overuse during childcare activities is also implicated (146,149). Symptoms may persist until nursing is discontinued (84). Exercise programs have not been studied when evaluating the epidemiology of this overuse injury in pregnancy.

Summary

Research is limited in the area of chronic maternal musculoskeletal conditions related to physical activity and exercise in pregnancy. Regular exercise in pregnancy has been shown to provide medical and psychological benefits to both mother and child (6). It may also be useful in preventing chronic musculoskeletal conditions, but this deserves further study. The impact of biomechanical and hormonal changes of pregnancy on the musculoskeletal system should be factored into a woman's exercise program during pregnancy to reduce her risk of injuries and their sequelae.

MATERNAL PHYSICAL ACTIVITY-EFFECTS ON BREASTFEEDING AND POSTPARTUM WEIGHT LOSS

Excess weight gain during pregnancy lifestyle changes during the postpartum period are likely important contributors to obesity among women (43,76,173,177). While many epidemiological studies report that average pregnancy related weight retention (PRWR) ranges from only 0.5–3.0 kg, 15–20% of women are at least 5 kg heavier at 6–18 months postpartum than they were before pregnancy (76). Rooney and Schauberger (139) measured weight change in 540 women during pregnancy and then 5–10 yr after delivery. They reported that women who lost their pregnancy weight by six months postpartum gained 2.4 kg in the following 8.5 yr, compared to an 8.3-kg gain in women who did not. Women with the smallest weight gain breastfed their infants for longer than 12 wk or participated in aerobic exercise. These data support the hypothesis that the postpartum period may be an ideal time to implement an exercise and diet program to prevent obesity. However, while exercise and caloric restriction may improve maternal health during lactation, their effect on milk volume and composition and consequently, infant growth and health, must be considered.

Lovelady et al. (102) investigated the impact of postpartum exercise on lactation performance in a cross-sectional study of exclusively breastfeeding women with infants aged 9–24 wk. Exercising women had significantly higher $\dot{V}O_{2max}$ (46 ± 2 vs. 30 ± 5 $mL \cdot kg^{-1} \cdot min^{-1}$), lower percent body fat (21.7 ± 3.5 vs. 27.9 ± 4.7%) and consumed significantly more calories (2739 ± 309 vs. 2051 ± 335 $kcal \cdot d^{-1}$) than the sedentary women. The women reported exercising (mainly swimming and running) ~88 $min \cdot d^{-1}$ during lactation, expending significantly more energy than the sedentary women (3169 ± 273 vs. 2398 ± 214 $kcal \cdot d^{-1}$, including the calories produced in breast milk). However, breast milk did not differ in volume, energy, protein, lactose, or lipid composition between exercising and sedentary women. These results suggest that aerobically fit and physically active women can exercise for long periods of time without affecting lactation performance if caloric intake is adequate to meet increased energy needs.

Dewey et al. (55) examined the effect of exercise on lactation performance in sedentary lactating women who had not been physically active during late pregnancy and early postpartum. At six to eight weeks postpartum, subjects were randomly assigned to either an exercise or control group. The exercise program consisted of walking, jogging or cycling at 60–70% of heart rate maximum, 5 $d \cdot wk^{-1}$ for 12 wk. Initial sessions lasted 20 min, with 5-min increases every 3 d until 45 $min \cdot d^{-1}$ was achieved. Women in the control group did not exercise more than once per week during the study. All participants were instructed to maintain their normal dietary intake.

Both groups in the Dewey et al. study lost an average of 1.6 kg over 12 wk (55). However, women in the exercise group showed greater increases in aerobic fitness (25% vs. 5%), and greater decreases in insulin response to a test meal, compared to controls (103). Plasma triglycerides, total cholesterol and LDL-cholesterol decreased significantly in both groups over time. There was a trend for HDL-cholesterol to increase in the exercise group and decrease in the control group. There were no differences between groups in breast milk volume or composition. Infant weight gain was also similar between groups. These results demonstrated that sedentary women can begin an exercise program without affecting milk composition or volume. However, exercise without energy (calorie) restriction did not promote weight loss.

While some researchers have investigated the effect of exercise on breast milk macronutrients (protein, lipid and lactose) or volume, others have examined the effect of exercise on other biological compounds in breast milk. Investigators comparing sedentary women with women who exercised aerobically for at least 30 $min \cdot d^{-1}$, 3 $d \cdot wk^{-1}$, reported no significant difference in breast milk concentrations of vitamin B6 (104) and long-chained polyunsaturated fatty acids (19). Wright et al. (179) measured lactic acid levels in milk before and after either a 30-min bout of moderate exercise or rest, and reported no difference in lactic acid concentrations after either session. However, there was an increase in milk lactic acid after a maximum exercise test. Using the same protocol, Lovelady et al. (101) reported no differences in concentrations of S-IgA, lactoferrin or lysozyme in breast milk after a 30-min exercise session compared with seated rest. These results are in contrast to those reported by Gregory et al. (74) who reported S-IgA concentrations were lower 10 and 30 min after maximal exercise, compared to sitting. By 60 min postexercise, sIgA concentrations had returned to baseline. Difference in exercise intensity between the Lovelady et al.

(101) and Gregory et al. (74) studies may have caused the conflicting results. Thus, while moderate exercise may have no effect on immunological components in breast milk, exhaustive exercise may be detrimental.

McCrory et al. (109) examined the effects of exercise and 11 days of calorie restriction on milk volume and composition. Exclusively breastfeeding women were randomly assigned to one of three groups at approximately 12 wk postpartum: 1) diet group, which restricted energy intake by approximately 1000 $kcal{\cdot}d^{-1}$, 2) diet plus exercise group, which decreased energy intake by approximately 720 $kcal{\cdot}d^{-1}$ and increased exercise to 86 $min{\cdot}d^{-1}$ for 9 of 11 days; or 3) control group, which had no energy deficit. Women in the diet group lost 1.9 ± 0.7 kg, the diet and exercise group lost 1.6 ± 0.5 kg, and the control group lost 0.2 ± 0.6 kg. This short-term energy deficit did not affect infant growth, nor breast milk volume and macronutrient composition.

Lovelady et al. (100) investigated the effects of a 10-wk calorie restriction and exercise program on infant growth in overweight (BMI = 25–30 $kg{\cdot}m^{-2}$), sedentary, exclusively breastfeeding women. Beginning at 4 wk postpartum, the diet and exercise group restricted energy intake by 500 $kcal{\cdot}d^{-1}$ and exercised for 4 $d{\cdot}wk^{-1}$ at 65–80% of maximum heart rate. Exercise sessions were initially 15 min, and were increased gradually until women were walking, jogging or aerobic dancing for 45 $min{\cdot}d^{-1}$. Women in the control group were instructed not to restrict calorie intake or exercise vigorously more than once per week. Women in the diet and exercise group lost significantly more weight (4.8 ± 1.7 kg vs. 0.8 ± 2.3 kg) and increased their aerobic fitness significantly more (13 vs. 2%) than mothers in the control group. Infant weight and length gains were not different between groups.

Summary

Results of studies performed on breastfeeding women suggest that exercise improves aerobic fitness, plasma lipids and insulin response. However, exercise alone without calorie restriction does not promote weight loss. Once lactation is established, overweight women may restrict energy intake by 500 $kcal{\cdot}d^{-1}$ to promote a weight loss of 0.5 $kg{\cdot}wk^{-1}$ without affecting infant growth. In addition, moderate exercise does not affect immunological component concentrations (sIgA, lactoferrin and lysozyme), vitamin B6, or essential fatty acids in breast milk. While these studies have determined the safety and efficacy of moderate exercise and calorie restriction during lactation, further research is needed to determine the most effective way to implement these lifestyle changes during the postpartum period.

MATERNAL PHYSICAL ACTIVITY AND MENTAL HEALTH

Mood fluctuations are common during pregnancy. During the first trimester, negative mood symptoms such as fatigue, anxiety, and somatic complaints are often reported. Symptoms generally improve during the second trimester and worsen during the third. During the first few weeks postpartum, most women exhibit negative mood symptoms or emotional reactivity (i.e., *baby blues*), which resolves without treatment (111,174). In addition to normal experiences of negative mood or mood lability during the perinatal period, women also have greater susceptibility to clinically defined mood disorders, namely depression and anxiety.

Major Depressive Disorder (MDD) is the second leading global disease burden in industrialized nations (118) and occurs twice as often in women as in men. Most studies performed during the perinatal period suggest that MDD prevalence is similar during and after pregnancy, with an estimated prevalence rate of 10–20% (111). Anxiety disorders are also common in the perinatal period and often occur comorbidly with depression.

Several factors may increase the risk for mood disturbances during the perinatal period. Reproductive hormones influence limbic and stress response system function in the brain (31). Psychosocial factors—such as weight gain and body image, maternal stress and worry, sleep difficulties, change in routine, perceived lack of control, and changing role functions—can also contribute to stress vulnerability. Recognized risk factors for perinatal depression include positive family history of depression, previous depressive episodes, social isolation, chronic health conditions, and life stress (174).

Potential consequences of untreated perinatal mood disorders are substantial. Depression can contribute to substance use, lack of compliance with medical care, fewer positive health practices, reduced role functioning, and loss of income. Disruptions may occur in family relationships, including infant attachment, and vulnerability to subsequent depression (98,111). Thus, recognition and treatment of perinatal mood disorders are important to the physical and psychosocial well-being of both mother and child.

Antidepressant treatment recommendations during the perinatal period generally follow standard guidelines (111,174). Antidepressant medications are commonly administered during postpartum as well as pregnancy. However, little is known about their effects on the developing fetus, and low medication concentrations have been found in breast milk. Thus, use of medications during the perinatal period requires careful consideration, with many women being reluctant to take them. Psychotherapy, including cognitive behavioral therapy and interpersonal therapy, has also shown benefit during the perinatal period. However, treatment for mood disorders is often inadequate; thus, additional treatment modalities, such as exercise, warrant investigation.

Exercise and Mental Health

There is consistent evidence for improved mood with both acute and chronic physical activity. Improvements include increased vigor, reduced fatigue, reduced stress and anxiety, decreased symptoms of negative mood and depression, and improved self-concept (56). Evidence suggests that exercise can also be effective in preventing and treating mild to moderate depression and anxiety (60). For example, Blumenthal et al. (17) examined the effectiveness of exercise compared to antidepressant medication in older adults diagnosed with mild to moderate MDD. After 16 wk of treatment, all groups showed improved depression scores. After six months of follow-up, reported exercise participation, independent of original group assignment, was associated with a decreased likelihood of depression diagnosis. More recently, authors of the Depression Outcomes Study of Exercise (DOSE) examined the dose-response relation of exercise, in terms of total weekly energy expenditure and frequency, on symptoms of depression in adults diagnosed with mild to moderate MDD (59). After 12 wk of treatment, the energy expenditure dose of exercise that approximated public guidelines was associated with lower depression scores relative to the control and low dose groups. There was no effect of exercise frequency (59). Although most research has focused on depression in clinical populations, there is also evidence that exercise can reduce anxiety symptoms among patients with conditions such as panic disorder (22).

Exercise and Mental Health during Pregnancy

Despite increased attention to perinatal mood disturbances and heightened recognition of the mental health benefits of exercise, few studies have examined maternal physical activity and mental health. Within available research, there is consistent evidence for a beneficial effect of physical activity on body image, self-esteem, and general well-being during pregnancy. For example, Wallace et al. (166) examined pregnant women participating in an aerobic exercise program and found that exercisers had higher self-esteem and lower fatigue compared to sedentary controls. Similarly, Hall and Kaufmann showed that pregnant women with high attendance in exercise classes had better self-image and less tension compared to women who had low attendance (77). Studies have also shown a positive association between physical activity and mental health during pregnancy (133). For example, Goodwin et al. (73) examined different aspects of mood and well-being during pregnancy by self-reported exercise categories. The researchers found that exercisers reported better well-being in the dimensions of total, somatic, and anxiety/insomnia. Symptoms of depression and anxiety have also been found to be lower in pregnant women who reported being physically active (50).

Although few studies have examined the effects of a physical activity intervention on mental health during pregnancy, available evidence supports a beneficial effect. For example, Koniak-Griffin (91) compared pregnant adolescents with high levels of depressive symptoms who elected to participate in a 6-wk, supervised exercise program to nonexercise controls. Participants in the exercise group reported reductions in depression symptoms whereas there were no changes in the control group. In a randomized study of exercise during pregnancy, women in an exercise group reported positive changes in energy level as well as improvements in perceptions of health and physical self-concept compared to sedentary controls (107).

Exercise and Postpartum Mental Health

The influence of physical activity during pregnancy on postpartum depressive symptoms could have significant clinical implications in terms of preventing postpartum negative mood or depression. For example, moderate physical activity during the third trimester has been associated with lower depression scores 6 wk postpartum (126). Similarly, Abraham et al. (1) examined physical activity in the context of eating disordered behaviors during pregnancy and observed that women who exercised during early pregnancy also reported lower postnatal distress.

Recent evidence also suggests that a postpartum exercise intervention may be effective in reducing symptoms of depression (8). Women at risk for postpartum depression were identified using the Edinburgh Postpartum Depression Scale and randomized to exercise or control groups. Exercise consisted of 3 $d \cdot wk^{-1}$ of group stroller walking at moderate intensity. Once per week, informal social time followed the walking. The exercise group exhibited significantly greater reductions in depressive symptoms at 6 and 12 wk (8). Study limitations included confounding of the exercise stimulus with social support, small sample size, and use of a no-treatment control. However, results support the potential for an exercise intervention to treat postpartum depression effectively, and demonstrate that new mothers reporting symptoms of depression are willing to engage in structured physical activity.

Motivational Considerations

The perinatal period may represent a prime intervention point for promoting physical activity for mental, as well as physical, health. Well-being and mood are top motivators for physical activity reported by women during and after pregnancy (158). Women are more aware of mood vulnerability during this life stage, and the psychosocial mechanisms associated with physical activity (e.g., social support, body image, distraction, control) provide reasonable explanations for mental health benefits. Many women are reluctant to use psychotropic medications during pregnancy or breastfeeding and look for alternative treatments to manage mood, particularly depressive symptoms. In a large survey of Australian mothers, an overwhelming majority endorsed walking as a way to reduce stress and depression (49).

There are also challenges to prescribing physical activity for mental health. Negative mood symptoms common to pregnancy such as fatigue, helplessness and lack of motivation, may pose barriers to physical activity. With new role responsibilities, many women may have problems planning realistic strategies to be active, particularly postpartum. Planning for exercise is likely to be even more difficult for women experiencing depression symptoms. In addition, women often receive mixed advice on physical activity from health professionals, which may be more problematic during pregnancy when fears of harming the baby may escalate. Also, many women are advised to delay activity until their first postpartum exam, usually 4–6 wk after delivery. Thus, they are not likely to be active during the time when most women experience baby blues or mood lability.

Recommendations for Future Research

Key limitations of previous research on maternal physical activity and mental health include small sample size, self-selection and observational design, and positive mental health at baseline. Research is needed in several areas to expand our current knowledge base. First, it is important to study at-risk populations, including women with a history of major depression or perinatal mood disturbances. In terms of postpartum depression, women who exhibit elevated depressive symptoms during pregnancy or severe baby blues are at risk for future depression and would be good candidates for inclusion in intervention studies. Second, it is imperative that randomized intervention studies be conducted to both treat and prevent depression. Currently, there is no evidence suggesting that exercise would not be at least as beneficial for mental health during the perinatal period as during other life stages. Given psychosocial mechanisms, physiological stress associated with pregnancy, and problems with traditional treatment modalities, exercise may be even more effective during this time. However, much evidence for a positive effect of physical activity on mental health during the perinatal period has involved self-selected samples. Randomized studies are needed to establish a causal relationship, as individuals with higher self-esteem and better mental health may be more likely to be active. Third, valid measures should be used to assess both mental health and physical activity. To understand the totality of mental health benefits, multiple mood variables are important, particularly anxiety, depression, fatigue, and self-esteem. When studying depression and anxiety, clinical rating scales should be used to assess both frequency and severity of symptoms. Lastly, more frequent monitoring of symptoms, during pregnancy and postpartum, may give important insight to mood changes and potential effects of physical activity.

Summary

Most women experience negative mood sometime during the perinatal period. The prevalence of clinically defined postpartum depression is approximately 10–15%. Depression screening and treatment are often not adequate during pregnancy and postpartum. Stress, anxiety, and fatigue are also common in the perinatal period. These symptoms are problematic in isolation and may contribute further to the development of mood disorders. In nonpregnant populations, exercise prescriptions consistent with public health recommendations generally demonstrate a reduction in depression and anxiety symptoms comparable to standard pharmacological and psychotherapeutic treatments. Available evidence suggests that physical activity during pregnancy is associated with improved mental health throughout gestation and the postpartum period. Additional research is needed to evaluate more thoroughly, the role of physical activity in promoting mental health during the perinatal period.

MATERNAL RECREATIONAL EXERCISE AND OFFSPRING HEALTH AND DEVELOPMENT

Introduction

Regular sustained exercise during pregnancy has been a cause for concern because exercise-associated changes in visceral blood flow, body temperature, carbohydrate utilization and shear stress could adversely affect the course and outcome of pregnancy (15,32,33,36). During pregnancy, potential adverse effects include: abortion, malformation, growth restriction, premature labor, hypoxia, brain damage, death and premature separation of the placenta. Potential adverse neonatal outcomes include: low Apgar score, acidosis, hypo or hypertonia, poor suck, seizures, and failure to thrive. Potential problems during infancy and childhood are: poor growth and neurodevelopmental delay manifested by poor coordination, short attention span and poor academic performance. Through adolescence and young adulthood, long-term negative effects could include: poor athletic performance, dropping out of school, obesity, hypertension and insulin resistance (12). This review of actual outcomes observed suggests that concerns regarding maternal physical activity are not warranted, and that most forms of exercise during pregnancy appears to provide some benefit rather than risk to the offspring (34).

However, although current data is extremely positive, all exercise is not the same and many forms of physical activity have not yet received adequate attention. Furthermore, the women studied to date are probably not representative of society at large; study designs and the quality of data obtained are often marginal; and sample sizes for specific outcomes (congenital malformation for example) are inadequate to detect a significant statistical (2 cases/1000) as opposed to a significant clinical (2 cases/100) difference in outcome. Clearly, more work is needed, especially in the area of physical activity interventions for sedentary women and those at the two extremes of reproductive age.

Observed Fetal Outcomes

Detailed, prospective, observational data are available in over 250 healthy, physically fit, middle and upper socioeconomic class women who continued regular weight bearing aerobic exercise regimens during pregnancy. In this populace, the clinical incidence of abortion and malformation is not increased, fetuses exhibit normal stress responses to exercise and have normal non-stress tests and biophysical profiles (36,80). Furthermore, fetuses exhibit clinically normal growth and the incidences of premature labor and premature separation of the placenta are not increased (33). Results appear to be similar when previously sedentary women begin a variety of exercise regimens at various time points during pregnancy (37) but sample sizes are relatively small (20–30 per group). Finally, fetuses of women who continue vigorous weight-bearing exercise until onset of labor have normal amniotic fluid erythropoietin levels, fewer worrisome fetal heart patterns during labor, and decreased rates of both meconium staining and cord entanglement at birth (33,44). While these reports are encouraging, detailed observational and interventional studies in large, more diverse populaces are needed.

Observed Neonatal Outcomes

Although the problems of sample size and selective study populaces persist, more information is available for multiple types of exercise. At birth, offspring of women who engage in a wide variety of exercise regimens have normal 1- and 5-min Apgar scores. Newborns of women who continued a moderate to high volume weight-bearing exercise regimen throughout pregnancy demonstrate advanced neurodevelopment at 5 days of age (45). However, similar data is not available for other exercise regimens. Neonatal morphometrics vary with exercise performance and diet (38,39,41,42). Birth weights of offspring of women who engage in stationary cycling, spinning, swimming, weight training and/or yoga are unchanged or increased (37,120). If women perform weight-bearing exercise, birth weight appears to be dependent on the pattern of exercise performance during pregnancy (37,41,42). Mean (±SEM) values from one large prospective observational and two small prospective randomized studies of weight-bearing exercise are shown in Table 2. Note that low physical activity level (beginning walking, water or low impact aerobics) throughout pregnancy produces an effect similar to that seen in physically active women who do not exercise regularly. Decreasing exercise volume in late pregnancy results in higher birth weight, while offspring born to women who increase exercise volume in late pregnancy are born lighter. Furthermore, the type of carbohydrate in the maternal diet modifies the effect of both low and moderate to high levels of weight-bearing exercise on birth weight. For example, 10 women who performed low level exercise and were randomized to a diet containing 55–60% high-glycemic index carbohydrates (processed foods and root vegetables) delivered infants who weighed and average of 4.17 kg. A similar number of women randomized to a diet containing 55–60% low-glycemic index carbohydrates (fruits, vegetables, nuts and whole grains) delivered infants who weighed an average of 3.33 kg (38).

TABLE 2. Mean (± SD) birth weights according to maternal exercise history.

Exercise History	Birth Weight (kg)
Sedentary Control (*N* = 24)	3.47 ± 0.07
Physically Active Control (*N* > 250)	3.69 ± 0.04
Low Level Throughout (*N* = 22)	3.75 ± 0.08
Decrease in Late Pregnancy (*N* = 25)	3.82 ± 0.06
Increase in Late Pregnancy (*N* = 26)	3.34 ± 0.07

Data are taken from references (37), (41), and (42).

Observed Outcomes at 1 and 5 Years of Age

Information on outcomes at 1 and 5 years of age is currently limited to small numbers of offspring from women who either began or continued weight-bearing exercises during pregnancy (46). In an unmatched urban populace from Cyahoga County, OH, 52 offspring born of women who exercised were compared to those of 50 physically active controls. Their weights (9.7 versus 9.8 kg), lengths (75 versus 75 cm) abdominal (47 versus 48 cm) and head (47 versus 47 cm) circumferences were virtually identical at 1 year of age. Preliminary unpublished data indicate that their anthropometric characteristics are still similar at 5 years of age. In the same populace, the exercise offspring have demonstrated normal to advanced neurodevelopment (Bayley scales of infant development) and preliminary data at age 5 indicate normal neurodevelopment and normal blood pressure. Additional data are available from a smaller but carefully matched rural populace from northern Vermont (35). At age 5, the 20 offspring from the exercising women are 2 kg lighter, have less subcutaneous fat, but have similar axial growth compared to 20 matched controls. They also scored significantly higher on tests of oral language skills and general intelligence (Wechsler Preschool and Primary Scale of Intelligence) with no differences noted in academic readiness, perceptual motor or motor development.

Observed Outcomes at Ages 8 to 12 Years

Preliminary questionnaire data from over 75 urban exercisers in the greater Cleveland area indicate that the growth and general health of their offspring continues to be normal (unpublished observations). To date, their academic performance is significantly better than that reported in control offspring, as is their performance in nonathletic extracurricular activities. Sports performance also indicates equal or advanced hand–eye coordination, balance, strength, speed and endurance in offspring of mothers who exercised during pregnancy.

Observed Outcomes at Ages 17 to 20 Years

Detailed physiological evaluations of the rural college age offspring of Vermont women who continued vigorous weight-bearing exercise regimens are currently underway. Limited information currently available suggests continued superior academic and sports performance with no evidence of compromised health, specifically in the areas of obesity, cardiovascular.

Summary

Many types of maternal non–weight-bearing and weight-bearing exercise have been studied during pregnancy and none appear to increase the risk of an abnormal short-term outcome. Long-term follow-up data are quite limited, but it appears that beginning or continuing weight-bearing types of exercise during pregnancy has no adverse effects on postnatal growth, health or neurodevelopment. Beginning or continuing recreational weight-bearing exercise during pregnancy appears to have some positive short- and long-term effects on offspring outcome. However, the volume and quality of much of the information is not ideal and there is a great need for prospective, randomized, exercise-intervention studies in more diverse populaces, which carefully monitor compliance and examine both short- and long-term outcomes of both mothers and their offspring obesity, cardiovascular function, and insulin resistance.

CONCLUDING THOUGHTS

In the past few decades, research on the role of physical activity during pregnancy has come a long way. Research questions no longer focus on cautious concern for the health and well-being of mother and offspring, but rather, how maternal physical activity might affect future chronic disease risk. Although one must remember that each pregnancy is different, and a woman's physical activity experience should be considered in concert with guidance from her health care providers, positive results from studies examining exercise during pregnancy are very encouraging.

Recent research on the Leading Health Indicators from Healthy People 2010 indicate that increasing physical activity and reducing obesity are the greatest priorities for enhancing women's health (105). Future randomized clinical trials will help sort out the appropriate physical activity regimens that are optimal to help prevent chronic disease and obesity in women, and be most beneficial for offspring growth and development. Results from this Scientific Roundtable have helped provide direction for these future research efforts.

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