ARTICLE

No Need for a Pregnant Pause: Physical Activity May Reduce the Occurrence of Gestational Diabetes Mellitus and Preeclampsia

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Available data, though sparse, consistently show that women who engage in recreational physical activity during pregnancy have approximately 50% reduction in the risk for gestational diabetes mellitus compared with inactive women. Physically active women have approximately 40% reduction in preeclampsia risk. Available data support the American College of Obstetrician and Gynecologists' recommendations that promote exercise during pregnancy. **Key Words:** exercise, physical activity, pregnancy, pregnancy-related disorders, gestational diabetes mellitus, preeclampsia

INTRODUCTION

Epidemiological, clinical, and experimental literature clearly points to favorable physiological changes and overall health benefits associated with regular physical activity among men and nonpregnant women (9). Benefits include favorable alterations in plasma lipid and lipoprotein concentrations, systolic and diastolic blood pressures, endothelial function, glycemic control, reductions in risk of essential hypertension, coronary heart disease (CHD), type 2 diabetes, and certain cancers, as well as increased longevity (9). On the basis of this substantial body of scientific evidence, the U.S. Centers for Disease Control and Prevention and the American College of Sports Medicine have recommended that adults should accumulate 30 min or more of moderate-intensity physical activity on most, and preferably all, days of the week. Moderate-intensity physical activity is defined as activity with an energy requirement of 3–5 metabolic equivalents (MET). For a typical healthy adult, this is equivalent to brisk walking at 3–4 mph. A recent report from the Institute of Medicine noted that at least 60 min of moderate-intensity physical activity are necessary to prevent weight gain, achieve a higher level of physical fitness, and obtain the full health benefits of activity. Hence, guidelines promoted by several health organizations endorse moderate and/or high intensity levels of physical activity of varying durations as a health promotion and disease prevention modality for the general adult population.

Pregnant women, however, represent one segment of the adult population that has received limited attention with regard to clearly articulated guidelines that promote physical activity as a lifestyle choice compatible with good health and disease prevention. To date, there are few published reports from observational studies that were designed to assess the health benefits of regular physical activity during pregnancy.

Until the early 20th century, physical activity during pregnancy had been discouraged primarily because of theoretical concerns of exercise-induced injury and adverse fetal and maternal outcomes (6). Consequently, many saw pregnancy as a state of confinement in which women were not encouraged to engage in recreational physical activity. Some studies conducted before the 1970s focused on the health effect of extremely high-intensity activities, whereas others did not distinguish between physical labor and recreational physical activity. Results from these studies served to reinforce the theoretical concerns of exercise-induced adverse pregnancy outcomes. Since the late 1970s, however, much clinical research (primarily metabolic studies involving small numbers of pregnant women) has been devoted to evaluating

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fetomaternal physiological changes resulting from regular leisure time physical activity during pregnancy (1,6). Findings from clinical and epidemiological studies, completed since 1985, have demonstrated no adverse maternal or fetal effects in women engaged in mild and moderate exercise activities. On the basis of the most current literature, the American College of Obstetricians and Gynecologists (ACOG) in 2002 published new recommendations and guidelines for exercise during pregnancy and the postpartum period. Recognizing that pregnancy is a unique time for behavior modification and that available evidence no longer support the concept that pregnancy is a medical condition requiring the endorsement of a sedentary lifestyle, ACOG currently recommends 30 min or more of moderate-intensity exercise per day for most days of the week during pregnancy in the absence of medical or obstetric complications.

Two new components of the current ACOG guidelines merit special mention. First, for the first time, the recommendations promote exercise for previously sedentary pregnant women and those with medical or obstetric complications, but only after they have undergone medical evaluation and clearance. Second, also for the first time, the guidelines suggest that exercise may play an important role in the prevention and management of gestational diabetes mellitus (GDM).

SHOULD PREGNANT WOMEN EXERCISE, AND IF SO, HOW MUCH EXERCISE IS APPROPRIATE?

In this communication, we highlight some of the evidence regarding whether physical activity plays any role in the prevention of GDM and preeclampsia. We have elected to consider these two disorders, in part, because they are consistently associated with maternal prepregnancy adiposity, and because they share characteristic endocrinological and immunological pathophysiologies. We discuss available evidence regarding specific details (*e.g.*, duration, type, and intensity) of physical activity required to achieve health benefits during pregnancy. This communication is not intended to be an exhaustive review of the current literature. Rather, we cite selected published reports that are intended to be representative of the available literature concerning physiological status (*e.g.*, endocrine and immunological function) and pregnancy outcomes (*e.g.*, placental and fetal growth, gestational age at delivery, and length of labor) among physically active and inactive pregnant women. We end this communication with recommendations for a comprehensive research agenda that fills gaps in our current understanding concerning the type, frequency, and intensity of physical activity associated with optimal fetal and maternal outcomes, including reductions in the occurrence of GDM and preeclampsia.

WHY IS IT IMPORTANT TO ESTABLISH PHYSICAL ACTIVITY GUIDELINES FOR PREGNANT WOMEN?

Physical inactivity is a major risk factor for cardiovascular and obesity-related disorders including hypertension, atherosclerosis, and type 2 diabetes mellitus. Currently, physical inactivity is a central theme of the disease prevention agenda in the United States and worldwide. Promoting physical activity is difficult, however, caused in part by barriers obstructing participation in some populations. Pregnancy, for example, is an important time in the lives of women that may result in decreased physical activity. Previously active women may find the added physical demands of pregnancy to be stressful and may stop exercise or reduce it significantly. This behavior change may occur despite the fact that in most cases, there is no medical reason for women to reduce their physical activity levels. For instance, Yi *et al.* reported that up to 23% of previously active women cease to engage in any exercise during pregnancy (12). These data, along with reports from other investigators concerning the low prevalence of regular exercises among young women, highlight the importance of clearly promoting physical activity among women of reproductive age by providing clear guidelines that may help them make informed choices about the types, intensity, and duration of exercise associated with optimal maternal and infant outcomes. Such guidelines would promote regular exercise as a lifestyle choice that consequently yields health benefits far beyond the brief 9 months of pregnancy.

DOES PHYSICAL ACTIVITY REDUCE THE LIKELIHOOD OF GDM AND PREECLAMPSIA?

Studies of physical activity and the occurrence of maternal pregnancy-related disorders suggest that moderate exercise during pregnancy may be associated with reductions in the risk of GDM and preeclampsia. We discuss the association of recreational physical activity with each of these common complications of pregnancy.

DOES PHYSICAL ACTIVITY REDUCE THE OCCURRENCE OF GDM?

GDM, a disorder of glucose metabolism, complicates between 4 and 7% of pregnancies in the United States and is associated with long- and short-term morbidity in the offspring and mother. Adverse infant outcomes include macrosomia, hypoglycemia, erythremia, hypocalcemia, jaundice, and birth trauma. Later in life, children of gestational diabetic mothers are more likely to become obese, have an abnormal glucose tolerance, and have diabetes in adolescence or early adulthood when compared with offspring of euglycemic women. Women with GDM experience an increased risk for other pregnancy complications such as preeclampsia, infection, and postpartum hemorrhage and are more likely to have overt diabetes develop after pregnancy (8).

Despite the morbidity associated with GDM, few modifiable risk factors have been identified. Physical activity has attracted the attention of investigators in part because in nonpregnant insulin-resistant individuals, exercise improves glucose tolerance and blunts the insulin response to a glucose load.

At least four studies have examined the association between physical activity before and/or during pregnancy and

the risk for developing GDM. Here we summarize the results of two studies. In a case-control study of 155 women with GDM and 386 pregnant controls in the state of Washington, Dempsey *et al.* noted that those engaged in any physical activity during pregnancy or during the first 20 wk of pregnancy had reductions in risk of 55 and 48%, respectively (7). Observed reductions in GDM risk persisted after adjustment for potential confounding factors. Characteristics suggestive of an active lifestyle, such as daily stair climbing, were also associated with statistically significant reductions in risk of GDM, irrespective of participation in recreational physical activity during pregnancy (7).

In a prospective cohort study of approximately 1000 women, also conducted in the state of Washington, investigators observed similar reductions in GDM risk associated with physical activity before and during pregnancy. Compared with inactive women, those who spent $\geq$4.2 h·wk^{-1} engaged in recreational physical activity experienced a 76% decrease in GDM risk (8). Furthermore, those who expended 21.1 MET-hours per week or more (the equivalent of 5.3 h·wk^{-1} of moderate-intensity exercise such as brisk walking) experienced a 74% reduction, compared with inactive women (8). Thus it appears that approximately 30 min·d^{-1} of moderate-intensity physical activity performed during pregnancy may be sufficient to decrease the risk of GDM (Fig. 1).

CAN PHYSICAL ACTIVITY BE USED TO MANAGE GDM?

Available data suggest that glycemic control is improved among gestational diabetic subjects who are treated with a physical activity regimen, and that the improvements are similar to those attained when gestational diabetic subjects are treated with standard pharmacologic therapies. Most of the investigators who have evaluated the role of physical activity in the treatment of GDM have concentrated on the effects of only a single bout of exercise or a training program taking place over several weeks. Overall, the results of studies so far have been encouraging (a representative subset of available studies is summarized in Table 1). Generally, women receiving an exercise therapy (*e.g.*, a 1-h self-paced bout of walking after a meal, or two 30-min sessions on the cycle ergometer), as compared with those receiving a standard dietary intervention, had greater glycemic control, lower fasting and postprandial glucose concentrations, and improved cardiorespiratory fitness.

Taken together, results from observational studies and clinical trials suggest that physical activity, by mitigating the metabolic abnormalities of GDM, may be an important component of prevention and control. Available data support the recommendation of ACOG for physical activity during pregnancy and the thesis that physical activity may play a role in preventing and treating GDM. Further studies should quantify the amount, intensity, and duration of physical activity required to achieve optimal maternal glucose tolerance and fetal growth throughout pregnancy, particularly during the third trimester when the rate of fetal weight gain is estimated to be high.

DOES PHYSICAL ACTIVITY REDUCE THE OCCURRENCE OF PREECLAMPSIA?

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 (11). Hypertension in pregnancy is associated with potentially lethal complications including abruptio

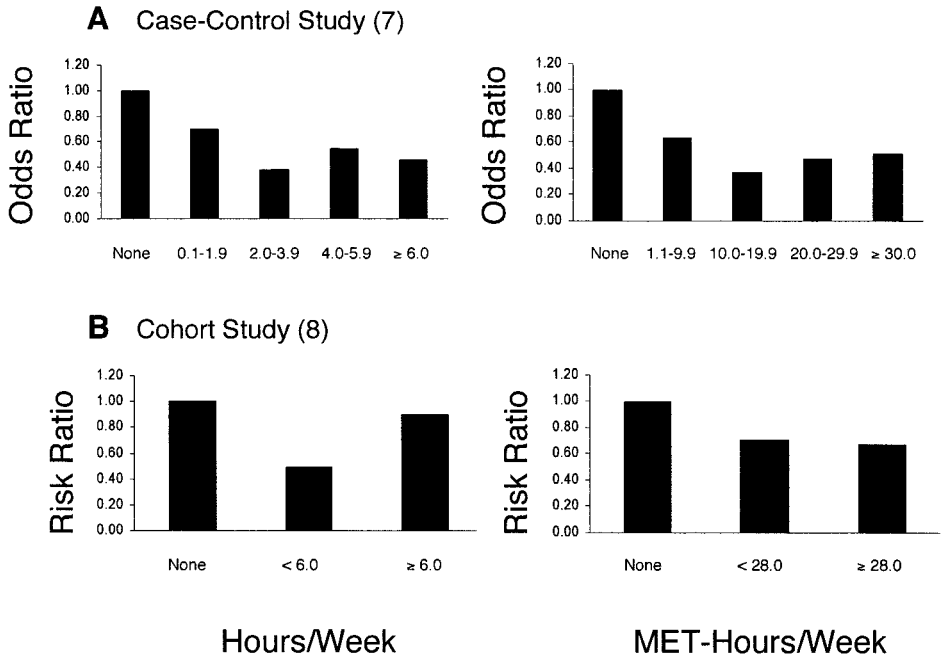

Figure 1. Risk of gestational diabetes mellitus (GDM) in relation to time (h·wk^{-1}) and energy expenditure (metabolic equivalent [MET] h·wk^{-1}) spent on physical activity during the first 20 wk of pregnancy.

TABLE 1

Summary of results of physical activity intervention trials among women with gestational diabetes mellitus

First Author Year	Intervention *N*	Description	Control *N*	Description	Results*
Jovanovic-Peterson 1989	10	6-wk diet + arm ergometer (20 min, 3 per wk)	9	6-wk diet	Lower 6-wk glycosylated hemoglobin, (4.2 vs 4.7%, $p < 0.001$). Lower 6-wk fasting glucose (70 vs 88 mg · dL^{-1}, $P < 0.001$). Lower 1-h postchallenge glucose (106 vs 188 mg · dL^{-1}, $P < 0.001$).
Bung 1991	17	Cycle ergometer (45 min, 3 per wk)	17	Insulin instruction	Similar gestational age at delivery (39 vs 38 wk, NS) Similar birthweight (3379 vs 3482 g) 2 vs 4 macrosomic infants (*P* unknown) Similar neonatal blood glucose (59 vs 58 mg · dL^{-1}, NS) Similar neonatal bilirubin, 1- and 5-min Apgar, blood calcium
Lesser 1996	6†	Cycle ergometer 30 min, 60% $\dot{V}O^2_{max}$	6	No activity	Similar peak glucose (166 vs 160 mg · dL^{-1}, NS). Similar fasting glucose, area under glycemic curve, and plasma insulin after mixed nutrient meal.
Avery 1997	15	Cycle or unsupervised 30 min, 3–4 per week, 70% max HR	14	Usual activity	Similar 2-h postprandial glucose (86 vs 96 mg · dL^{-1}, $P = 0.1$). Similar fasting and postprandial hemoglobin A1C, exogenous insulin therapy use, newborn hypoglycemia.
Avery 2001	15†	30 min of low- or moderate-intensity cycling	15	Rest	Post-cycling glucose (rest, low- and moderate-intensity): 5.2, 4.3, 3.9 mmol · L^{-1} ($P = 0.001$ vs resting for both) Similar results for 15- and 30-min postcycling glucose
Garcia-Patterson 2001	20†	Self-paced walk for 1 h after standard meal	20	Rest after meal	Lower 1-h postprandial glucose (5.4 vs 6.2 mmol · L^{-1}, $P = 0.001$) Similar fasting glucose, 2-h glucose.

*Intervention vs control. †Crossover trial. NS, statistically nonsignificant. Complete list of references available on request.

placentae, disseminated intravascular coagulation, cerebral hemorrhage, hepatic failure, and acute renal failure (11). Preeclampsia, one of the hypertensive disorders of pregnancy, occurs in 3–7% of pregnancies. The pathophysiological features of preeclampsia include impaired glucose tolerance, hypertriglyceridemia, chronic systemic inflammation, and diffuse endothelial dysfunction. These characteristics are generally well defined and are remarkably similar to those seen in men and nonpregnant women with essential hypertension and type 2 diabetes (15). Nonetheless, little is known about disease occurrence in relation to modifiable risk factors such as physical activity.

We are aware of only three published studies that assessed the occurrence of preeclampsia in relation to maternal recreational physical activity. More than a decade ago, Marcoux *et al.* performed a case-control study of Canadian women and reported that those who participated regularly in recreational physical activity during the first 20 wk of pregnancy experienced a 43% reduction in risk of preeclampsia as compared with sedentary gravidas (10). The investigators also noted that the relative risk of preeclampsia decreased as the average time spent performing physical activities increased. Sorensen *et al.* found that regular participation in recreational physical activity during the first 20 wk of pregnancy was associated with a 35% reduced risk of preeclampsia. The risk of preeclampsia decreased with increasing intensity and amount of energy expended during the activities (14). The authors also documented a possible reduction in risk of preeclampsia in relation to walking and stair climbing, activities performed routinely by pregnant women. Women who regularly climbed stairs experienced a 44–69% 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.* (13) reported results from a nested case-control study of women in New Haven, Connecticut that corroborated the reports from Montreal and Seattle (10,14). Results from these and other relevant published studies are summarized in Table 2 and Figure 2.

WHAT MECHANISMS ACCOUNT FOR THE OBSERVED REDUCTIONS IN GDM AND PREECLAMPSIA RISK?

Results from clinical studies suggest that hypertension, chronic systemic inflammation, dyslipidemia, and oxidative stress are common pathophysiologies of GDM and preeclampsia, respectively. Taken together with evidence from observational studies, controlled clinical trials, and animal

TABLE 2

Results from observational studies examining the relation between physical activity and prevention of preeclampsia

First Author Year	Study Design	*N*	Physical Activity Measure	Results
Marcoux 1989	Case-control among Canadian women	172 PE 505 controls	Type, frequency, and intensity of leisure PA in first 20 wk gestation from interview	Regular leisure PA protective (aOR, 0.67; 95% CI, 0.46–0.96) Trend with increasing time in leisure PA (aORs, low–high: 1.00, 0.77, 0.57; $P = 0.01$)
Irwin* 1994	Cohort military	5065 active	Low to high occupational PA classified by job title	Protective effect among construction craftsmen (RR, 0.37; 95% CI, 0.10–0.76) and unskilled laborers unskilled laborers (RR, 0.71; CI, 0.25–0.77) vs low-activity jobs
Sorensen 2003	Case-control in western WA state	201 PE 383 controls	Type, frequency, intensity, and duration of leisure PA in first 20 wk gestation and year before pregnancy from interview	PA during early pregnancy protective (aOR, 0.65; 95% CI, 0.43–0.99) Trends with increasing PA time, peak intensity, energy expenditure ($0.007 < P < 0.04$) and daily stair climbing ($P = 0.04$) Similar results with PA in year before pregnancy
Saftlas 2004	Nested case-control	44 PE 2422 controls	Sedentary job: more sitting than walking/standing Any PA: regular exercise ≥ Once/week	No relation with sedentary vs active job PA during pregnancy appears protective among unemployed women (aOR, 0.66; 95% CI, 0.35–1.22), and among those with non-sedentary jobs (aOR, 0.71; 95% CI, 0.37–1.36)

*Outcome was pregnancy-induced hypertension, identified with hospital discharge diagnosis codes. aOR, adjusted odds ratio. Complete list of references available on request.

studies, this suggests that physical activity may impact the occurrence of GDM and preeclampsia through a number of overlapping and independent biological pathways (Fig. 3). For instance, evidence from studies primarily conducted in men and nonpregnant women indicate that physiological effects of physical activity include improved insulin sensitivity, reduced blood pressure, decreased concentrations of proinflammatory cytokines in peripheral circulation, reduced oxidative stress, and improved plasma lipid and lipoprotein concentrations. Next, we provide a brief overview of some of literature that describes the relationship between physical activity and concentrations of biological markers indicative of GDM and/or preeclampsia risk.

During pregnancy, the increased fetal demand for glucose, the major substrate for growth and development, produces a shift in maternal metabolism toward greater fat production and storage, resulting in decreased glucose utilization. Moderate- and vigorous-intensity physical activity is associated

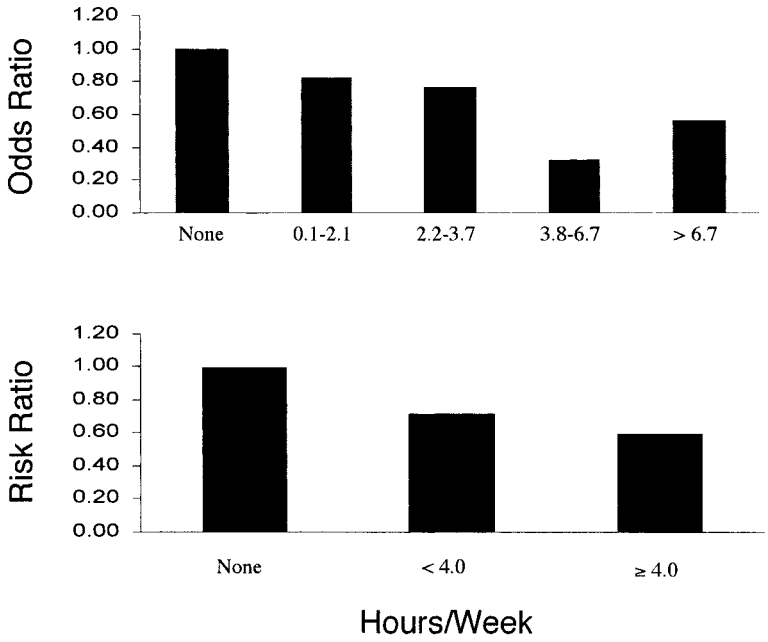

Figure 2. Risk of preeclampsia in relation to time spent ($h \cdot wk^{-1}$) engaged in recreational physical activity during the first 20 wk of pregnancy. The upper figure summarizes data from Sorensen *et al.* (14); the lower figure summarizes data from Marcoux *et al.* (10).

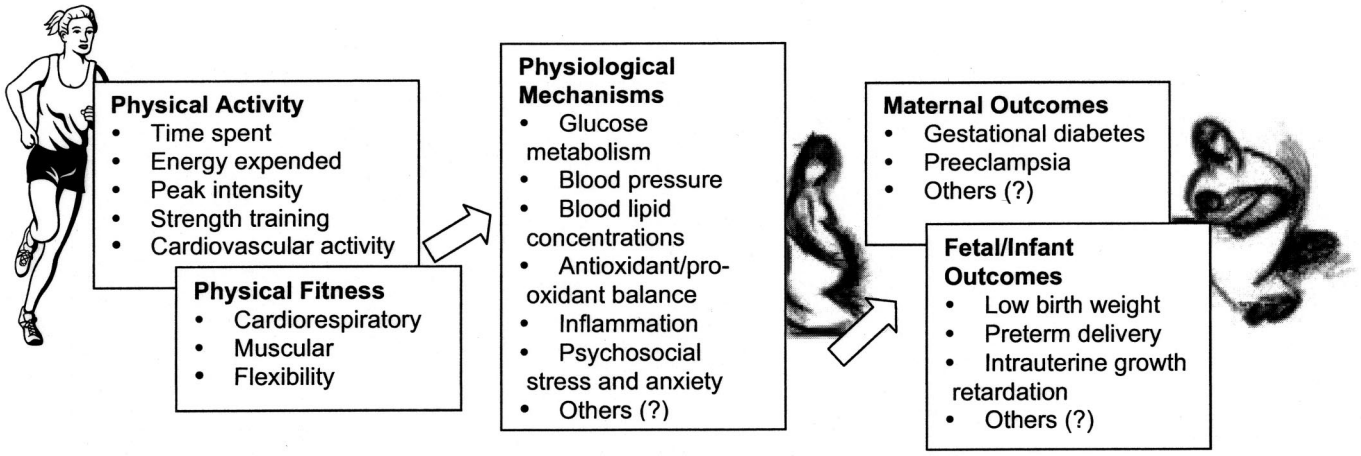

Figure 3. The effects of physical activity during pregnancy on the occurrence of gestational diabetes mellitus, preeclampsia, and other fetomaternal outcomes may be mediated through multiple independent and overlapping biological pathways.

with improved insulin sensitivity and reductions in fat mass (4,6). Aerobic dance and walking, the most popular forms of exercise among pregnant and nonpregnant women (12), have been shown to result in a reduction in plasma insulin even during pregnancy (4). Importantly, carefully designed and conducted metabolic studies suggest that pregnancy may be characterized by a set of compensatory mechanisms that attenuate acute adverse influences exercise may have in glucose handling. Clapp and Capeless reported that the typical exercise-induced hyperglycemia observed in nonpregnant subjects appears to be reversed in healthy pregnant women who regularly engage in recreational physical activities. Although the authors did not measure maternal hepatic lipase synthesis, they attributed the variation in exercise-induced response to a pregnancy-associated decrease in hepatic glucose synthesis and an increase in fractional glucose use by maternal muscle during exercise (4). Overall, these data provide evidence to support the biological plausibility of using recreational physical activity as a disease prevention modality in pregnant women.

Preeclampsia, though characterized clinically by maternal high blood pressure and proteinuria, is also characterized by subclinical metabolic disorders such as hypertriglyceridemia, excessive lipid peroxidation or oxidative stress, insulin resistance, systemic chronic inflammation, and elevated plasma homocysteine (2,14). Physical activity profoundly affects many of these physiological functions.

Results from observational studies and from randomized trials have consistently demonstrated an inverse relation between recreational physical activity and blood pressure in nonpregnant and pregnant women. For instance, results from randomized controlled trials indicate that aerobic exercise performed by nonpregnant women aged 18 yrs or older results in statistically significant reductions in resting systolic and diastolic blood pressures. Exercise therapy is also associated with reductions in diastolic blood pressures in pregnant women with a history of mild hypertension, gestational hypertension, or family history of hypertensive disorder.

Recreational physical activity is also associated with improvements in lipid concentrations in men and nonpregnant women, specifically, reduced plasma triglycerides and increased high-density lipoproteins. Every aspect of lipid metabolism is dramatically altered during pregnancy. For instance, maternal serum or plasma cholesterol and triglyceride concentrations increase 1.5- and threefold, respectively, above nonpregnant levels by the midthird trimester (2,15). Pregnancy-associated hyperlipidemia is further exaggerated in women with preeclampsia and gestational diabetes (2,15). In 2004, Butler *et al.* reported that mean triglyceride concentrations were lower (-23.6 $mg \cdot dL^{-1}$) among women in the highest tertile (>12 $h \cdot wk^{-1}$) of time performing physical activity as compared with inactive women. Reductions in mean total cholesterol were also observed among women in the highest levels of time performing physical activity, energy expenditure, and maximal intensity of maternal exercise. Linear relationships were observed across levels of physical activity measures for triglyceride and total cholesterol (Fig. 4). There was no association between physical activity and high density lipoprotein (HDL) cholesterol (2). These data suggest that habitual physical activity performed during pregnancy may mitigate the pregnancy-associated dyslipidemia commonly noted in hypertensive and diabetic pregnancies.

Moderate-intensity physical activity results in decreased concentrations of proinflammatory cytokines and C-reactive protein in peripheral circulation. Clapp and Kiess reported recently that regular weight-bearing exercise during pregnancy influences alterations in plasma tumor necrosis factor-α during pregnancy (5). Women randomized to the physical activity group, as compared with inactive women, experienced greater attenuation of the proinflammatory cytokine concentrations during pregnancy (5). Because late pregnancy is characterized by an increase in insulin resistance and elevated circulating tumor necrosis factor-α levels, regular weight-bearing exercise during pregnancy may moderate insulin resistance.

Strenuous physical activity has also been noted to increase the risk of oxidative stress by some but not all investigators (14). Evidence suggests that physical activity also results in increased antioxidant enzyme activity; this increase compensates for any possible increase in oxidative stress that may be

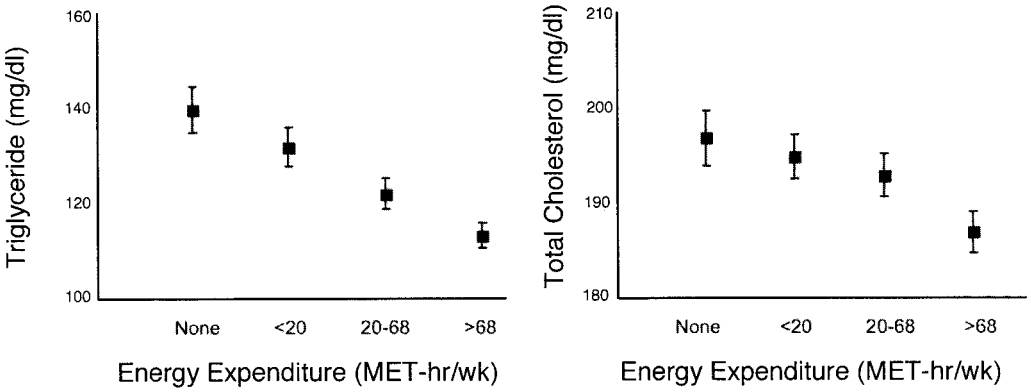

Figure 4. Mean maternal plasma triglyceride and total cholesterol concentrations according to recreational physical activity energy expenditure (metabolic equivalent [MET] h·wk^{-1}) (2).

attributable to vigorous physical activity. Given the central role of oxidative stress in the pathophysiology of preeclampsia (11), more studies are needed to clarify the relation between maternal and fetal enzymatic and nonenzymatic antioxidant response to physical activity during pregnancy.

Lastly, recreational physical activity has been linked to improvements in emotional well-being and reductions in stress and anxiety (14). Investigators have shown that pregnant women experiencing anxiety and/or depression are at a threefold increased risk for preeclampsia (14). 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.

ARE THERE ADVERSE EFFECTS OF EXERCISE IN PREGNANT WOMEN?

As noted, historically, pregnant women were persuaded to take a "pregnant pause" in terms of participation in recreational physical activity. We offer some insights into why scholars and clinicians may have adopted the stance of discouraging physical activity during pregnancy during the early decades of the 20th century.

Results from animal studies published before the 1970s raised concern that physical activity during pregnancy could cause decreased uterine blood flow, fetal bradycardia, and poor outcomes such as preterm delivery and reduced fetal growth. Research findings, published since the 1970s, however, provide reason to believe that most of the previous findings in animals cannot be directly applied to humans. Exercise stimuli used in animals were often not exercise *per se*, but rather thermal, nutritional, or biophysical stressors. Moreover, the physiological impact of stimuli used in these studies did not simulate physiologically relevant levels of physical stress likely to be experienced by healthy, well-nourished pregnant women engaged in recreational exercise. As recently reviewed by several investigators (1,6), pregnancy is known to be characterized by several important compensatory mechanisms that offset adverse effects of exercise-induced changes in uteroplacental blood flow, fetal bradycardia, maternofetal thermoregulatory control, and musculoskeletal function, among others. We provide a brief summary of evidence from clinical and epidemiological studies that assess hypothesized adverse effects of physical activity during pregnancy.

Decrease in uteroplacental blood flow secondary to maternal participation in physical activity has been a topic of many reports in the obstetric literature. These studies were in part motivated by concerns regarding exercise-induced diversions of maternal blood flow away from the uteroplacental compartment to exercising skeletal muscles and skin. Researchers have hypothesized that such diversions may induce placental hypoxemia and compromise fetal growth by depriving the fetus of oxygen and nutrients. These concerns were reinforced somewhat by data that indicated that moderate- to high-intensity physical activity can result in a 50–80% reduction in uteroplacental blood flow. Results from studies involving healthy pregnant women who engage in recreational physical activity, however, have not supported these early concerns. Overall, maternal participation in recreational physical activity has not been associated with reduced in infant birth weight.

Concerns about exercise-induced alterations in uteroplacental blood flow also led some investigators to predict an increased incidence of transient fetal bradycardia secondary to reduced availability of oxygen to the fetus during maternal exercise. Fetal heart rate has been reported to increase, decrease, and remain unchanged during and after maternal exercise. Importantly, fetal heart rates have been shown to increase during maternal participation in activities characterized by high levels of exertion. Data from studies that evaluated fetal outcomes at birth indicate that increased maternal physiological fitness caused by sustained exercise during pregnancy is associated with similar or better outcomes than those observed among inactive and presumably less physically fit mothers.

Concerns about exercise-induced uterine irritability resulting in premature uterine contractions and preterm delivery have also been expressed. Investigators once reasoned that maternal physical activity results in a metabolic milieu consistent with an increase in the synthesis and release of prostaglandins and norepinephrine, potent uterine stimulants capable of inducing premature contractions. A review of relevant studies has failed to support early concerns. Results

from more rigorously designed and executed epidemiological studies are consistent with a reduction in risk of preterm delivery among women engaged in recreational physical activity as compared with inactive women.

Exercise-induced increases in body temperature and evidence of the teratogenic effects of hyperthermia have led some investigators to speculate that maternal exercise during pregnancy may induce adverse fetal outcomes via fetal hyperthermia. Available data, however, suggest that maternal heat dissipation is enhanced during pregnancy. Clapp *et al.* noted that the increase in rectal temperature during exercise performed during the third trimester was statistically significantly lower than when the same exercise was performed during the period before conception (6).

Several authors have hypothesized that the combination of pregnancy-induced joint laxity and recreational physical activity could increase the risk of musculoskeletal injuries such as sprains and strains (1). In early pregnancy, relaxin secretion increases to soften the cartilage in the pelvis to accommodate delivery; during this process, other joints become lax as well. Changes in the center of gravity, weight gain, other alterations in balance, and coordination during pregnancy may also potentially augment the chance of injury during exercise. Researchers should evaluate the determinants, frequency, types, and adverse fetomaternal outcomes associated with exercise-related injuries experienced during pregnancy. Results from such studies will contribute to developing maternal physical activity regimens and adopting guidelines for the treatment and prevention of injuries.

Occupational physical activity during pregnancy deserves special mention here because available evidence suggests that the effects may be unlike those of recreational physical activity (3). Working during pregnancy *per se* is not a risk factor for adverse outcomes, although excessive stair climbing, standing, and bending have been associated with low birth weight, preterm delivery, and spontaneous abortion. It is possible that standing for long periods of time may disrupt uteroplacental flow, alter hormonal balance, and increase intraabdominal pressure. These physiological changes may contribute to adverse maternal and fetal outcomes as premature labor and restricted fetal growth.

WHAT ARE THE CURRENT GAPS IN KNOWLEDGE?

Despite increased attention to physical activity in pregnancy over the past two decades, much remains unknown about the long- and short-term fetomaternal effects of exercise during pregnancy. By necessity, much attention has been paid to testing hypotheses motivated by theoretical concerns of adverse fetal outcomes associated with maternal exercise. Consequently, evidence amassed from studies that have followed healthy pregnant women does not support these early concerns. We believe the time is right to motivate a paradigm shift towards identifying maternal and fetal benefits of exercise in pregnancy.

Future investigations should be designed to study in greater detail the types, frequency, duration, and dose-response patterns of recreational physical activity in relation to pregnancy-related disorders. Studies should also assess the joint and potentially divergent effects of occupational physical activity, as well as activity associated with daily living (*e.g.*, transportation and child care) on pregnancy outcomes. Carefully designed controlled metabolic studies are required to evaluate the effect of physical activity on endocrinological, hemodynamic, respiratory, immunological, and uteroplacental physiology during 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, in pregnancy women presenting with mild hypertension may be directed to go on bed-rest. Should women with high-normal or slightly elevated blood pressures in early pregnancy be encouraged to begin a supervised moderate-intensity physical activity regimen? Prospective studies, conducted in diverse populations, are needed to address this question.

Lastly, as noted, there are virtually no data specific to the epidemiology of sports- or exercise-related injury among active pregnant women. We believe that now, more than ever, there is a clear need to design and conduct surveys of pregnant women as a first step toward better understanding the distribution and determinants of musculoskeletal injury likely to be experienced during pregnancy. Knowledge gained from such studies will provide insights toward preventing sports-related injuries among expectant mothers.

CONCLUSIONS

The current literature does not support concerns that once promoted many to think about pregnancy as a period of confinement. It is encouraging that the ACOG and other similar organizations now publish guidelines that more assertively promote physical activity during pregnancy. Additional research is needed to increase the precision with which exercise programs may be designed for all groups of pregnant women (*e.g.*, those with pregestational diabetes, essential hypertension, or those who are obese). We recommend that investigators now shift their efforts toward documenting the epidemiology of exercise-related injuries likely to be experienced by active reproductive-aged and pregnant women. We also support a research agenda that aggressively and rigorously tests hypotheses concerning health benefits of exercise during pregnancy.

In the mean time, we know that for most women the risks of exercise during pregnancy are far outweighed by confirmed health benefits. We also suspect that women who maintain their exercise habits during pregnancy may set a pattern of behavior that will confer health benefits well beyond their reproductive years. Hence, with proper medical evaluation and approval, women need not take a "pregnant pause" from their active lifestyle.

NOTE

A more complete list of references than that provided here can be obtained from Dr. Michelle A. Williams, Center for Perinatal Studies, Swedish Medical Center, 747

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