Symposium Proceedings

Health Benefits of Physical Activity during Pregnancy: An International Perspective

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ABSTRACT

MUDD, L. M., K. M. OWE, M. F. MOTTOLA, and J. M. PIVARNIK. Health Benefits of Physical Activity during Pregnancy: An International Perspective. *Med. Sci. Sports Exerc.*, Vol. 45, No. 2, pp. 268–277, 2013. While early studies on the effects of leisure time physical activity (LTPA) during pregnancy were concerned about possible harm to the mother or fetus, these fears have not been substantiated. Instead, a growing body of literature has documented several health benefits related to pregnancy LTPA. The purpose of this article was to synthesize evidence from epidemiological studies conducted in the United States, Canada, and Scandinavia on the benefits of LTPA and exercise during pregnancy with regard to maternal health, pregnancy outcomes, and child health. We focused on studies evaluating relations between pregnancy LTPA and gestational diabetes, hypertensive disorders, excessive gestational weight gain, birth weight, timing of delivery, and child body composition. The bulk of evidence supports beneficial effects of pregnancy LTPA on each outcome; however, most previous studies have been observational and used self-reported LTPA at only one or two time points in pregnancy. Limitations of the current knowledge base and suggestions for future research on the health benefits of LTPA during pregnancy are provided. **Key Words:** BIRTH, EXERCISE, FETAL, PRENATAL

In 1985, the American College of Obstetricians and Gynecologists (ACOG) published its first guidelines for exercise during pregnancy and the postpartum period. Given the paucity of research on the subject of exercise (which will be called leisure time physical activity [LTPA] from here forward) during pregnancy at the time, these guidelines were cautiously conservative (2). The recommended limits to LTPA were comparable to the low end of the range suggested by the American College of Sports Medicine (ACSM) in 1978 (6). Anecdotally, we would suggest that most individuals who were involved with LTPA and pregnancy remember the 140 beats·min^{-1} maternal HR limit more than any other precaution. This HR guideline was not based on scientific evidence. Unfortunately, many of today's health care providers still believe that this is the upper limit of LTPA intensity during pregnancy (11); else, harm might come to the maternal–fetal unit. Moreover, there was an infrequently read and followed statement in these initial ACOG guidelines that said:

> It should be noted that recommendation designed for a general cross-section of the population may not be appropriate for a particular patient. A physically fit pregnant patient may tolerate a more strenuous program, whereas an unfit, overweight individual with a sedentary lifestyle should restrict activities to those that are less vigorous (2).

Thus, even as early as 1985, the ACOG experts recognized that volume and intensity of LTPA programs should be more reflective of a woman's activity history rather than one absolute standard.

Early studies both before and after the publication of the 1985 ACOG Guidelines focused mostly on the question of whether the active woman was doing harm to herself and to the fetus (72). A review of the few early scientific reports based on highly competitive athletes who continued to be active during and immediately after pregnancy noted no

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complications (73). Other studies measuring fetal HR and umbilical/uterine blood flow responses to exercise focused on birth outcomes such as birth weight, gestational length, and adverse events occurring during labor and delivery. With few exceptions, no adverse maternal–fetal effects were found in these early studies (57). As a result of this research, indicating no significant adverse health outcomes resulting from maternal LTPA, the ACOG Guidelines were revised in 1994 (3). The overall tone of the document was encouraging, with more focus on the benefits of LTPA during pregnancy, less on concern for adverse outcomes, and no mention of HR limits. Specifically, women were encouraged to perform mild to moderate activity at least 3 $d \cdot wk^{-1}$, to modify intensity according to maternal symptoms, and to resume LTPA postpartum gradually on the basis of their capabilities. The second revision of the ACOG Guidelines occurred in 2002 (4). The Canadian Clinical Practice Guidelines (28) and Danish National Guidelines (29) followed in 2003, while the Norwegian National Guidelines (32) were published in 2005. All of these documents recommended women undergoing a normal pregnancy perform at least 30 min of moderate aerobic and strength/conditioning activity on most days of the week.

The most recent guidelines for LTPA during pregnancy were incorporated in the 2008 Department of Health and Human Services Physical Activity Guidelines for Americans (89). For the less active woman, the following was suggested:

> Healthy women who are not already highly active or doing vigorous-intensity aerobic activity should get *at least 150 minutes* (2 hours and 30 minutes) of moderate-intensity aerobic activity per week during pregnancy and the postpartum period. Preferably, this activity should be spread throughout the week.

This recommended level of activity is prudent and obtainable because it is the same as that recommended for sedentary nonpregnant adults and similar to the ACOG, Canadian, and Scandinavian guidelines for pregnant women (28,29,32). For women who were regularly active before pregnancy, the following was suggested:

> Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health-care provider how and when activity should be adjusted over time.

Taken together, these specific recommendations formalize the 1985 ACOG inference that suggested one size does not fit all when considering appropriate LTPA levels during pregnancy.

As reflected in the changes to LTPA guidelines during pregnancy, the field has progressed well beyond the original questions related to "doing no harm." Indeed, an ACSM Roundtable held in 2005 evaluated the literature to date and concluded that not only is LTPA not harmful but also may be of significant benefit to the mother and child, during, and after pregnancy (72). Much research has occurred since the 2005 roundtable.

In response to the need for a reevaluation of the literature on the role of LTPA during pregnancy, in 2011, the authors presented a symposium at the ACSM annual meeting. The purpose of the symposium was to synthesize evidence from epidemiological studies conducted in the United States, Canada, Norway, and Denmark on the benefits of LTPA during pregnancy with regard to maternal health, pregnancy outcomes, and child health. These countries were chosen because each has contributed a significant amount of research on the topic using rigorous study designs. In addition, although LTPA guidelines during pregnancy are similar among these countries, they represent a range of LTPA participation rates and differing cultural influences on LTPA. For example, whereas studies on the prevalence of any LTPA during pregnancy in the United States (35) and Norway (69) report similar participation rates of 56% and 59%, respectively, Canadian (37) participation rates are much higher at 85%. However, only 23% of pregnant women in the United States and Canada meet LTPA guidelines during pregnancy (35,37), whereas 28% of pregnant women in Norway participate in "regular exercise" (>3 $d \cdot wk^{-1}$) (69). This article is not intended to be all-encompassing with respect to maternal LTPA research throughout the world, rather it will summarize the material presented in the symposium, which sought to provide an overview of the strength of evidence for health benefits related to LTPA during pregnancy while highlighting gaps in current knowledge.

METHODS

Although this article is not a systematic review of the existing literature, general guidelines for selection and summary of articles were followed. Outcomes of interest were categorized as maternal health outcomes (gestational diabetes mellitus [GDM], gestational hypertensive disorders, and excessive gestational weight gain [GWG]), delivery outcomes (birth weight and gestational age at delivery), and child body composition. These outcomes were selected because they represent adverse health conditions occurring most commonly during pregnancy, are those with the greatest effect on maternal and infant mortality/morbidity, and/or have been studied most frequently with respect to their occurrence and relationship to maternal LTPA. For each health outcome, authors searched peer-reviewed literature databases (i.e., PubMed, EMBASE, Cochrane Reviews) for research evaluating associations between LTPA performed during pregnancy and the health outcome. Multiple literature searches were conducted from January 2011 to November 2011. To provide an international perspective, studies conducted in the United States, Canada, and Scandinavian countries were primarily selected for review.

When available, articles including a representative sample of pregnant women from the source country were chosen preferentially for review because the results of these studies are more likely to generalize to the "typical" pregnant woman. The authors focused on presenting results from prospective cohort and case–control studies, rather than cross-sectional designs, because they are better able to control for covariates and provide evidence to support causality. In general, there is a paucity of appropriately powered randomized control trials examining LTPA interventions during pregnancy, but when available, these studies were highlighted. Because this article is meant to provide an overview of the wide range of health benefits related to LTPA during pregnancy, results from recently published meta-analyses were used to summarize previous work in some cases.

The Norwegian Mother and Child Cohort Study (MoBa) and the Danish National Birth Cohort (DNBC) are highlighted throughout the article because they are the two largest prospective studies on pregnancy outcomes that included maternal LTPA measures. The MoBa recruited 106,981 pregnancies from 1999 to 2008 and asked women to self-report frequencies of selected activities at gestational weeks 17 and 30 (13). The DNBC recruited 101,042 pregnancies from 1996 to 2002 and asked women to self-report frequency, type, and duration of LTPA at gestational weeks 16 and 30. An overview summary of the results of all studies reviewed is provided in Table 1. A full summary of all studies reviewed, including research design details, is provided in the supplemental table online (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190).

STUDY RESULTS

Maternal Health Outcomes

Gestational diabetes. GDM is hyperglycemia with first diagnoses during pregnancy. Diagnosis of GDM is

TABLE 1. Summary of results from reviewed studies by health outcome.[a]

Selected Studies on LTPA and Gestational Diabetes Mellitus (Meta-analysis = 82)				
Significant ↓ Odds	**Borderline[b] ↓ Odds**	**No Association**	**Borderline[b] ↑ Odds**	**Significant ↑ Odds**
• HI Prepregnancy LTPA (US: 40, 82) • HI pregnancy LTPA (US: 31, 40)	• HI Prepregnancy LTPA (US: 76, 95)	• HI Prepregnancy LTPA (US: 20, 64) • HI pregnancy LTPA (US: 20, 30, 64)	NA	NA
Selected Studies on LTPA and Preeclampsia				
Significant ↓ Odds	**Borderline ↓ Odds**	**No Association**	**Borderline ↑ Odds**	**Significant ↑ Odds**
• HI prepregnancy LTPA (US: 81) • HI pregnancy LTPA (Scandinavia: 55; US: 86)	NA	• HI prepregnancy LTPA (US: 36, 80, 83, 86) • HI pregnancy LTPA (Scandinavia: 67, 93; US: 36, 80, 83)	NA	• HI pregnancy LTPA with severe subtypes of preeclampsia (Scandinavia: 67)
Selected Studies on LTPA Intervention and GWG in Overweight and Obese Women				
Successful	**Partially Successful[c]**		**Not Successful**	
• Aqua aerobic classes (Scandinavia: 21) • Walking/biking programs (US: 7; Canada: 61) • Lifestyle modification (US: 85)	• Walking program (Canada: 27) • Counseling + free gym membership (Scandinavia: 91) • Counseling + feedback on GWG (US: 8)		• Media campaign (Canada: 38) • Educational materials (Belgium: 39; US: 65, 71, 75) • Individual counseling + GWG goals (Finland: 50)	
Selected Studies on LTPA and Birth Weight				
Significant ↓ Odds SGA/Low Birth Weight	**Borderline ↓ Odds SGA/Low Birth Weight**	**No Association SGA/Low Birth Weight**	**Borderline ↑ Odds SGA/Low Birth Weight**	**Significant ↑ Odds SGA/Low Birth Weight**
NA	NA	• HI pregnancy LTPA (US: 1) • Second- or third-trimester sports/LTPA (Scandinavia: 43)	NA	NA
Significant ↓ Odds LGA/Macrosomia	**Borderline ↓ Odds LGA/Macrosomia**	**No Association LGA/Macrosomia**	**Borderline ↑ Odds LGA/Macrosomia**	**Significant ↑ Odds LGA/Macrosomia**
• HI pregnancy LTPA (US: 1, 62; Scandinavia: 47, 68)	• HI prepregnancy LTPA (Scandinavia: 68)	• Second- or third-trimester sports/LTPA (Scandinavia: 43)	NA	• LO prepregnancy LTPA (Scandinavia: 92)
Selected Studies on LTPA and Preterm Delivery				
Significant ↓ Odds	**Borderline ↓ Odds**	**No Association**	**Borderline ↑ Odds**	**Significant ↑ Odds**
• HI pregnancy LTPA (US: 41, 59; Scandinavia: 46, 70)		• HI prepregnancy LTPA (US: 34) • First- or second-trimester LTPA (US: 34)		
Selected Studies on LTPA and Child Weight Status				
Significant Findings			**Borderline Significant Findings**	
• Offspring of women who exercised throughout pregnancy significantly lighter and leaner at 5 yr compared to offspring of women who stopped exercising during pregnancy (US: 22)			• Third-trimester LTPA inversely correlated ($P = 0.06$) with toddler weight and weight-for height *z*-score at 16–22 months (US: 56)	

[a] The term "HI prepregnancy" or "HI pregnancy" LTPA has variable definitions that depend on how LTPA was measured and categorized within each study. Please see the supplemental table online (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190) for exact study-specific definitions of "HI" LTPA.
[b] Borderline refers to associations with *P* values of 0.05–0.10.
[c] Partially successful interventions are those that resulted in reduced GWG in only one prepregnancy weight category or those that had borderline significant differences in weight gain between intervention and control groups.

associated with perinatal complications and long-term increased risk for type 2 diabetes. Notably, women with GDM have four times higher odds of delivering a macrosomic (≥4 kg) or large-for-gestational age (LGA, ≥90th percentile of weight-for-gestational age) newborn compared to women with normal glucose tolerance (33). In addition, offspring from diabetic pregnancies have a higher risk for childhood obesity and metabolic disorders (17). Established risk factors for GDM include prepregnancy obesity, advanced maternal age, family history, and non white race/ethnicity. International prevalence rates for GDM range from <1% to 28% of all pregnancies, with most developed countries reporting prevalence rates of 2%–10% (45).

Recently, Tobias et al. (87) conducted a meta-analysis of epidemiological studies examining relations between prepregnancy or pregnancy LTPA and risk of developing GDM. Of 442 citations identified, 18 articles underwent full review and 8 articles reporting on seven unique studies were included in the meta-analysis (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190) (20,30,31,40,64,76,82,95). To be included, studies had to include GDM diagnosis as an outcome variable (not merely impaired glucose tolerance) and authors had to specify that LTPA measures referred to a period before GDM diagnosis. To account for variable LTPA measures, the authors only considered results comparing highest to lowest LTPA categories. All studies reported a protective effect of LTPA on GDM risk; however, often the confidence intervals (CI) were wide and indicated statistical nonsignificance (Table 1). Overall estimates indicated that participation in a high versus low level of LTPA prepregnancy (odds ratio [OR] = 0.45, 95% CI = 0.28–0.75) or during pregnancy (OR = 0.76, 95% CI = 0.70–0.83) significantly reduced odds of GDM (87).

It is well known that LTPA participation is related to improved insulin sensitivity and glucose control among nonpregnant populations diagnosed with type 2 diabetes. It is plausible that the same effects would be seen among pregnant women. In fact, even mild LTPA walking programs have been shown to help treat GDM by improving glucose control and reducing the need for insulin (27). In addition, participation in LTPA is related to enhanced weight control during pregnancy (see section on GWG), which would reduce odds of GDM. Further work on exact biological mechanisms relating LTPA to reduced risk of GDM is warranted.

Although the relation between LTPA and GDM has been relatively well studied, several limitations in the current knowledge base persist. The bulk of evidence on LTPA and GDM has been provided by US-based studies, as neither the MoBa nor DNBC has evaluated this outcome. As yet, the minimum dose of LTPA needed to prevent GDM has not been established. It is worth restating that results from the meta-analysis by Tobias et al. (87) compared only the highest category of LTPA participation to the lowest. Often, the ''high'' LTPA category was four to five times higher than current LTPA recommendations (i.e., 7.5 MET·h·wk^{-1}; see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190). Whether participation in recommended amounts of LTPA may lead to similar health benefits has yet to be determined. Although not specifically addressed in the meta-analysis, two US studies noted significant reductions in GDM risk associated with participating in ''any'' versus ''none'' LTPA in prepregnancy or early pregnancy (30,31) and one study reported a significant risk reduction with any vigorous LTPA participation before pregnancy (64). Current results are based on observational data; thus, it is difficult to separate the effects of prepregnancy and pregnancy-related LTPA because few women choose to *start* exercising during pregnancy, unless directed to by their healthcare provider as a result of GDM diagnoses. Randomized control trials currently underway will help to answer these questions (16,19,53,66).

Hypertensive disorders. Hypertension during pregnancy can be classified as preeclampsia/eclampsia, gestational hypertension (developing during pregnancy), chronic hypertension (preexisting pregnancy), or chronic hypertension superimposed with preeclampsia. Preeclampsia is diagnosed when the mother displays both hypertension and proteinuria after midgestation (78). Hypertensive disorders, particularly preeclampsia, are associated with several perinatal complications including preterm delivery and are the leading cause of maternal mortality worldwide (78). Similar to GDM, established risk factors for hypertensive disorders during pregnancy include prepregnancy obesity, advanced maternal age, family history, and non white race/ethnicity. In addition, carrying multiples and being diagnosed with GDM are also considered risk factors. Hypertensive disorders are relatively common, affecting about 3%–9% of pregnancies worldwide, with preeclampsia affecting 2%–4% of all pregnancies (77).

The majority of research relating LTPA participation to hypertensive disorders in pregnancy has focused on preeclampsia, and results to date are mixed. Case–control studies in the United States have mainly shown protective effects from prepregnancy (reduced odds of 30%–80%) and pregnancy LTPA (reduced odds of 45%–65%) (81,83,86). However, prospective cohort studies have mostly failed to show statistically significant results when analyses are adjusted for important confounders (Table 1; see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190) (36,80). Thus, although data from the United States suggest a possible protective effect, these results are not conclusive.

Data from 59,573 pregnant women in the MoBa study showed that participating in LTPA ≥25 times per month in early to midpregnancy (i.e., <16 wk of gestation) was associated with reduced odds of preeclampsia (OR = 0.79, 95% CI = 0.65–0.96) compared to no LTPA participation (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital

EPIDEMIOLOGY

Content 1, http://links.lww.com/MSS/A190), after adjusting for well-known confounders (i.e., smoking, parity, prepregnancy BMI, education, age, year of childbirth, height, and physically demanding jobs) (55). Lower LTPA frequency was associated with nonsignificantly reduced odds (55). These results support those from US case–control studies; however, results from the DNBC have failed to substantiate a protective effect. The DNBC study considered minutes per week of LTPA reported at 17 wk of gestation in relation to diagnosis of preeclampsia among 85,139 women (67). The authors found no significant associations among LTPA and preeclampsia in adjusted analyses (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190). However, when considering severe subtypes of preeclampsia (e.g., hemolysis, elevated liver enzymes, and low platelet count or eclampsia, $n = 28$ cases), LTPA of 270–419 $\text{min}\cdot\text{wk}^{-1}$ (OR = 1.6, 95% CI = 1.1–2.4) or ≥420 $\text{min}\cdot\text{wk}^{-1}$ (OR = 1.8, 95% CI = 1.1–3.0) significantly *increased* odds (67). It is important to note that all other preeclampsia investigations show either protective effect of LTPA or no relation. A more recent prospective investigation of more than 3000 women in The Netherlands found no significant associations among the amount of time or intensity of LTPA and preeclampsia risk (93).

LTPA during pregnancy may reduce the risk of preeclampsia by lowering blood pressure, improving maternal lipid profiles, reducing oxidative stress and inflammation, and improving placental growth and vascularity (15,24,25). However, the true effect of LTPA on any of these mechanisms and on preeclampsia as a whole is unknown.

Similar to the state of knowledge of the relation between LTPA and GDM, more information is needed on the dose of prepregnancy and/or pregnancy LTPA needed for a beneficial effect on preeclampsia. Given the findings from the DNBC, researchers should also consider whether an upper safety threshold of LTPA during pregnancy exists. In addition, more research is needed on the effects of LTPA on gestational hypertension and/or chronic hypertension during pregnancy because these conditions are becoming more prevalent. To date, three randomized controlled trials have evaluated the effects of LTPA during pregnancy on risk of preeclampsia, but these were small and not sufficiently powered to detect any significant effects (56). Larger randomized trials of different doses of LTPA during pregnancy would provide stronger evidence on the true effect of LTPA on preeclampsia risk.

Gestational weight gain. Women in their reproductive years are at an increased risk for obesity and diabetes because of excessive GWG and weight retention after delivery (79,90). Population estimates of maternal overweight and obesity range from 22% to 69% and from 16% to 34%, respectively, worldwide (26,48,49). Maternal GWG is directly associated with maternal postpartum weight retention. Overweight women who have experienced previous weight retention have a higher rate of weight gain early in their next pregnancy leading to excessive GWG (63). Excessive GWG, in turn, is strongly associated with maternal weight retention at 6 and 12 months postpartum, and each subsequent pregnancy is likely to result in more weight gain, with additional weight retention in the postpartum period (74). This escalating problem may contribute to the obesity epidemic and other disease risks because overweight women who gain ≥10% of their prepregnancy mass are at a higher risk for complications such as GDM and gestational hypertension (74).

Excessive GWG is defined according to prepregnancy BMI by the Institute of Medicine (Table 2) (44). A recent report from Health Canada stated that 55% of overweight women and 41% of normal-weight women gained above-recommended guidelines and the majority of women who gained excessive weight gave birth to a macrosomic infant (52). Thus, prepregnancy overweight and obesity may lead to a vicious cycle of excessive GWG and adiposity passed on from the mother to her offspring (84). The recent opinion statement from the ACOG on obesity during pregnancy strongly suggests aggressive preventative management in all overweight and obese pregnant women both before conception and after delivery (5). Women should be encouraged and supported to achieve and maintain a healthy weight during and after pregnancy. Prevention of excessive GWG and appropriate weight loss between pregnancies are highly recommended as interventions to reduce the occurrence of GDM and prevent the development of true diabetes and hypertension after delivery (74).

A healthy lifestyle approach for limiting GWG is intuitive, and to date, 13 studies have examined the effectiveness of an intervention designed to prevent excessive GWG that included LTPA/exercise (7,8,21,27,38,39,50,61,65,71,75,85,91). Many studies included all BMI classifications and two focused on GWG in women diagnosed with GDM (7,79). As shown in Table 1, 6 (46%) of 13 studies were not successful in preventing excessive GWG (38,39,46,65,71,75). Seven (54%) were successful or partially successful, meaning that not all BMI classifications experienced significant reductions in rates of excessive GWG (7,8,21,27,61,85,91). Studies using education alone as an intervention or behavioural interventions without individualized nutrition and LTPA prescriptions were not effective in preventing excess GWG.

Among successful interventions, those that targeted overweight and obese women included a variety of activities. LTPA prescriptions included aqua-aerobics 1–2 $\text{d}\cdot\text{wk}^{-1}$

TABLE 2. Institute of Medicine guidelines for GWG according to prepregnancy weight status (2009) (44).

Prepregnancy Weight Status	Prepregnancy BMI ($\text{kg}\cdot\text{m}^{-2}$)	Total Weight Gain (lb), Range	Rates of Weight Gain[a]: Second and Third Trimesters ($\text{lb}\cdot\text{wk}^{-1}$), Mean (Range)
Underweight	<18.5	28–40	1 (1–1.3)
Normal weight	18.5–24.9	25–35	1 (0.8–1)
Overweight	25.0–29.9	15–25	0.6 (0.5–0.7)
Obese (includes all classes)	≥30	11–20	0.5 (0.4–0.6)

[a] Calculations assume a 1.1- to 4.4-lb weight gain in the first trimester.

(23), supervised walking/biking at 60% of aerobic max 1 d·wk^{-1} with logs for unsupervised activity (7), supervised progressive walking program at 30% HR reserve 3–4 d·wk^{-1} (27,61), and unsupervised free gym membership with personal coaching (91).

It is useful to note that even mild walking programs may be successful at controlling excessive GWG. A case–control pilot study of a walking program among overweight women with GDM starting at 25 min per session, three to four times per week, building slowly by adding 2 min·wk^{-1} until 40 min was reached, showed that not only did 50% of women avoid excessive GWG, glucose regulation also improved and insulin requirements were reduced (27). The control women who did not receive a walking program did not display improvements in glucose regulation and insulin requirements. The low-intensity walking program allowed previously sedentary overweight and obese women to follow the LTPA prescription. A larger nonrandomized intervention study using historical controls found that excessive GWG was prevented with a nutrition and similar walking intervention (using a pedometer to count steps) for overweight and obese women (61). By the end of the program, intervention participants took more than 10,000 steps, three to four times per week, bringing them into the ''Active'' category (88). Because walking has been shown to be the most popular activity during pregnancy (60), the use of pedometers may aid in compliance for overweight and obese women.

Although both structured/supervised LTPA and unstructured home LTPA programs seem to be successful at preventing excessive GWG, it may be easier for women to comply with a home-based walking program. Structured exercise classes may be difficult for time management and not all participants have access to a gym or a pool. However, in Scandinavian countries, where swimming is a more popular mode of LTPA (69), aquatics-based interventions have been successful. Additional studies are required to determine the appropriate exercise prescription and lifestyle management necessary to prevent excessive GWG in women of all BMI categories.

Pregnancy Health Outcomes

Birth weight. Size at birth has long been used as an indicator of the fetal environment as well as a predictor for future health outcomes. Most often, researchers are concerned with the tails of the birth weight distribution, i.e., low birth weight or small-for-gestational age (SGA) and macrosomia or LGA. Regardless of the terminology used, being born either too small or too large is associated with adverse short- and long-term health outcomes for the offspring.

Research has shown that LTPA during pregnancy does not increase risk of delivering an SGA newborn (42). On the other end of the birth weight distribution, recently published studies have shown that LTPA may reduce odds of delivering an LGA newborn (1,47,62,68). Two retrospective US studies have shown that reported participation in either ≥120 or ≥150 min·wk^{-1} of at least moderate LTPA during pregnancy significantly reduces risk of delivering LGA by ~30% with no effect on delivering SGA (1,62). Prospective data from 36,869 pregnancies in the MoBa and 79,692 pregnancies in the DNBC also show inverse associations between prospectively measured self-reported LTPA during pregnancy and extreme birth weight. In MoBa, the risk of macrosomia was reduced by ~23% in women exercising three or more times per week compared to nonexercisers (adjusted OR [aOR] = 0.77, 95% CI = 0.61–0.96) (68). Similar effect estimates were observed for women exercising more than five times a week in the DNBC on risk of LGA (adjusted hazard ratio = 0.72, 95% CI = 0.57–0.91), even after adjusting for confounding factors (47). Taken together, these results indicate that LTPA during pregnancy may help to normalize birth weight into the healthy range by reducing LGA deliveries without increasing risk of SGA deliveries.

In contrast, two smaller Scandinavian studies failed to show associations among sports/LTPA during pregnancy and macrosomia (43,92). Discrepancies among results may be due to methodological differences in defining birth weight outcomes (i.e., using different weight cut point vs using weight for gestational age), study design (prospective/retrospective), and/or differences in assessing LTPA during pregnancy. In particular, previous studies used varying methods of self-reported LTPA participation, often without complete information on frequency, intensity, duration, and type of activity (18). Also, most studies assessed LTPA only once, and at variable times in pregnancy, which hinders comparison of their results.

Currently, it is thought that LTPA during pregnancy may influence size at birth by normalizing maternal blood glucose, reducing maternal insulin resistance, and altering placental blood flow and nutrient delivery (24,94). Placental blood flow may decrease intermittently *during* activity but is increased at rest because of physical training adaptations. Although LTPA during the first and second trimesters seems to improve placentation and vascularization, LTPA during the third trimester may have the most direct effect on fetal growth (23). However, more work is needed to determine the dose–response relationship between LTPA and risk of macrosomia/LGA. Overall, the majority of US and Scandinavian studies have shown a beneficial effect of LTPA to reduce the odds of delivering an LGA infant.

Gestational age at delivery. Unlike birth weight, length of gestation can only be estimated approximately through maternal recall of their last menstrual period and/or ultrasound dating. Preterm delivery is defined as birth <37 completed weeks of gestation and is the leading cause of neonatal morbidity and mortality, accounting for 75% of neonatal deaths (14). Although causes of preterm delivery are unknown, risk factors include low socioeconomic status, maternal age (<20 or >40 yr), high prepregnancy BMI, smoking, multiple gestation, and diagnosis of GDM or preeclampsia. Approximately 9.7% of births worldwide are preterm, with prevalence ranging from 4% to 12% among developed countries (51).

Madsen et al. (54) interviewed 92,671 women enrolled in the DNBC to examine the association between LTPA during pregnancy and miscarriage, defined as fetal death before 22 wk of gestation. The authors combined retrospective (for those who had miscarried by the time of the first interview at gestational weeks 12–16) and prospective LTPA data and examined risk of miscarriages at <11, 11–14, 15–18, and 19–22 wk. When retrospective data were included, LTPA participation was associated with *increased* risk of miscarriage at 11, 11–14, or 15–18 wk (54). However, when analyses were restricted to women with prospectively measured LTPA, risk estimates for miscarriage in any period were small and nonsignificant, indicating recall bias may have been partly driving the previous findings (54). These results suggest that some degree of caution may be needed concerning high-intensity and/or long-duration LTPA very early in pregnancy; however, studies with prospective measures of LTPA early in pregnancy are needed before more specific recommendations can be made.

Existing evidence concerning the effects of LTPA on preterm delivery is much more encouraging. Prospective cohort studies from the United States have consistently demonstrated protective effects of varying amounts of LTPA on preterm delivery risk, although these results are not strong and are rarely statistically significant (see Table, Full summary of selected studies on LTPA during pregnancy and health outcomes, Supplemental Digital Content 1, http://links.lww.com/MSS/A190) (34,41,59). Results from 61,098 pregnancies enrolled in the MoBa, showed that women exercising three to five times per week at 17 or 30 wk of gestation had significantly reduced risk of preterm birth (aOR = 0.82, 95% CI = 0.73–0.91 and aOR = 0.74, 95% CI = 0.65–0.83, respectively) compared to nonexercisers (70). LTPA during pregnancy in this study shifted the gestational age distribution slightly upward resulting in reduced preterm births and slightly increased postterm births (70). Data from the DNBC also showed significant protective effects of LTPA on preterm birth, even at the lowest level (0–5 MET·h·wk^{-1}) (46).

It is plausible that LTPA participation could decrease risk of preterm delivery by improving placentation and vascularization while reducing oxidative stress (24,25). It is encouraging that investigators have found either no relation (US study) or a slight decreased risk (US and Scandinavian studies) of preterm delivery in relation to LTPA. However, more research is warranted to determine whether LTPA may have differing effects on odds of spontaneous versus medically indicated and early versus late preterm delivery. These investigations will allow us to better understand biological mechanisms that may connect LTPA with timing of delivery.

Child Body Composition

The majority of past research has focused on maternal health outcomes of LTPA during pregnancy; however, mounting evidence suggests that *in utero* exposures may affect not only fetal development but also offspring health outcomes through fetal programming (10). In particular, both low and high birth weight have been related to obesity, metabolic disease, and cardiovascular disease later in life (9,12). As we have seen, LTPA during pregnancy seems to decrease odds of high birth weight without affecting odds of low birth weight (62,68). It is plausible that this normalization of birth weight may translate into improved child health outcomes associated with LTPA during pregnancy; however, few have examined this possibility.

Dr. Clapp (United States) was the first to examine long-term child health outcomes related to maternal LTPA during pregnancy in 1996. He followed the offspring of 20 women who exercised vigorously throughout pregnancy and 20 previously active women who chose to not exercise during pregnancy. The results showed that children of the exercising women were lighter and leaner at birth and continued to be significantly lighter (mean ± SD = 18.0 ± 0.5 vs 19.5 ± 0.6 kg) and leaner (sum of skinfolds = 37 ± 1 vs 44 ± 2 mm) at age 5 compared with children of nonexercising women (22). More recently, a study of 23 women/toddler pairs in Michigan found that recalled third-trimester MET-minutes per week of LTPA tended to be inversely correlated with toddler weight ($r_s = -0.39$, $P = 0.06$) and weight-for-height *z*-score ($r_s = -0.40$, $P = 0.06$) at 16–22 months of age (56).

The results of both studies to date on offspring size provide encouraging evidence that LTPA during pregnancy may have beneficial effects. However, more evidence from larger, prospective studies with measures of maternal LTPA during and after pregnancy, as well as child LTPA behaviors, is needed. Longer-term follow-up studies of the MoBa or DNBC may be able to evaluate these relations among representative samples of women and children. If the relation between LTPA during pregnancy and child weight status is substantiated, prenatal interventions to prevent childhood obesity might prove to be effective.

Limitations and Future Directions

We have presented results from epidemiological studies on the health benefits of LTPA during pregnancy using an international perspective. The bulk of evidence is encouraging and supports the current recommendation that pregnant women perform at least 150 min·wk^{-1} of at least moderate aerobic LTPA (89). However, there are several limitations to the knowledge base that must be addressed.

Most studies presented are observational and rely on self-reported LTPA measures. Self-report data may suffer from reporting bias because of social desirability and/or poor recall. However, misclassification of LTPA in prospective cohorts such as the MoBa and DNBC is likely to be nondifferential and would most likely bias associations toward the null. Another important weakness of existing studies is incomplete information on frequency, intensity, duration, and type of LTPA, precluding the calculation of total LTPA volume. Most investigators asked about LTPA at only one time point in pregnancy. These limitations make results difficult to compare and hamper our ability to detect dose–response and/or threshold effects of LTPA on maternal and child health outcomes. As well, most women report participation in aerobic activity; thus, the potential health effects of resistance training during pregnancy remain poorly understood. We also know that women who self-select LTPA participation during pregnancy tend to be healthier in other ways (69). In contrast, being overweight and having children, multiple gestation, pelvic girdle pain, and nausea are all negatively associated with regular LTPA during pregnancy (69). Thus, it can be difficult to adequately control for potential confounding factors.

Among the studies presented, the MoBa and DNBC studies represent the two largest pregnancy cohorts in the world. Although both used self-reported measures of LTPA, these were collected prospectively twice during pregnancy. In addition, a multitude of relevant maternal data was collected by questionnaires and linkage to national medical birth registries, making it possible to adjust for potential confounders. Although results from these studies most likely provide the best available estimate of relations among LTPA and different health outcomes, their observational nature do not preclude bias or unmeasured confounding. Adequately powered randomized trials are needed to estimate the true effect of LTPA on these health outcomes.

This review is limited because a systematic approach for extracting results was not used, and several previous articles related to individual health outcomes were not included because of page limitations. However, this review adds to existing literature by demonstrating the wide range of health benefits associated with LTPA during pregnancy with global evidence. In addition, many limitations to the existing knowledge base about LTPA during pregnancy are similar, regardless of health outcome. This article highlights the need for more careful, prospective measures of LTPA during pregnancy to more precisely inform interventions and health promotion programs targeting pregnant women.

Future studies should focus on collecting prospective and objective measures of LTPA during pregnancy, along with self-report, to more accurately define what minimum dose of activity is needed for a beneficial health effect. LTPA should also be measured at multiple time points in pregnancy to determine whether trimester-specific effects exist. For example, the majority of fetal growth occurs during the third trimester; thus, LTPA during this time may be especially important for birth weight and child weight outcomes. More detailed studies on the biological mechanisms underpinning relationships among LTPA and maternal and child health outcomes are needed to better inform future guidelines and provide the background needed for effective behavioral interventions. Finally, larger intervention studies with various exercise prescription levels among previously sedentary pregnant women are needed to separate out effects of prepregnancy and pregnancy-related LTPA on the health outcomes presented here.

In conclusion, current knowledge on the health benefits of LTPA/exercise during pregnancy is encouraging for the health of the mother, her pregnancy and her child. However, there is much still to learn. Research on the long-term effects of LTPA and exercise prescription during pregnancy on both maternal and child health is in its infancy. More research on these relations could prove vital to the effort to combat increasing rates of chronic disease worldwide.

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EPIDEMIOLOGY

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