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Physical Activity During Pregnancy and Risk of Hyperglycemia

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Abstract

Objective: To determine the association between moderate and vigorous physical activities (MVPA) during midpregnancy and the risk of hyperglycemia.

Methods: Data were from 1437 pregnant women. Frequency, duration, and intensity of MVPA during the previous 7 days were collected via questionnaire at 17–22 weeks' gestation. Modes of MVPA included work, recreation, transportation, caregiving, and indoor and outdoor household activities. Hyperglycemia was defined as a glucose concentration ≥ 130 mg/dL on a 1-hour, 50-g glucose challenge test or gestational diabetes mellitus (GDM) assessed at ~27 weeks' gestation. Multivariable Poisson regression estimated risks of hyperglycemia associated with total and mode-specific MVPA.

Results: There were 269 women (18.7%) with hyperglycemia. Any metabolic equivalent (MET) hours/week of recreational MVPA was associated with a 27% lower risk of hyperglycemia (adjusted relative risk, [aRR] 0.73, 95% confidence interval [95%CI] 0.54-0.99). Multiplicative interaction terms were significant for prepregnancy body mass index (BMI) and recreational MVPA ($p = 0.01$). Among women with prepregnancy BMI $< 25\,kg/m^2$, recreational MVPA was associated with a 48% lower risk of hyperglycemia (aRR 0.52, 95%CI 0.33-0.83) compared to women who reported none. There was no association of hyperglycemia and recreational MVPA among women with prepregnancy BMI $< 25\,kg/m^2$.

Conclusions: Recreational MVPA during pregnancy is associated with a lower risk of hyperglycemia, specifically among women with prepregnancy BMI $< 25\,kg/m^2$. Further research is warranted to determine recommended amounts and intensities of physical activity and to discern whether there are differences in the effects of physical activity between specific modes of physical activity or among subgroups of women in relation to hyperglycemia.

Introduction

Hyperglycemia disorders during pregnancy, such as gestational diabetes mellitus (GDM), are metabolic complications that are associated with several adverse pregnancy and health outcomes, including the development of type 2 diabetes mellitus (T2DM) in both the mother and child.[1–3] GDM is estimated to occur in approximately 7% of pregnancies in the United States,[4] and data suggest an increase in the incidence of GDM over the past several years.[5,6] The identification of modifiable lifestyle behaviors to control glucose levels during pregnancy and reduce the risk of GDM is needed.

In nonpregnant populations, physical activity has been shown to reduce the risk of developing T2DM.[7] Evidence from previous studies in pregnant women also suggests that physical activity is inversely associated with the risk of developing GDM. In a recent meta-analysis[8] of eight studies, it was estimated that physical activity before and during early pregnancy was associated with a 55% and 24% lower risk of GDM, respectively. However, several of these studies did not prospectively measure physical activity,[9,10] were limited to assessments of recreational activities,[9,11–14] or lacked measurements of physical activity with evidence of validity during pregnancy.[9,10,12,13]

In the current study, we sought to determine if moderate to vigorous physical activity (MVPA) measured at midpregnancy (17–22 weeks' gestation) is associated with a lower risk of developing hyperglycemia, defined as a glucose concentration ≥ 130 mg/dL on a 1-hour, 50-g glucose challenge test or a diagnosis of GDM assessed at ~27 weeks' gestation. We improved on limitations of previous studies by using a

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comprehensive measurement of MVPA with evidence for validity and reliability, assessing both absolute and perceived (relative) measures of MVPA, and including all modes of MVPA in addition to recreational activities.[15] The information gained from this study may be useful for planning of early pregnancy intervention efforts to help women achieve normal glucose concentrations throughout pregnancy.

Materials and Methods

Data were from the third cohort of the Pregnancy, Infection, and Nutrition (PIN3) Study, described elsewhere.[16] The recruitment protocols were documented previously,[17,18] and details of the studies are available at www.cpc.unc.edu/projects/pin/. Briefly, the PIN3 Study was a longitudinal, prospective investigation of adverse birth outcomes conducted at selected prenatal clinics in central North Carolina. Women attending their second prenatal visit who were no more than 20 weeks' gestation, at least 16 years old, carrying a singleton fetus, planning to continue care at the clinics, and had access to a telephone were eligible to participate.

Women in this analysis were recruited from January 1, 2001, to June 30, 2005. A total of 2006 (63%) participants were recruited out of 3203 eligible women. Women who had preexisting diabetes mellitus ($n=71$); did not have a live birth ($n=54$); or had missing physical activity information ($n=185$), fasting blood glucose measurement ($n=145$), prepregnancy body mass index (BMI) ($n=23$), or race/ethnicity ($n=1$) were excluded. Some women were recruited into the cohort more than once because of additional pregnancies within the recruitment period; therefore, data from only one of the pregnancies from each woman were used ($n=90$ excluded pregnancies). In these instances, the pregnancy with the most complete data or the first pregnancy (when data were complete for both pregnancies) was included in the analysis. The remaining 1437 pregnancies were included in the current analyses. [Compared to included women ($n=1437$), those who were excluded ($n=568$) were more likely to be black, obese, less educated, younger, not married, multiparous, smokers during the first 6 months of pregnancy, and to have lower household incomes.]

The PIN3 Study protocols were reviewed and approved by the Institutional Review Boards of the School of Medicine at the University of North Carolina at Chapel Hill. Information on prenatal and perinatal factors, including sociodemographic characteristics and medical history, was assessed by interviews, self-administered questionnaires, and medical records. Medical records were abstracted for all women in the cohort to collect data on reproductive history, weight gain, and pregnancy complications.

Exposure assessment

Information on physical activity was collected during a telephone interview at 17–22 weeks' gestation (median gestational age 19.0 weeks). Interviews took place before women were tested for hyperglycemia. The questionnaire was designed to assess the frequency and duration of all MVPA in the previous 7 days, with evidence for reliability and validity.[15] Physical activity domains included work, recreation, transportation, caregiving (child and adult), and indoor and outdoor household activities. Women were asked to report the number of sessions, average duration per session, and intensity level (fairly light, somewhat hard, and hard or very hard) of all activities that increased their breathing and heart rate. Physical activity intensity was measured as both perceived (hours/week) and absolute (metabolic equivalents [MET] hours/week) measures.

Perceived intensity of activity was assessed using a modified Borg scale of perceived exertion[19]; activities reported as somewhat hard were classified as moderate and those reported as hard or very hard were classified as vigorous. Activities that were fairly light were not included in this analysis. Hours/week of MVPA were calculated by multiplying the number of times a participant reported an activity by the reported number of hours. Absolute intensity of activity was based on published MET tables[20,21] (the final compendium of activities used for scoring can be found at www.cpc.unc.edu/projects/pin/design_pin3/docs_3/PIN-MET-Table-080207.pdf). MET hours/week of MVPA were calculated by multiplying the number of times the participant reported the activity by the number of reported hours and then multiplying by the MET value for the activity. Following standards specific for women of childbearing age (20–39 years), MET values of 4.8–7.1 were classified as moderate intensity, and values >7.1 METs were classified as vigorous activity.[22] The standard MET values for all adults[23] were not used because more light physical activities would have been misclassified as MVPA. Reported levels of MVPA in this sample were low; therefore, MVPA was dichotomized as participation in MVPA (any) compared to no MVPA (none), the reference category. There were no women who reported ≥ 4.8 MET hours/week of transportation-related physical activities; therefore, only hours/week of transportation MVPA could be included in analyses.

Outcome assessment

Maternal hyperglycemia was assessed during the second trimester (median gestational age 26.9 weeks) using a two-step process: a 1-hour, 50-g glucose challenge test (GCT)[24] followed by a 3-hour oral glucose tolerance test (OGTT). Women with abnormal plasma glucose concentrations on the GCT received the OGTT to determine a diagnosis of GDM using criteria by Carpenter and Coustan.[25] In this study, hyperglycemia was defined as maternal plasma glucose concentrations ≥ 130 mg/dL on the GCT or a diagnosis of GDM or both. Normal glycemia was defined as glucose concentrations <130 mg/dL on the GCT. The cutoff point of 130 mg/dL was chosen because glucose concentrations at this level or higher are suggestive of hyperglycemia[25] and are associated with adverse pregnancy outcomes.[26,27] Women with glucose concentrations ≥ 130 mg/dL with and without a GDM diagnosis were combined in order to be more consistent with recent recommendations from the International Association of Diabetes and Pregnancy Study Group (IADPSG), which are less restrictive than previous recommendations and do not include abnormal glucose tolerance (maternal hyperglycemia without a diagnosis of GDM) as a separate diagnosis during pregnancy.[28]

Measurement of covariates

Maternal prepregnancy BMI (kg/m^2) was calculated using self-reported prepregnancy weight and measured height collected during the prenatal examination. For quality assurance, weight measurements taken at the first prenatal clinic visit (within 15 weeks' gestation) were compared to the self-reported prepregnancy weights to identify biologically implausible weight gains. Women with implausible values ($n=66$) had their prepregnancy weights imputed following previously published methods.[17] BMI was categorized using the 2009 Institute of Medicine (IOM) guidelines[29]: underweight, $<18.5\,kg/m^2$; normal weight, $18.5–<25.0\,kg/m^2$; overweight, $25.0–<30.0\,kg/m^2$; and obese, $\geq 30\,kg/m^2$. Maternal prenatal smoking (months 1–6 of pregnancy), household income, education, marital status, age at conception, race/ethnicity, and parity were collected from prenatal interviews and categorized as shown in Table 1. Household income was expressed as percent of the poverty line and calculated using the 2001 U.S. Department of Health and Human Services Federal Poverty Guidelines[30]; a percentage ≤185% is the cutoff for the Special Supplemental Nutrition Program for Women, Infants, and Children.

Statistical methods

Analyses were performed using STATA 11. Chi-square tests were used to test for differences in distributions of baseline characteristics by hyperglycemia status. Potential confounders were identified *a priori* from a literature review and using causal diagrams.[31] Identified confounders were included in all models. Multivariable Poisson regression with a robust error variance was used to estimate associations of total and mode-specific MVPA with risk of maternal hyperglycemia. This method is useful for directly estimating relative risks (RR) for dichotomous, common outcomes in prospective studies.[32] Final models were adjusted for maternal age, race/ethnicity, and prepregnancy BMI. Models for each mode of MVPA were also adjusted for MVPA undertaken in all the remaining modes. Additional adjustment of models for education, household income, parity, and marital status did not substantially alter effect estimates and were not included in the final models.

Prepregnancy BMI was explored as a potential effect modifier of the association between MVPA and risk of hyperglycemia using interaction terms and Wald tests with an *a priori* significance p value of <0.05. These analyses were done to determine if the association of MVPA and maternal hyperglycemia differed by prepregnancy BMI status, as

Table 1. Baseline Characteristics Overall and by Participation in Total Moderate to Vigorous Physical Activity During Midpregnancy Among Women in the Third Cohort of Pregnancy Infection and Nutrition Study ($n=1437$)

Characteristic	*Total* n	%	*No MVPA (n=906)* n	%	*Any MVPA (n=531)* n	%	p[a]
Maternal age at conception							
16–24	313	21.8	242	26.7	71	13.4	
>24–29	413	28.7	259	28.6	154	29.0	<0.0001
>29–34	477	33.2	264	29.1	213	40.1	
>34	234	16.3	141	15.6	93	17.5	
Prepregnancy body mass index							
Underweight	62	4.3	45	5.0	17	3.2	
Normal Weight	795	55.3	455	50.2	340	64.0	<0.0001
Overweight	279	19.4	185	20.4	94	17.7	
Obese	301	21.0	221	24.4	80	15.1	
Parity (number of previous births)							
0	717	49.9	415	45.8	302	56.9	<0.0001
≥1	720	50.1	491	54.2	229	43.1	
Race							
White	1029	71.6	589	65.0	440	82.9	
Black	269	18.7	222	24.5	47	8.8	<0.0001
Other	139	9.7	95	10.5	44	8.3	
Marital status							
Married	1091	75.9	637	70.3	454	85.5	
Not married	346	24.1	269	29.7	77	14.5	<0.0001
Household Income (% of the 2001 poverty line)							
<185	284	20.6	222	25.7	62	12.0	
185–350	274	19.9	190	22.0	84	16.3	<0.0001
>350	821	59.5	451	52.3	370	71.7	
Education (highest grade completed)							
≤12	293	20.4	245	27.1	48	9.0	
13–16	676	47.0	426	47.0	250	47.1	<0.0001
≥17	468	32.6	235	25.9	233	43.9	
Prenatal smoking							
No	1212	89.6	736	87.6	476	93.0	0.002
Yes	140	10.4	104	12.4	36	7.0	

[a]p values refer to chi-square tests for differences in distributions of characteristics by total MVPA (none and any).
MVPA, Moderate to vigorous physical activity measured in MET hours/week.

reported previously.[12,33] Because of small sample sizes within strata, prepregnancy BMI categories were collapsed as prepregnancy BMI $<25\,kg/m^2$ ($n=858$) and prepregnancy BMI $\geq 25\,kg/m^2$ ($n=580$).

Results

Among the 1437 participants with glucose concentration and physical activity data, 269 (18.7%) had hyperglycemia, of which 62 (23.0%) were diagnosed with GDM. All analyses were conducted using perceived (hours/week) and absolute (MET hours/week) measures of total MVPA and mode-specific MVPA. Results using both perceived and absolute measures were similar; therefore, only results for absolute measures are presented in the tables. Table 1 presents the selected baseline characteristics overall and by participation in MVPA; nearly two thirds (63.0%) of the women reported any MVPA. The majority of women were white (71.6%), high school graduates (79.6%), from high household incomes (59.5%, >350% of the 2001 poverty line), married (75.9%), and nonsmokers during pregnancy (89.6%); 40.4% of the women were overweight or obese before pregnancy, and half (49.5%) were >29 years at conception. Higher percentages of women who were aged 16–24 years, overweight/obese, parous, black, or not married reported no MVPA. Additionally, women who were from low-income households, had a high school diploma or less, or smoked during pregnancy were also more likely to report no MVPA.

In adjusted models, women who reported any MET hours/week of recreational MVPA had a 27% lower risk of hyperglycemia (adjusted RR [aRR] 0.73, 95% confidence interval [95% CI] 0.54-0.99) compared to women who reported no recreational MVPA (Table 2). The associations for all remaining MVPA modes and total MVPA were not suggestive of an association with hyperglycemia. All the effect estimates were similar, but less precise, when analyses were repeated separately among women with glucose concentrations $\geq 130\,mg/dL$ without a GDM diagnosis ($n=207$) and among women with a GDM diagnosis ($n=62$).

We performed interaction analyses to determine if the association of hyperglycemia and recreational MVPA differed by prepregnancy BMI status (dichotomized as prepregnancy BMI $<25\,kg/m^2$ and $\geq 25\,kg/m^2$). Multiplicative interaction terms were significant for pregnancy BMI and MET hours/week of recreational MVPA ($p=0.01$). Among women with prepregnancy BMI $<25\,kg/m^2$, those who reported any MET hours/week of recreational MVPA had a nearly 50% lower risk of hyperglycemia compared to those who reported none (aRR 0.52, 95% CI 0.33-0.83). There was no association among women with prepregnancy BMI $\geq 25\,kg/m^2$ (aRR 1.14, 95% CI 0.78-1.66).

Discussion

We used data from a large, prospective cohort of pregnant women to determine if MVPA during midpregnancy (17–22 weeks' gestation) is associated with a lower risk of developing hyperglycemia measured late in the second trimester. The results showed that women who reported any MET hours/week of recreational MVPA had a 27% lower risk of developing hyperglycemia compared to those who reported none. Among women with prepregnancy BMI $<25\,kg/m^2$, those who reported any MET hours/week of recreational MVPA had a nearly 50% lower risk of hyperglycemia compared to those who reported none. There was no association among women with prepregnancy BMI $\geq 25\,kg/m^2$.

The beneficial biologic effects of physical activity on glucose metabolism and insulin sensitivity are well documented

Table 2. Risks of Hyperglycemia Associated with Total and Mode-specific Moderate to Vigorous Physical Activity Among Women in the Third Cohort of Pregnancy Infection and Nutrition Study ($n=1437$)

		Unadjusted			*Adjusted*[a]		
Type of MVPA	*Cases/*n *(%)*	*RR*	*95% CI*	p	*RR*	*95% CI*	p
Total							
None	174/906 (19.2)		Reference			Reference	
Any	95/531 (17.9)	0.93	0.74-1.17	0.54	0.93	0.74-1.17	0.55
Recreation							
None	226/1128 (20.0)		Reference			Reference	
Any	43/309 (13.9)	0.69	0.51-0.94	0.02	0.73	0.54-0.99	0.04
Outdoor household							
None	260/1383 (18.8)		Reference			Reference	
Any	9/54 (16.7)	0.89	0.48-1.63	0.70	0.90	0.49-1.66	0.74
Indoor household							
None	247/1334 (18.5)		Reference			Reference	
Any	22/103 (21.4)	1.15	0.78-1.70	0.47	1.10	0.76-1.60	0.61
Caregiving							
None	261/1386 (18.8)		Reference			Reference	
Any	8/51 (15.7)	0.83	0.44-1.59	0.58	0.80	0.43-1.51	0.49
Work							
None	242/1330 (18.2)		Reference			Reference	
Any	27/107 (25.2)	1.39	0.98-1.96	0.06	1.26	0.90-1.78	0.18

There were no women with MET hours of transportation MVPA.

[a]Model 2, excludes 1 woman with missing race/ethnicity and is adjusted for maternal prepregnancy body mass index (BMI), age at conception, and race/ethnicity. MVPA mode-specific models are also adjusted for MVPA undertaken in all the remaining modes.

CI, confidence interval; RR, relative risk.

in nonpregnant populations.[7] Participation in physical activity lowers blood glucose concentrations, increases insulin sensitivity, improves cardiovascular fitness, and decreases body fat.[7] There is evidence to suggest that these beneficial effects, with respect to insulin sensitivity and β cell response, also occur during pregnancy.[34]

There are a limited number of observational studies that examine the association between physical activity and hyperglycemia during pregnancy. Studies that assessed physical activity before pregnancy as well as those that assessed it during pregnancy provide evidence for a reduced risk of GDM,[8] with the greatest reduction being observed among women who engage in physical activity both before and during pregnancy.[12,13] In the current study, we found a lower risk of hyperglycemia associated with any MET hours/week of recreational MVPA during midpregnancy. There were no associations of hyperglycemia and other modes of MVPA. These findings may be due to a lack of power, as fewer women reported MVPA in other modes of physical activity compared to recreational activities. It is also possible that women who have indoor household or work-related activities that require MVPA may have unmeasured habits or health-related factors, such as stress, that negatively affect glucose concentrations and counteract the benefits of MVPA.

Our results for recreational MVPA are consistent with those from three other prospective cohort studies that measured physical activity during pregnancy.[12,13,35] Using cohorts of predominantly white women, both Dempsey et al.[13] and Oken et al.[12] found that recreational physical activities during pregnancy were associated with reductions in risks of GDM ranging from approximately 10% to 40%; however, none of the estimates reached statistical significance in adjusted models. Among Hispanic women, Chasen-Taber et al.[35] reported an 80%–90% lower risk of GDM for women in the highest quartiles of household/caregiving and sports/exercise activities at ~28 weeks' gestation compared to those in the lowest quartile. There was no association between GDM and physical activities measured at recruitment (<24 weeks' gestation).

Few studies have examined the association of physical activity and maternal glucose concentration in the absence of GDM. Physical activity before pregnancy is associated with a lower risk of glucose intolerance and increased insulin sensitivity.[36] In the study by Oken et al.,[12] physical activity during pregnancy was associated with a 20%–30% lower odds of abnormal glucose tolerance (defined as a failed result on the 1-hour, 50-g nonfasting oral glucose challenge test); however, only the effect estimate for women engaging in any light, moderate, or vigorous physical activity during pregnancy was statistically significant in adjusted models (adjusted odds ratio [aOR] 0.76, 95% CI 0.57-1.00). Chasen-Taber et al.[35] also observed 40%–60% reduced risks of abnormal glucose tolerance (>135 mg/dL on a 1-hour, 50-g GTT) associated with household/caregiving and sports/exercise-related physical activities in early and midpregnancy.

Prepregnancy BMI may be an effect modifier of the association between hyperglycemia and recreational MVPA. Among women with prepregnancy BMI $<25\,kg/m^2$, recreational MVPA was associated with a lower risk of hyperglycemia; however, there was no association among women with prepregnancy BMI $\geq 25\,kg/m^2$. These findings are similar to those by Oken et al.,[12] who reported that vigorous recreational physical activity during pregnancy, as well as total recreational physical activity before pregnancy, was associated with a reduced risk of developing abnormal glucose tolerance only among women with prepregnancy BMI $<25.0\,kg/m^2$. In contrast, one study observed a lower odds of GDM associated with any exercise during pregnancy (at least 30 minutes of exercise in addition to usual activities on 1 or more days per week) among women with prepregnancy BMI $>33.0\,kg/m^2$,[33] whereas other studies reported no evidence of an interaction by BMI status when GDM was the outcome.[9,35] It is possible that there is a specific threshold of physical activity (in terms of duration, intensity, or frequency) during pregnancy necessary to alter glucose concentrations in women with prepregnancy BMI $<25\,kg/m^2$ compared to those with prepregnancy BMI $\geq 25\,kg/m^2$. With such limited and conflicted research in this area, more studies are needed to determine if differences exist in the benefits of physical activity for women of varying prepregnancy BMI.

Limitations

The results of this study should be interpreted with respect to its limitations. The study population may not be generalizable to other pregnant populations; excluded women were more likely to be a minority, obese, less educated, lower income, younger, not married, multiparous, and smokers. There was a lower prevalence of GDM among participants compared to estimates from national data (there are no national estimates for hyperglycemia). There were also low numbers of women who reported MVPA within each mode, which limited our statistical power to examine the risk of hyperglycemia within modes. We also lacked a comprehensive assessment of women's physical activity habits before pregnancy and cannot state whether recreational MVPA during pregnancy alone may decrease the risk of hyperglycemia later in pregnancy. It is likely that many women who reported MVPA during pregnancy also participated in similar activities before pregnancy.[37] Lastly, we chose hyperglycemia as the outcome to be more consistent with the IADPSG's most recent recommendations, which are less restrictive than previous guidelines. Future studies that define GDM using the diagnostic strategies and criteria from these recent recommendations are necessary.

Conclusions

Among nonpregnant populations, physical activity has long been acknowledged as a strategy for preventing the development of T2DM and controlling blood glucose and insulin levels in individuals with T2DM.[38,39] Evidence from previous studies suggests that physical activity before and during pregnancy is useful for controlling maternal glucose concentrations and preventing GDM.[9,12,13,35] Results from the current study suggest that recreational MVPA during midpregnancy is associated with a lower risk of hyperglycemia, specifically among women with prepregnancy BMI $<25\,kg/m^2$. Randomized controlled trials are needed to determine recommended amounts and intensities of physical activity and to discern whether differences in the effects of physical activity exist between specific modes of physical activity or among subgroups of women in relation to GDM.

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Disclosure Statement

The authors have no conflicts of interest to report.

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