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Prospective Study of Gestational Diabetes Mellitus Risk in Relation to Maternal Recreational Physical Activity before and during Pregnancy

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Physical activity has been associated with a reduced risk of gestational diabetes mellitus, but inferences have been hampered by recall and selection bias. The authors examined the relation between recreational physical activity before and during pregnancy and risk of gestational diabetes mellitus in a prospective cohort study. In 1996–2000, 909 normotensive, nondiabetic women in Seattle and Tacoma, Washington, were questioned during early gestation about physical activity performed during the year before and 7 days prior to the interview during pregnancy. Compared with inactive women, women who participated in any physical activity during the year before experienced a 56% risk reduction (relative risk (RR) = 0.44, 95% confidence interval (CI): 0.21, 0.91). Women spending ≥4.2 hours/week engaged in physical activity experienced a 76% reduction in gestational diabetes mellitus risk (RR = 0.24, 95% CI: 0.10, 0.64), and those expending ≥21.1 metabolic equivalent-hours/week experienced a 74% reduction (RR = 0.26, 95% CI: 0.10, 0.65) compared with inactive women. Physical activity during pregnancy was also associated with reductions in gestational diabetes mellitus risk. Women who engaged in physical activity during both time periods experienced a 69% reduced risk (RR = 0.31, 95% CI: 0.12, 0.79). Findings suggest that efforts to increase maternal physical activity may contribute to substantial reductions in gestational diabetes mellitus risk.

diabetes, gestational; motor activity; pregnancy; prospective studies; recreation; risk factors

Abbreviations: BMI, body mass index; CI, confidence interval; MET, metabolic equivalent; RR: relative risk.

Physical activity has been associated with a reduced risk of type 2 diabetes mellitus (1–3). Investigators have reported that regular and even infrequent exercise may ameliorate metabolic anomalies associated with this condition, such as insulin resistance (4–6), oxidative stress (7, 8), increased body fat (9), dyslipidemia (10, 11), and elevated blood pressure (12, 13). Recently, attention has been given to the relation between physical activity and gestational diabetes mellitus. As in type 2 diabetes, peripheral insulin resistance contributes to the hyperglycemia of gestational diabetes mellitus. Animal studies have suggested that the primary site of maternal insulin resistance is skeletal muscle (14), which is the location of increased uptake and use of glucose during exercise (15).

Although evidence is still emerging, three observational studies (16, 17; J. C. Dempsey, Swedish Medical Center, unpublished manuscript) and several small treatment studies (18–21) support the thesis that recreational physical activity performed before and/or during pregnancy modifies the risk of gestational diabetes mellitus. Using a population-based birth registry, Dye et al. (16) reported that maternal exercise during pregnancy was associated with a 47 percent reduction

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in risk of gestational diabetes mellitus among obese women. Solomon et al. (17) noted that participants in the Nurses' Health Study II who engaged in vigorous activity or brisk walking prior to pregnancy were less likely to develop gestational diabetes mellitus, although these associations were not statistically significant. In a case-control study of 155 women with gestational diabetes mellitus and 386 controls, we observed that women who engaged in any physical activity during the year before pregnancy or during the first 20 weeks of pregnancy experienced reductions in risk of 55 percent and 48 percent, respectively (J. C. Dempsey, Swedish Medical Center, unpublished manuscript).

While results from cross-sectional case-control studies are encouraging, inferences are limited by possible recall bias of self-reported physical activity and selection bias. Therefore, in an ongoing cohort study of women receiving prenatal care prior to 16 weeks of gestation, we sought to further test our a priori hypothesis that maternal recreational physical activity reduces gestational diabetes mellitus risk.

MATERIALS AND METHODS

The OMEGA Study

The population for the present analysis was drawn from participants of the ongoing OMEGA Study, designed primarily to examine maternal dietary risk factors for preeclampsia. The study population consists of women attending prenatal care clinics affiliated with the Swedish Medical Center and Tacoma General Hospital in Seattle and Tacoma, Washington, respectively. Recruitment began in December 1996. Women eligible for inclusion were those who initiated prenatal care prior to 16 weeks of gestation. Women were ineligible if they were younger than 18 years of age, did not speak and read English, did not plan to carry the pregnancy to term, and/or did not plan to deliver at either of the two research hospitals. During the period 1996–2000, we primarily approached and enrolled nulliparous women who had completed ≥16 weeks of gestation (while gradually expanding our recruiting efforts to study clinics and expanding our interviewing staff). During this period, multiparous women were approached and enrolled when study personnel were available.

Enrolled participants were asked to take part in a 45–60-minute interview in which trained research personnel used a structured questionnaire to elicit information regarding maternal sociodemographic characteristics, lifestyle habits, and medical and reproductive histories. Participants were also provided with a 121-item semiquantitative food frequency questionnaire and a self-addressed stamped envelope, along with instructions for completing and returning the questionnaire to our research offices. Nonfasting blood and urine samples were collected in early pregnancy. Samples were processed and stored in continuously monitored freezers. Pregnancy outcome information was ascertained by reviewing participants' hospital labor and delivery medical records or clinic records after the estimated delivery date.

The procedures used in this study were in agreement with the protocols approved by the institutional review boards of the Swedish Medical Center and Tacoma General Hospital, respectively. All participants provided written informed consent.

Analytical population

The study population for this report was derived from information collected from those participants who enrolled in the OMEGA Study between 1996 and 2000. During this period, 1,219 eligible women were approached, and 1,000 (approximately 82 percent) agreed to participate. Thirty-six women who were lost to follow-up (moved, delivered elsewhere, records not found, etc.) were excluded from the analysis. Also excluded were women who experienced a spontaneous (n = 25) or induced (n = 6) abortion, those for whom glucose tolerance test data were missing (n = 3), those with preexisting diabetes mellitus (n = 6), and those for whom physical activity data were incomplete (n = 15). Hence, a cohort of 909 women remained for analysis. The women included in this sample were similar to the 57 women (less than 6 percent of the cohort eligible for the study) who were lost to follow-up and/or for whom data on age, parity, and body mass index (BMI) were missing. However, those excluded were more likely to be Caucasian, unmarried, have less than 12 years of education, and have smoked during pregnancy.

Pregnancy outcome

Maternal and infant medical records were reviewed approximately 7–9 months after participants were enrolled in the study to collect detailed information concerning antepartum, labor, and delivery characteristics as well as conditions of the newborn. From medical records, we abstracted laboratory results of participants' 50-g, 1-hour oral glucose tolerance tests and diagnostic 100-g, 3-hour oral glucose tolerance tests. Women were classified as having a pregnancy complicated by gestational diabetes mellitus if the results of their diagnostic test met criteria described by the National Diabetes Data Group (22). Briefly, women were classified as having gestational diabetes mellitus if two or more of the following plasma glucose concentrations obtained during the 100-g, 3-hour oral glucose tolerance test were abnormal according to National Diabetes Data Group criteria: fasting, ≥105 mg/dl; 1-hour, ≥190 mg/dl; 2-hour, ≥165 mg/dl; 3-hour, ≥145 mg/dl (22). The 50-g, 1-hour glucose tolerance test is used to screen for gestational diabetes mellitus. Women in this cohort underwent routine screening between 24 and 28 weeks of gestation. Those whose 1-hour plasma glucose levels from this test were ≥140 mg/ml were considered at increased risk for gestational diabetes mellitus and underwent the diagnostic 3-hour oral glucose tolerance test within 1–2 weeks of the initial screening test.

In-person interviews

Using structured questionnaires, interviewers collected information on maternal sociodemographic, behavioral, and medical characteristics when the mean gestational age of members of the cohort was 12.7 weeks. Covariate information included maternal age, height, prepregnancy weight, and reproductive and medical histories. We also obtained information regarding maternal educational attainment, annual household income, occupation, prenatal vitamin supplement use, and smoking and alcohol consumption before and during pregnancy. Maternal age was determined at the time of interview and was expressed in years. Parity was reported as the number of previous pregnancies lasting beyond 20 weeks of gestation. Maternal race and educational attainment were based on self-reports during the interview. Prepregnancy BMI, used as a measure of overall maternal adiposity, was calculated as weight in kilograms divided by height in meters squared.

Physical activity assessments

We asked women to specify what recreational physical activities they engaged in during the year before the study pregnancy. For each activity, we further inquired about the frequency and average time spent participating in that activity. For our assessment of physical activity during pregnancy, we limited questions to the 7 days before the interview.

Specification of physical activity variables

Women were categorized into two groups (not active and active) with respect to participation in any recreational physical activity during each assessment period. We also considered gestational diabetes mellitus risk in relation to the following dimensions of physical activity for both periods of study: 1) amount of time engaged in recreational physical activities and 2) energy expended during the performance of those activities. The number of hours spent per week participating in recreational physical activity, either during pregnancy or during the year before pregnancy, was calculated by dividing the total number of hours spent on each activity by the number of weeks during which the activity was performed, and then summing these values over all reported activities. After we specified inactive women as the referent group, physically active women were categorized as those below and above the median of weekly hours spent engaging in physical activity. The medians were 4.2 hours for activities performed during the year before pregnancy and 6.0 hours during pregnancy.

We assessed risk of gestational diabetes mellitus in relation to weekly energy expenditure on recreational physical activity, which integrates intensity and the amount of time spent exercising during pregnancy and during the year before pregnancy. Energy expenditure was calculated as described by Ainsworth et al. (23) and was expressed in metabolic equivalent (MET)-hours per week. MET-hours per week were calculated by dividing the total number of hours spent on each activity by the number of weeks during which the activity was performed, multiplying the result by the activity intensity score (MET score), and summing over all reported activities. After inactive women were specified as the referent group, physically active women were categorized into those below and above the median of weekly energy expenditure. The median energy expenditure was 21.1 MET-hours per week during the year before pregnancy (equivalent to 3.5 hours per week of vigorous exercise such as running or aerobic dance or 5.3 hours per week of moderate-intensity exercise such as brisk walking). The median was 28.0 MET-hours per week during pregnancy (equivalent to 4.7 hours per week of vigorous exercise or 7.0 hours per week of moderate exercise).

Statistical analyses

We examined frequency distributions of maternal sociodemographic characteristics and medical and reproductive histories according to maternal recreational physical activity before pregnancy. We estimated the relative association between the various dimensions of recreational physical activity (e.g., time and energy expenditure) and risk of gestational diabetes mellitus by using Stata version 7.0 software (Stata Corporation, College Station, Texas). We fit generalized linear models, using a log-link function, to derive relative risks and 95 percent confidence intervals. To assess confounding, we entered variables into the generalized linear model one at a time and then compared the adjusted and unadjusted relative risks. Final generalized linear models included covariates that altered unadjusted relative risks by at least 10 percent as well as those covariates of a priori interest (e.g., advanced maternal age and prepregnancy adiposity).

We considered the following covariates as possible confounders in this analysis: maternal age, race, parity, smoking during pregnancy, first-degree family history of type 2 diabetes, prepregnancy adiposity, and annual household income. Whenever appropriate, we used the most parsimonious variable specification that achieved the greatest control of confounding. For instance, to control potential confounding from prepregnancy BMI, we expressed prepregnancy BMI as a continuous variable, categorical variable (<20.0, 20.0–24.9, ≥25.0 kg/m^2), and grouped linear variable, respectively, in multivariable models. In a grouped linear variable for prepregnancy BMI, the three categories are given a score (e.g., 1, 2, 3) and then modeled as a continuous variable (24). The greatest amount of control for confounding was achieved when BMI was expressed as a grouped linear variable. Maternal prepregnancy BMI is likely to be an intermediate outcome in the causal pathway between physical activity and gestational diabetes mellitus. Thus, separate multivariate analyses were carried out and presented adjusting for each of the following: 1) maternal age, race, and parity; 2) prepregnancy BMI; and 3) maternal age, race, parity, and prepregnancy BMI. In this population, however, controlling for prepregnancy BMI did not materially alter the relative risks for any of the physical activity measures. Therefore, when reporting adjusted relative risks, we refer to those adjusted for maternal age, race, parity, and prepregnancy BMI. We evaluated effect modification by maternal prepregnancy BMI by using an approach similar to the one described above, but with cross-product terms.

We also evaluated the model-fit statistics for models with and without cross-product terms. The p values associated with these interaction terms and likelihood ratio tests were

TABLE 1. Characteristics of the study cohort according to maternal recreational physical activity status during the year before pregnancy, Seattle and Tacoma, Washington, 1996–2000

Characteristic	Not active* (*n* = 88)		Active <4.2 hours/week (*n* = 410)		Active ≥4.2 hours/week (*n* = 411)	
	No.	%	No.	%	No.	%
Maternal age (years)						
<35	67	76.1	296	72.2	296	72.0
≥35	21	23.9	114	27.8	115	28.0
Non-White race	22	25.0	66	16.1	52	12.7
Unmarried	20	22.7	33	8.1	51	12.4
<12 years of education	11	12.6	22	5.6	8	2.0
Annual household income (US$)						
<30,000	9	10.8	19	4.7	12	3.0
30,000–69,000	28	33.7	125	31.1	115	28.6
≥70,000	46	55.4	258	64.2	275	68.4
Nulliparous	60	68.2	345	84.2	370	90.0
No prenatal vitamin use	5	5.7	11	2.7	9	2.2
Smoking during pregnancy	11	34.4	29	23.2	16	14.4
Prepregnancy body mass index (kg/m^2)						
<20	26	29.9	68	16.6	91	22.2
20–24.9	29	33.3	230	56.2	240	58.5
≥25	32	36.8	111	27.1	79	19.3

* No recreational physical activity.

all well above 0.10 and thus were not pursued further in these analyses. All reported *p* values are two-tailed, and confidence intervals were calculated at the 95 percent level.

RESULTS

In table 1, the sociodemographic and reproductive characteristics of the study cohort are summarized according to the amount of physical activity performed during the year before pregnancy. Overall, participants included in this analysis were primarily Caucasian, well educated, and nulliparous. A total of 90.3 percent of these women (821 of 909) reported participating in any recreational physical activity during this time period.

Physical activity during the year before pregnancy

Forty-two women in this cohort (4.6 percent) developed gestational diabetes mellitus. Compared with those who were inactive, women who participated in any recreational physical activity during the year before pregnancy experienced a 66 percent reduction in risk of gestational diabetes mellitus (relative risk (RR) = 0.34, 95 percent confidence interval (CI): 0.17, 0.70) (table 2). This association was attenuated somewhat after adjusting for maternal age, race, parity, and prepregnancy BMI (RR = 0.44, 95 percent CI: 0.21, 0.91). The median number of hours per week spent performing recreational physical activities during this time period was 4.2. Compared with inactive women, women who engaged in physical activity for <4.2 hours per week were 42 percent less likely to develop gestational diabetes mellitus (adjusted RR = 0.58, 95 percent CI: 0.27, 1.24), although this association was not statistically significant. Women who exercised ≥4.2 hours per week experienced a 76 percent reduction in risk (adjusted RR = 0.24, 95 percent CI: 0.10, 0.64). Energy expenditure was also associated with a reduced risk of gestational diabetes mellitus. Expending <21.1 MET-hours per week (the median) on recreational physical activity was associated with a 43 percent reduction in risk (adjusted RR = 0.57, 95 percent CI: 0.27, 1.21) compared with inactivity, and expending ≥21.1 MET-hours per week was associated with a 74 percent reduction in risk of gestational diabetes mellitus (adjusted RR = 0.26, 95 percent CI: 0.10, 0.65).

Physical activity during pregnancy

During the index pregnancy, 615 women (67.7 percent) reported participating in any recreational physical activity. Compared with inactive women, these women experienced a 31 percent reduction in risk of gestational diabetes mellitus (adjusted RR = 0.69, 95 percent CI: 0.37, 1.29), although this association was not statistically significant (table 3). The median number of hours per week spent performing recre-

TABLE 2. Unadjusted and adjusted relative risks and 95% confidence intervals for gestational diabetes mellitus according to recreational physical activity performed during the year before the index pregnancy, Seattle and Tacoma, Washington, 1996–2000

Measurement	Gestational diabetes mellitus cases		Total population (no.)	Unadjusted values		Adjusted values*		Adjusted values†		Adjusted values‡	
	No.	%		RR§	95% CI§	RR	95% CI	RR	95% CI	RR	95% CI
Any recreational physical activity											
No¶	10	11.4	88	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
Yes	32	3.9	821	0.34	0.17, 0.70	0.36	0.18, 0.76	0.44	0.21, 0.90	0.44	0.21, 0.91
Time spent performing recreational physical activity (hours/week)											
None¶	10	11.4	88	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
<4.2	23	5.6	410	0.49	0.23, 1.04	0.51	0.24, 1.09	0.58	0.27, 1.22	0.58	0.27, 1.24
≥4.2	9	2.2	411	0.19	0.08, 0.48	0.20	0.08, 0.51	0.25	0.10, 0.64	0.24	0.10, 0.64
Energy expended performing recreational physical activity (MET§-hours/week)											
None¶	10	11.4	88	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
<21.1	23	5.6	412	0.49	0.23, 1.03	0.51	0.24, 1.08	0.56	0.27, 1.20	0.57	0.27, 1.21
≥21.1	9	2.2	409	0.19	0.08, 0.48	0.20	0.08, 0.51	0.26	0.10, 0.65	0.26	0.10, 0.65

* Adjusted for maternal age, race, and parity.
† Adjusted for prepregnancy body mass index.
‡ Adjusted for maternal age, race, parity, and prepregnancy body mass index.
§ RR, relative risk; CI, confidence interval; MET, metabolic equivalent.
¶ No recreational physical activity.

ational physical activities during this time period was 6.0. Women who spent <6.0 hours per week engaged in physical activity were 58 percent less likely than women who were inactive to develop gestational diabetes mellitus (RR = 0.42, 95 percent CI: 0.19, 0.97). This association was altered slightly and became nonstatistically significant after we

TABLE 3. Unadjusted and adjusted relative risks and 95% confidence intervals for gestational diabetes mellitus according to recreational physical activity performed during the index pregnancy, Seattle and Tacoma, Washington, 1996–2000

Measurement	Gestational diabetes mellitus cases		Total population (no.)	Unadjusted values		Adjusted values*		Adjusted values†		Adjusted values‡	
	No.	%		RR§	95% CI§	RR	95% CI	RR	95% CI	RR	95% CI
Any recreational physical activity											
No¶	19	6.5	294	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
Yes	23	3.7	615	0.58	0.32, 1.06	0.60	0.33, 1.10	0.68	0.37, 1.26	0.69	0.37, 1.29
Time spent performing recreational physical activity (hours/week)											
None¶	19	6.5	294	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
<6.0	8	2.8	292	0.42	0.19, 0.97	0.43	0.19, 0.99	0.49	0.21, 1.12	0.49	0.21, 1.13
≥6.0	15	4.6	323	0.72	0.37, 1.41	0.76	0.38, 1.50	0.86	0.43, 1.72	0.90	0.45, 1.80
Energy expended performing recreational physical activity (MET§-hours/week)											
None¶	19	6.5	294	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
<28.0	12	4.2	289	0.64	0.31, 1.32	0.65	0.32, 1.34	0.71	0.34, 1.46	0.71	0.35, 1.47
≥28.0	11	3.4	326	0.52	0.25, 1.10	0.55	0.26, 1.17	0.65	0.30, 1.38	0.67	0.31, 1.43

* Adjusted for maternal age, race, and parity.
† Adjusted for prepregnancy body mass index.
‡ Adjusted for maternal age, race, parity, and prepregnancy body mass index.
§ RR, relative risk; CI, confidence interval; MET, metabolic equivalent.
¶ No recreational physical activity.

TABLE 4. Unadjusted and adjusted relative risks and 95% confidence intervals for gestational diabetes mellitus according to recreational physical activity performed before and during the index pregnancy, Seattle and Tacoma, Washington, 1996–2000

Measurement	Gestational diabetes mellitus cases		Total population (no.)	Unadjusted values		Adjusted values*		Adjusted values†		Adjusted values‡	
	No.	%		RR§	95% CI§	RR	95% CI	RR	95% CI	RR	95% CI
Not active either period¶	6	12.2	49	1.00	Reference	1.00	Reference	1.00	Reference	1.00	Reference
Active last year only	13	5.3	245	0.43	0.16, 1.14	0.45	0.17, 1.20	0.41	0.16, 1.09	0.40	0.15, 1.07
Active last week only	4	10.3	39	0.84	0.24, 2.97	0.83	0.23, 2.94	0.61	0.17, 2.21	0.59	0.16, 2.14
Active both periods	19	3.3	576	0.27	0.11, 0.67	0.28	0.11, 0.73	0.31	0.12, 0.78	0.31	0.12, 0.79

* Adjusted for maternal age, race, and parity.
† Adjusted for prepregnancy body mass index.
‡ Adjusted for maternal age, race, parity, and prepregnancy body mass index.
§ RR, relative risk; CI, confidence interval.
¶ No recreational physical activity.

adjusted for maternal age, race, parity, and prepregnancy BMI (RR = 0.49, 95 percent CI: 0.21, 1.13). Participating in physical activity for ≥6.0 hours per week was associated with a 10 percent reduction in risk of gestational diabetes mellitus (adjusted RR = 0.90, 95 percent CI: 0.45, 1.80). Compared with inactive participants, those expending <28.0 MET-hours per week (the median) were 29 percent less likely to develop gestational diabetes mellitus (RR = 0.71, 95 percent CI: 0.35, 1.47) after we adjusted for confounding factors. Energy expenditure of ≥28.0 MET-hours per week was associated with a slightly reduced risk of gestational diabetes mellitus (adjusted RR = 0.67, 95 percent CI: 0.31, 1.43), although statistical significance was not reached.

Physical activity before *and* during pregnancy

Of the 909 study cohort members, 576 (63.4 percent), including 19 who developed gestational diabetes mellitus, were physically active both during the year before and during the index pregnancy. Compared with inactive women, these participants experienced a 73 percent reduction in risk of gestational diabetes mellitus (RR = 0.27, 95 percent CI: 0.11, 0.67) (table 4). The association was slightly attenuated after adjusting for maternal age, race, parity, and prepregnancy BMI (RR = 0.31, 95 percent CI: 0.12, 0.79). Compared with inactivity, any physical activity during either of these time periods was associated with a reduced risk of gestational diabetes mellitus, but these associations did not reach statistical significance.

DISCUSSION

In this prospective cohort study of 909 pregnant women, we observed that participation in any recreational physical activity during the year before pregnancy, compared with no physical activity, was related to a statistically significant reduced risk of gestational diabetes mellitus. We found that time and energy expended performing physical activities during this time period were both associated with significant reductions in risk after adjustment for maternal age, race, parity, and prepregnancy BMI. While women engaging in physical activity during pregnancy were 31 percent less likely than inactive women to develop gestational diabetes mellitus, this association did not approach statistical significance. However, women who were physically active during both of the aforementioned time periods experienced a 69 percent reduction in risk (RR = 0.31, 95 percent CI: 0.12, 0.79).

Our study bridges a gap in the current literature by documenting an association between maternal recreational physical activity both before and during pregnancy and a decreased risk of gestational diabetes mellitus in a prospective cohort of women. To the best of our knowledge, only one other prospective study has examined this relation, but the investigators did not explore physical activity during pregnancy. Participants in the Nurses' Health Study II were queried about their physical activity level (MET score), frequency of vigorous activity (times/week), and walking pace at least 1 year prior to a completed singleton pregnancy. The investigators found a decreased, although nonstatistically significant, risk of gestational diabetes mellitus for those who frequently engaged in vigorous physical activity (≥4 times/week) compared with those who did so infrequently (<1 time/week) (adjusted RR = 0.78, 95 percent CI: 0.47, 1.29). In addition, brisk walking, compared with casual walking, was associated with a 15 percent reduction in risk (adjusted RR = 0.85, 95 percent CI: 0.64, 1.12), but the relation was not statistically significant. When the investigators restricted their analyses to those women considered at high risk for gestational diabetes mellitus (BMI ≥25 kg/m^2, history of diabetes in a first-degree relative, and/or age ≥35 years), the associations were essentially unaltered (17). Dye et al. (16) examined physical activity during pregnancy by using data from a population-based birth registry. They reported that women who did not exercise during this time period, compared with active women, experienced a 1.9-fold increase in risk of gestational diabetes mellitus (95 percent CI: 1.2, 3.1), but this effect was limited to obese women (BMI >33 kg/m^2).

Given these two published reports and encouraging results from intervention studies suggesting that the physiologic benefits of physical activity are similar to those attained by standard pharmacologic treatments (18–21), we analyzed available data from a case-control study (J. C. Dempsey, Swedish Medical Center, unpublished manuscript). We noted that women who participated in any recreational physical activity during the year before pregnancy (adjusted odds ratio = 0.45, 95 percent CI: 0.28, 0.74), during the first 20 weeks of pregnancy (adjusted odds ratio = 0.40, 95 percent CI: 0.33, 0.80), or during both time periods (odds ratio = 0.40, 95 percent CI: 0.23, 0.68) experienced significant reductions in risk of gestational diabetes mellitus when they were compared with inactive women. In addition, women who climbed stairs daily, irrespective of their participation in recreational physical activity, experienced a reduction in risk (J. C. Dempsey, Swedish Medical Center, unpublished manuscript). Although this study suggests that maternal physical activity may contribute to substantial reductions in gestational diabetes mellitus risk, the study design did not make it possible to eliminate concerns regarding differences between women who chose to participate and those who did not and potential biased reporting of participation in physical activity.

In the present study, these limitations were minimized because of the prospective study design and the high follow-up rate. However, other limitations merit discussion. First, although we adjusted for several potential confounders, we cannot exclude the possibility of residual confounding due to misclassification of adjusted variables or confounding by other unmeasured variables.

Second, while the recall of physical activity during pregnancy was only 7 days, it was 1 year for the period prior to pregnancy. Women were asked to recall not only the type of activities performed but also the frequency, intensity, and duration, a difficult and often imprecise task. These measurements are likely affected by random misclassification due to recall error and variability in physical activity, especially during the early weeks of pregnancy when symptoms such as fatigue, nausea, and vomiting are frequently present. Within-subject variance has been shown to be the largest proportional source of variance in the reporting of physical activity when a series of 24-hour recalls is used (25). The physical activity questions we used were not validated in our cohort. However, the fact that results from our study were similar to those provided by other investigators suggests that the relation between physical activity and gestational diabetes mellitus is robust and can be detected even when physical activity is measured by using relatively imprecise techniques. Nevertheless, inferences concerning the protective effect of physical activity on the occurrence of gestational diabetes mellitus would likely be enhanced with data from larger prospective cohort studies that include objective measures of maternal cardiorespiratory fitness and from randomized lifestyle intervention trials. The present cohort study focused primarily on nulliparous women who initiated prenatal care prior to 16 weeks of gestation, and participants were predominately Caucasian and well educated. Therefore, the generalizability of our results may be limited.

Lastly, the diagnostic criteria for gestational diabetes mellitus used in our study (22) were changed in 2002 so that lower fasting and postprandial levels on the 3-hour, 100-g oral glucose tolerance test (fasting, ≥95 mg/dl; 1-hour, ≥180 mg/dl; 2-hour, ≥155 mg/dl; 3-hour, ≥140 mg/dl) would now be considered the diagnostic cutpoints (26). If the new criteria had been used in our study setting, some women who were classified as controls would have been classified as having gestational diabetes mellitus. However, our use of the then-current, more stringent diagnostic criteria for gestational diabetes mellitus cannot explain the positive association we found between participation in recreational physical activity and a decreased risk of gestational diabetes mellitus because including those women with gestational diabetes mellitus in the control group would tend to weaken such associations.

A strength of the present study was the examination of two time periods and multiple dimensions of recreational physical activity. Other strengths include the relatively large cohort (909 members) and an incidence of gestational diabetes mellitus comparable to that found in other studies (17, 27).

Our observations of an association between physical activity before and during pregnancy and a reduced risk of gestational diabetes mellitus are biologically plausible. Investigators have postulated that enhanced glycemic control is the result of insulin-independent, exercise-induced increases in recruitment of the glucose transporter protein GLUT4 (28–33), an encouraging finding for persons who have a defect in insulin-stimulated glucose transport (32, 33). Following an exercise bout, muscle glucose uptake becomes more insulin sensitive, which facilitates resynthesis of glycogen stores (30). Improved glucose tolerance and increased insulin sensitivity may also result from physical activity–induced reductions in fat mass and increases in muscle mass (9). The primary site of insulin resistance is likely skeletal muscle (14), which is the location of increased uptake and use of glucose during exercise (15).

In summary, findings from this prospective study are generally consistent with those reported from our previous cross-sectional case-control study of maternal recreational physical activity and gestational diabetes mellitus risk (J. C. Dempsey, Swedish Medical Center, unpublished manuscript). Our findings are also consistent with a larger body of evidence from investigations of physical activity in relation to risk of type 2 diabetes and/or insulin resistance in nonpregnant persons (1–6) and studies of physical activity and glucose tolerance among pregnant women (34, 35). Taken together, these converging lines of evidence suggest that current efforts to encourage populations to engage more frequently in physical activity (36) may also benefit pregnant women and result in substantial reductions in the incidence of gestational diabetes mellitus. However, concerns remain about the paucity of empirical evidence regarding physical activity associated with optimal pregnancy outcomes. Randomized lifestyle intervention trials and larger cohort studies are necessary to confirm our findings.

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