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Association of Physical Activity and Sedentary Behavior with Biological Markers Among U.S. Pregnant Women

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Abstract

Background: To examine the association between objectively measured light-intensity and moderate-to-vigorous-intensity physical activity (MVPA), sedentary behaviors, and biological markers in a national sample of U.S. pregnant women, as few studies have examined these relationships among this population.
Methods: The sample of noninstitutionalized U.S. civilians was selected by a complex, multistage probability design. Data from the 2003–2006 National Health and Examination Survey were used. Two hundred six pregnant women were included in the data analysis. Physical activity and sedentary data were objectively measured via accelerometry (ActiGraph 7164). Biomarker data was obtained in the mobile examination center from urine, blood samples, blood pressure, and anthropometric measurements. Urine and blood samples were obtained to determine pregnancy status, C-reactive protein (CRP), high-density lipoprotein (HDL) cholesterol, total cholesterol, and cotinine as well as fasting glucose, fasting triglycerides, and fasting low-density lipoprotein (LDL) cholesterol data. Multivariable regression was employed to examine the association between physical activity, sedentary behavior, and biomarker levels.
Results: There was a positive association between sedentary behavior and CRP levels (beta coefficient [b] = 0.001, p = 0.02) and LDL cholesterol (b = 0.12, p = 0.02). There was an inverse association between light-intensity physical activity and CRP (b = −0.003; p = 0.008) and diastolic blood pressure (b = −0.03; p = 0.02), with those engaging in higher levels of MVPA having higher HDL cholesterol (b = 6.7; p = 0.01).
Conclusion: Physical activity and sedentary behavior were favorably associated with various biomarkers among pregnant women, suggesting that healthcare providers should encourage pregnant women to participate in safe forms of physical activity behaviors while also reducing their amount of time spent in sedentary behaviors.

Introduction

Pregnancy provides an opportunity for midwives, physicians, and other healthcare professionals to communicate with women about healthy lifestyle management, including appropriate dietary practices and physical activity engagement. The conceptual framework used to guide this study comes from the Human Movement Framework introduced by Gabriel and Morrow.[1] Briefly, physical activity and sedentary behavior influences human movement, with human movement, in turn, influencing physiological attributes (e.g., energy expenditure and physical fitness); these attributes may then influence physiological (e.g., blood pressure) and other health-related parameters (e.g., diabetes). With regard to physical activity during pregnancy specifically, the American Congress of Obstetricians and Gynecologists (ACOG) recommends that healthy pregnant women participate in at least 30 minutes of physical activity on most if not all days of the week, with previously sedentary women also able to start such a program during pregnancy.[2] Similarly, the United States Department of Health and Human Services recommends that pregnant women who are not already highly active should engage in at least 150 minutes per week of moderate-intensity physical activity (pg. viii).[3] Unfortunately, a substantive portion of pregnant women are not sufficiently active. In a nationally representative sample,

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pregnant women only engaged in about 12 minutes a day of at least moderate-intensity physical activity, as measured from accelerometry.[4] Moreover, pregnant women spent more than half (57%) of their time engaging in sedentary behaviors. A study of low-income, pregnant African American women found that fatigue and low energy dictated activity and that motivation to exercise was lacking during pregnancy.[5]

Regular engagement in moderate-to-vigorous physical activity (MVPA) during pregnancy may result in several maternal benefits, such as reduced fatigue and swelling of the lower extremities,[6] fewer symptoms of depression,[7] improved sleep quality,[8] and reductions in the length of labor and decreased complications during delivery.[9,10] Additionally, MVPA during pregnancy may reduce the occurrence of preeclampsia and gestational diabetes.[11] The mechanisms through which MVPA may reduce the risk of preeclampsia is likely through favorable changes in blood pressure, markers of inflammation, oxidative stress, and plasma lipid and lipoprotein levels.[11] With respect to gestational diabetes, regular MVPA participation may help to improve glycemic control via contraction-mediated glucose uptake through increases in GLUT4 protein expression.[12] The influence of MVPA on these biomarkers (e.g., blood pressure), which we consider to be parameters that provide an indication of a biological state, have come from mostly studies in the general population.[13] Although minimally investigated, one study among pregnant women ($n=16$) showed that 10 weeks of moderate-intensity physical activity may help to lower blood pressure.[14] Similarly, self-reported physical activity among pregnant women is inversely associated with plasma lipids.[15] However, we have a limited understanding of the association between MVPA and these biomarkers among a national sample of pregnant women. Also, most physical activity-related studies in the general population, let alone pregnant women, have relied on self-report measures of physical activity, which are prone to considerable measurement error, such a recall bias, social desirability, and item-interpretation.[16] It is possible that previous reports of the association between physical activity and biomarkers (e.g., blood pressure) are underestimated, as increased measurement error from self-report methodology may attenuate associations. Unlike self-reported physical activity, accelerometry provides an objective measure of the frequency, intensity, and duration of physical activity. Additionally, emerging research is also showing that sedentary behavior and light-intensity behavior, which are understudied behaviors, are independently associated with health outcomes.[17,18] We currently have a limited understanding of the association between these behaviors and biomarkers among pregnant women. To address these gaps in the literature, the purpose of the present study was to, in a national sample of pregnant women, examine the association between accelerometer-assessed sedentary behavior, light-intensity behavior, and MVPA and several biomarkers (e.g., blood pressure, cholesterol, C-reactive protein [CRP]) known to associate with pregnancy-induced diseases, such as preeclampsia and gestational diabetes.

Methods

Design and participants

Data were obtained from the 2003–2006 National Health and Nutrition Examination Survey (NHANES). NHANES is an ongoing survey conducted by the National Center for Health Statistics that uses a representative sample of noninstitutionalized U.S. civilians, selected by a complex, multistage probability design. Briefly, participants are interviewed in their home and subsequently examined in a mobile examination center (MEC). The study was approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants prior to data collection. Among the 20,470 participants in the 2003–2006 cycles, 674 remained after excluding those who were not pregnant (as determined from a urine and serum sample or self-report); 264 remained after excluding those who had insufficient accelerometry data (i.e., did not wear the monitor for ≥ 4 days with 10+ hours/day); 257 remained after excluding those under 18 years of age; and 206 remained after excluding those with missing data on the covariates (age, smoking, education, marital status, poverty level, race/ethnicity, gestation, and body mass index). These 206 women comprise the study sample. With regard to these 206 participants and the other pregnant women who were excluded from the study ($n=468$; $674-206=468$), there were no differences ($p>0.05$) with the exception of age and cotinine. Those included in the study (28.4 years) were older than those excluded (26.4 years) ($p=0.01$); those included also had a lower cotinine level (3.5 vs. 15.3 ng/mL) ($p=0.003$).

Among the participants attending the MEC, approximately half were examined in a morning fasting session where fasting biomarkers were obtained, which was part of the study design (i.e., only half of the participants were examined for fasting biomarkers). From the morning fasting session, and for the present study, fasting triglycerides, fasting low-density lipoprotein (LDL) cholesterol, and fasting glucose concentrations were analyzed. Data was obtained from 107 participants providing fasting glucose, 107 providing fasting triglyceride, and 105 providing fasting LDL cholesterol data. Participants ranged in age from 20–43 years.

Measurement of pregnancy status

Participants self-reported whether they were pregnant or not. Additionally, a urine test was used to determine pregnancy status, using the Icon 25 hCG (human chorionic gonadotropin) test kit (Beckman Coulter). The Icon 25 hCG test kit is a rapid chromatographic immunoassay for the qualitative detection of hCG in urine or serum. This test utilizes a combination of monoclonal and polyclonal antibodies to selectively detect elevated levels of hCG in urine or serum.

Measurement of physical activity and sedentary behavior

At the MEC, participants who were not prevented by impairments of walking or wearing an accelerometer were issued an ActiGraph 7164 accelerometer. Participants were asked to wear the accelerometer on the right hip for 7 days following their examination. The accelerometer was affixed to an elastic belt worn around the waist. The output of an accelerometer is activity counts, which are proportional to acceleration. Detailed information on the ActiGraph accelerometer can be found elsewhere.[19] For the present study, activity counts were summarized in 1-min bouts. Time spent at different physical activity intensities was assessed, including light and MVPA. Moderate and vigorous intensity physical activity were combined given that participants spent little time in vigorous-intensity physical activity; mean (standard error) duration of vigorous-intensity was 0.29 minutes per day (0.09).

Activity counts between 0 and 99 counts per minute were used to classify time spent in sedentary behavior.[20] Activity counts between 100 and 2019 counts per minute were used to classify time spent in light-intensity physical activity; activity counts between 2020 and 5998 counts per minute were used to classify time spent at moderate-intensity[21]; and activity counts at or greater than 5999 counts per minute were used to classify time spent at vigorous intensity.[21] For the analyses described here, only those participants with at least 4 days with 10 or more hours per day of monitoring data were included in the analyses.[21] To determine when the monitor was worn, nonwear was defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1–2 minutes of activity counts between 0 and 100.[21]

Biological markers

Biomarkers known to be associated with physical activity in the general population were examined.[22,23] During examination at the MEC, blood samples were obtained from the participants. Fasting blood samples were obtained for triglycerides, LDL cholesterol, and glucose. Nonfasting samples were obtained for CRP, a key biomarker of systemic inflammation, high-density lipoprotein (HDL) cholesterol, and total cholesterol. At the MEC, blood pressure was obtained from the participants. After resting quietly in a sitting position for 5 minutes and determining the maximum inflation level, three and sometimes four blood pressure determinations (systolic and diastolic) were obtained. The average of the obtained systolic and diastolic measurements was used. As a marker of active smoking status or as an index of environmental exposure to tobacco (i.e., passive smoking), serum cotinine was measured. Serum cotinine was measured by an isotope dilution–high performance liquid chromatography/atmospheric pressure chemical ionization tandem mass spectrometry. Additionally, anthropometric measurements, including height and weight were obtained during the MEC. Body mass index (BMI) was calculated from measured weight and height (weight in kilograms divided by the square of height in meters). These biologically related variables were chosen for this study as they have previously been shown to be associated with physical activity.[24–27] Further details about the laboratory and examination procedures and quality control have been previously reported.[28]

Other measurements

Various covariates were selected based on previous research showing them to be associated with physical activity behavior. Information about age, gender, race/ethnicity, marital status, and education were obtained from a questionnaire. As a measure of socioeconomic status, poverty to income ratio (PIR) was determined. Ranging from 0 to 5, PIR was defined as the ratio of the family individual income to their poverty threshold. For example, a PIR of 0.5 suggests that the family income is 50% below the poverty threshold. Lastly, gestation was assessed by asking participants what month of pregnancy they were in.

Data analysis

All statistical analyses were performed using procedures from sample survey data using STATA (version 10.0) to account for the complex survey design used in NHANES. To account for oversampling, nonresponse, noncoverage, and to provide national estimates, all analyses included the use of appropriate survey sample weights, clustering and primary sampling units. New MEC sample weights were created for the combined NHANES cycles (2003–2004 and 2005–2006) following analytical guidelines for the continuous NHANES. In the situation where an analysis resulted in a stratum with a single cluster, the variance contribution from a stratum with a single cluster was centered at the overall cluster mean. To normalize the physical activity data, moderate- to vigorous-intensity data was normalized using a log transformation. Similarly, CRP was normalized using a log transformation.

Means and standard errors were calculated for continuous variables and proportions were calculated for categorical variables. To examine the association between physical activity intensity and sedentary behavior (independent variables) and the biological variables (dependent variable), a multivariable linear regression analysis was performed. Models controlled for age, smoking, education, marital status, PIR, race-ethnicity, BMI, and gestation. The sedentary and light-intensity physical activity models also controlled for MVPA. A $p < 0.05$ was considered statistical significance.

Results

Descriptive characteristics of the study variables are shown in Table 1. The multivariable association between physical activity and sedentary behavior and the biological variables are shown in Table 2. After controlling for age, smoking, education, marital status, PIR, race/ethnicity, gestation, BMI, and MVPA, there was a positive association between sedentary behavior and CRP levels (beta coefficient [b] = 0.001 [95% confidence interval, CI: 0.0001–0.003]; $p = 0.02$), LDL cholesterol ($b = 0.12$ [95% CI: 0.02–0.22]; $p = 0.02$), and glucose levels ($b = 0.02$ [95% CI: –0.001–0.04]; $p = 0.06$). Similarly, and after adjustments, there was an inverse association between light-intensity physical activity and CRP and diastolic blood pressure. After adjustments, those engaging in higher levels of MVPA tended to have lower CRP levels and higher HDL cholesterol. Although recognizing the limited sample size to detect interaction effects, additional analyses were computed across trimester (data not shown). Among the significant or marginally significant associations, associations only remained significant for pregnant women in the second and third trimester, which is when we see a decline in activity behavior during pregnancy[29]; these findings underscore the importance of engaging in safe forms of physical activity as pregnancy progresses.

Across intensity levels, there were no significant (or marginally significant) findings for the biomarkers systolic blood pressure, cotinine, BMI, total cholesterol, and triglycerides. However, and not shown in tabular format, after adjusting for age, education, marital status, PIR, race-ethnicity, gestation, and BMI, pregnant women meeting physical activity guidelines (i.e., engaging in ≥ 150 minutes per week of moderate-intensity physical activity or 75 minutes per week of vigorous-intensity physical activity) had lower cotinine levels (2.74 [95% CI:

Table 1. Weighted Means and Percentages (Standard Error) of the Study Variables, National Health and Nutrition Examination Survey 2003–2006 ($N=206$)

Variable	Mean/proportion (standard error)
Demographic variables	
Mean age (years)	28.4 (0.4)
% Non-Hispanic white	61.7 (5.9)
% College graduate or above	39.4 (5.8)
Poverty-income ratio score	2.84 (0.1)
% Married	72.5 (5.3)
Gestation	
% First trimester	21.3 (5.0)
% Second trimester	40.3 (5.9)
% Third trimester	38.3 (4.5)
Biological variables	
Mean systolic blood pressure (mmHg)	107.3 (0.8)
Mean diastolic blood pressure (mmHg)	58.4 (1.6)
Mean CRP (mg/dL)	0.66 (0.06)
Mean HDL (mg/dL)	73.0 (1.5)
Mean LDL (mg/dL)	124.3 (6.2)
Mean total cholesterol (mmol/L)	5.76 (0.1)
Mean triglycerides (mg/dL)	184.9 (11.2)
Mean glucose (mg/dL)	81.2 (1.7)
Mean cotinine (ng/mL)	3.51 (1.1)
Mean BMI (kg/m^2)	29.2 (0.7)
Physical activity variables	
Sedentary behavior (minutes/day)	460.5 (11.6)
Light-intensity physical activity (minutes/day)	325.4 (6.1)
Moderate-to-vigorous physical activity (minutes/day)	11.9 (0.9)

BMI, body mass index; CRP, C-reactive protein; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

0.31–5.16]) than those not meeting physical activity guidelines (4.33 [95% CI: 1.12–7.54]) ($p=0.08$).

Discussion

Previous research has demonstrated that self-reported physical activity behavior is favorably associated with biomarkers among pregnant women.[15] Here we examined the association between accelerometer-assessed sedentary, light, and MVPA and various activity-related biological markers among a national sample of pregnant women. The major findings were that objectively measured physical activity was inversely associated with CRP and diastolic blood pressure, and positively associated with HDL cholesterol. Another original contribution was the identification of a positive association between objectively measured sedentary behavior and CRP, LDL cholesterol, and glucose. These results, which are consistent with findings in the general population,[30] suggest that among pregnant women minimizing sedentary behavior may result in favorable changes to biomarkers associated with preeclampsia and gestational diabetes. This is supported by physical activity studies showing that physical activity during pregnancy may reduce the risk of gestational diabetes, weight gain, and preeclampsia.[31–33] Additionally, the significant CRP finding may be particularly important as research shows that elevated CRP, particularly in early pregnancy, is associated with preterm delivery.[34] Moreover, given that sedentary behavior was significant even after controlling for MVPA suggests that sedentary behavior may be a more important predictor of health than physical activity. Although not fully understood, research suggests that prolonged sedentary activities may negatively influence health outcomes through the inhibition of lipid metabolism.[35]

These findings, along with others, underscore the importance of promoting regular physical activity participation and minimizing sedentary behavior among pregnant women. Another important finding of the present study was that light-intensity physical activity was associated with several biological parameters. Engaging in light-intensity physical activity may be an attractive alternative to MVPA among

Table 2. Associations Between Accelerometer-Assessed Behaviors and Biological Markers Among Pregnant Women, National Health and Nutrition Examination Survey 2003–2006 ($N=206$)

Biological markers	Beta coefficient (95% CI)† Sedentary behavior	p	LPA	p	MVPA	p
C-reactive protein (mg/dL)	0.001 (0.0001 to 0.003)	0.02	−0.003 (−0.004 to −0.001)	0.008	−0.14 (−0.30 to 0.01)	0.07
Systolic blood pressure (mmHg)	−0.004 (−0.01 to 0.007)	0.41	−0.003 (−0.02 to 0.01)	0.78	0.34 (−0.39 to 0.29)	0.70
Diastolic blood pressure (mmHg)	0.002 (−0.02 to 0.03)	0.82	−0.03 (−0.05 to −0.005)	0.02	−0.65 (−4.10 to 2.78)	0.69
Body mass index (kg/m^2)	0.006 (−0.004 to 0.01)	0.21	−0.008 (−0.02 to 0.009)	0.36	0.38 (−1.33 to 2.09)	0.65
HDL-cholesterol (mg/dL)	0.007 (−0.05 to 0.06)	0.79	−0.009 (−0.07 to 0.05)	0.74	6.76 (1.77 to 11.76)	0.01
LDL-cholesterol (mg/dL)	0.12 (0.02 to 0.22)	0.02	−0.01 (−0.12 to 0.10)	0.84	7.73 (−2.05 to 17.51)	0.11
Total cholesterol (mmol/L)	−0.0004 (−0.003 to 0.002)	0.73	0.001 (−0.001 to 0.005)	0.29	0.11 (−0.07 to 0.31)	0.22
Triglycerides (mg/dL)	0.08 (−0.04 to 0.20)	0.17	0.01 (−0.16 to 0.20)	0.85	9.17 (−6.74 to 25.1)	0.24
Glucose (mg/dL)	0.02 (−0.001 to 0.04)	0.06	−0.009 (−0.03 to 0.01)	0.46	−0.63 (−1.96 to 0.69)	0.33
Cotinine (ng/mL)	0.004 (−0.01 to 0.02)	0.69	0.01 (−0.01 to 0.04)	0.33	−0.44 (−3.34 to 2.46)	0.75

†Models controlled for age, smoking, education, marital status, poverty-to-income ratio, race/ethnicity, gestation, and body mass index. Note, models for sedentary and light-intensity activity behavior also controlled for MVPA.

CI, confidence interval; LPA, light-intensity physical activity; MVPA, moderate-to-vigorous-intensity physical activity.

pregnant women, given the possible discomforts that may occur with higher intensity levels, particularly during late gestation. When feasible, healthcare professionals are encouraged to promote safe forms of physical activity to their pregnant patients. Also, healthcare professionals should encourage their pregnant patients to reduce prolonged sedentary activities by increasing sedentary breaks throughout the day. For example, assuming a pregnant woman is awake for 16 hours, if she were to walk for 2 minutes every hour, then not only would she be limiting prolonged sedentary behavior, but she would accumulate 32 minutes (16×2) of physical activity, and thus meet ACOG's recommended dose of daily physical activity (i.e., at least 30 minutes).[36]

Limitations to the present study include the cross-sectional design, which precludes any ability to render causation or identify how changes in activity levels during pregnancy may influence biomarker levels. As a result, future prospective and experimental studies on this topic are needed. Though not a prevalence study per se, among our study participants, adequate physical activity participation rates were relatively low, with only 13.9% of the women meeting the physical activity guidelines, with the mostly null MVPA findings likely a result of this floor effect. There was some evidence that gestation may moderate the association between physical activity/sedentary behavior and biomarker levels, with significant associations appearing to occur only in the latter trimesters. Although speculative, these significant associations might be from higher levels of biomarkers that result as pregnancy progresses.[37–39] Alternatively, these findings may be because of the greater proportion of participants in the second and third trimesters. Future studies with a larger sample size are needed to better test for the potential effect modification of gestation. Future studies may also wish to examine potential effect modification of race/ethnicity, weight status, and pregnancy-induced disease status (e.g., preeclampsia). Also of interest would be for future studies to develop accelerometer cut-points specifically for pregnant women. Lastly, prepregnancy physical activity levels were not available in the NHANES, which is a limitation worth noting, as prepregnancy activity levels, rather than activity levels during pregnancy, may have influenced the biomarker levels; however, there is evidence showing that prepregnancy activity is positively associated with activity behavior during pregnancy.[40]

In summary, the present study demonstrated an inverse association between objectively measured physical activity and CRP and diastolic blood pressure, and a positive association with HDL cholesterol. Additionally, objectively measured sedentary behavior was positively associated with CRP and LDL cholesterol, with a trend towards significance for plasma glucose. Although future prospective and experimental studies are needed, these results suggest that minimizing sedentary behavior and increasing physical activity behavior (both light-intensity and moderate-to-vigorous-intensity physical activity) may result in favorable changes in several biomarkers known to be associated with pregnancy-induced conditions, such as preeclampsia and gestational diabetes.

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Disclosure Statement

No competing financial interests exist.

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