JOURNAL OF WOMEN'S HEALTH
Volume 20, Number 7, 2011

DOI: 10.1089/jwh.2010.2091

Associations Between Physical Activity and Postpartum Depressive Symptoms

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Abstract

Background: Postpartum women are at increased risk for developing depression, which can contribute to the ill health of the mother and her family. Previous research indicates that mothers who are physically active during leisure experience lower levels of postpartum depressive symptoms than do inactive mothers. The objective of this investigation was to examine the associations between total and domain-specific moderate to vigorous physical activity (MVPA) and depressive symptoms postpartum.

Methods: Data were obtained from 550 women who participated in the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study, a prospective cohort of mothers who delivered liveborn infants from October 2002 to December 2005 in North Carolina. Three-month postpartum MVPA was investigated as a predictor of 12-month postpartum depressive symptoms.

Results: Those who participated in MVPA had two times the odds of developing elevated depressive symptoms at 12 months postpartum than those with no MVPA (odds ratio [OR] 2.00, 95% confidence interval [CI] 0.71-6.75). Different associations were suggested when examining domain-specific MVPA. Those participating in adult and child care and indoor household MVPA at 3 months postpartum had more than double the odds of developing elevated depressive symptoms at 12 months postpartum (OR 2.66, 95% CI 1.03, 8.11 and OR 2.72, 95% CI 0.96-10.18, respectively). Work MVPA conferred a doubling of the odds (OR 1.95, 95% CI 0.46-7.13), but recreational and outdoor household MVPA showed no associations with depressive symptoms.

Conclusions: Associations between MVPA and depressive symptoms differed by domain among postpartum women. Future studies of postpartum depressive symptoms should explore reasons for differences in physical activity by domain.

Introduction

Depression is a serious mental health condition, affecting more than 340 million people worldwide and serving as the leading cause of disability in high-income countries.[1,2] The risk of developing depression is increased for women during the childbearing years compared to earlier periods.[3] There is evidence that postpartum women are more likely to be depressed or report more symptoms than nonpostpartum women.[4–6] More than 50% of postpartum women report elevated depressive symptoms at some point in the first 12 months after birth, and 6.5% of women are depressed at 12 months postpartum.[7]

Depressive symptoms typically include sad mood, loss of interest in activities, feelings of helplessness and hopelessness, decreased energy, decision-making difficulties, sleep problems, restlessness, irritability, changes in eating patterns, suicidal ideations or attempts, and persistent physical symptoms that do not respond to treatment.[8] Depression has serious consequences at any point in life, but when it occurs postpartum, the disease can negatively impact the mother's health and the well-being of her newborn infant and family.[9,10] Mothers with postpartum depression (PPD) tend to provide less adequate care to their child, exhibit negative parenting behaviors, and have poorer mother-infant bonding.[10–12] Children of depressed mothers have poorer sleep patterns and are more likely to experience behavioral and development problems.[9–12] Depressed mothers report poorer partner satisfaction, and if the mother has depression, there is a 40%–50% risk that the child's father will also develop depression.[10,13]

Several reports in the literature have examined the association between physical activity and depression or depressive

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symptoms in nonpregnant populations, most finding that physical activity is associated with better mental health.[14] Research investigating the association in postpartum women is more limited. Most previous studies of this population have been exercise intervention trials that have been limited by the small sample size and representativeness,[15–21] and observational studies have examined either walking or recreational physical activity only and have not focused on other types or domains of physical activity.[22–24] Overall, results indicate that physical activity promotes lower depressive symptoms. The objective of this investigation was to determine the association between total and domain-specific moderate to vigorous physical activity (MVPA) and depressive symptoms in a prospective cohort of postpartum women. Given previous research, we hypothesized recreational MVPA would be associated with lower levels of depressive symptoms. In contrast, we hypothesized that work, adult and child care, and household MVPA would be associated with increased odds of developing elevated depressive symptoms.

Materials and Methods

Participants

This investigation used data from the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study, a prospective cohort of postpartum women originally enrolled during pregnancy in the third phase of the PIN Study. Eligible women delivered live-born infants between October 2002 and December 2005 and lived in the study's catchment area. Of the 2006 expectant mothers recruited in the prenatal study, 1169 women were eligible, 938 were invited to participate, and 688 (73.3%) agreed to participate and had data for the 3-month home interview. Reasons for attrition included moving out of the area, requesting no further contact, not delivering at the University of North Carolina Hospitals, and loss of pregnancy.[25] More detailed information on the PIN Study methods and attrition from the prenatal to the postpartum study is available elsewhere.[25]

Procedures

Women eligible for the PIN Postpartum Study who agreed to be contacted after-delivery were phoned for recruitment purposes, and written consent was obtained from those who participated in the 3-month home interview. At the 3-month home interview, women were asked about infant health and feeding, tobacco and drug use, psychosocial measures, sociodemographics, occupation, and physical activity; anthropometrics were measured. Women were interviewed again at 12 months postpartum and asked questions similar to those in the 3-month interview. The Institutional Review Board of the University of North Carolina at Chapel Hill School of Medicine reviewed and approved the study protocols.

Physical activity assessment

Women were asked to recall physical activity performed during the past week at the 3-month home interview, using a structured instrument with documented validity and reliability.[26] Assessments included occupational (e.g., carrying objects at work), recreational (e.g., swimming, dancing), child and adult care (e.g., playing with children, pushing a stroller or wheelchair), and indoor and outdoor household activity (e.g., scrubbing floors, gardening). Frequency, duration, and intensity of each activity type were determined. For each type of activity, women were first asked if they participated in activity that caused at least some increase in breathing and heart rate. If so, women were asked to list all the domain-specific activities they performed. Subsequently, they were asked to report the number of sessions, average duration per session, and perceived intensity level of each activity type. Perceived intensity was assessed based on the Borg scale: fairly light, somewhat hard, and hard or very hard.[27] Self-reported activities that were somewhat hard corresponded to moderate activity, and hard or very hard activities corresponded to vigorous activity.[28]

Physical activity for this analysis was characterized in two ways: hours/week and metabolic equivalent (MET)-hours/week, based on perceived and absolute intensity, respectively. Hours/week was calculated by multiplying the number of times a participant reported an activity by the number of hours she reported, focusing only on activities reported as somewhat hard or hard or very hard. Hours/week of activity was then aggregated by intensity and domain. We also created an aggregate, nonelective MVPA variable that combined the MVPA of all nonrecreational activities (e.g., work, adult and child care, indoor household, outdoor household). MET-hours/week was calculated by multiplying the number of times the participant reported the activity by the number of hours it was reported and then multiplying by the compendium-established MET value for the activity.[29,30] The standards for adults aged 20–39 years were used: MET values of 4.8–7.1 were classified as moderate intensity, and values of 7.2+ were classified as vigorous activity.[28] Documentation of the MET values and categories assigned to activities in our study is available elsewhere.[31] The MET-hour values were summed across activity type to establish total physical activity in MET-hours/week. MVPA in MET-hours/week was calculated for any activity that required at least 4.8 METs. The exposures of interest for this analysis were total and all domain-specific MVPA of perceived intensity and total MVPA of absolute intensity at 3 months postpartum.

Depression assessment

The Edinburgh Postnatal Depression Scale (EPDS) was used to assess postpartum depressive symptoms.[32] The EPDS is a 10-item PPD screening questionnaire that assesses mood during the past week using 4-point response categories. A composite score was calculated by summing across items, some of which required reverse-coding. A threshold score of 12 has been shown to indicate depression of various severities and persons needing further assessment.[32] Therefore, a score of ≥ 13 was considered as having elevated depressive symptoms. Depressive symptoms at 12 months postpartum was the outcome variable, and symptoms at 3 months postpartum was included as a covariate.

Covariates

Factors found to be associated with both physical activity and depressive symptoms in previous research and factors adjusted for in previous analyses of the association between physical activity and depression were considered potential confounders.[22,24,33–45] This included sociodemographic measures, such as maternal age, race, marital status, years of ed-

ucation, employment status, and poverty status at the 3-month interview. A cutoff point of 185% below the poverty line was used, as it is the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) income guideline cutoff point.[46] Health indicators included parity at the 3-month interview, smoking since birth, and current body mass index (BMI) based on height and weight measured at the 3-month interview categorized using National Heart, Lung, and Blood Institute (NHLBI) guidelines.[47] Three-month interview responses for any breastfeeding practice, sleep quality, and partner support were also investigated as potential confounders. Partner support was assessed with a single item about the amount of emotional support the woman receives from the man acting as the child's father.

Data analysis

Analyses were performed using version 9.1 of SAS statistical software (SAS Institute Inc, Cary, NC) and STATA 11 (StataCorp, College Station, TX). Univariate analysis was conducted to describe sample characteristics of potential covariates and physical activity. A factor was considered a confounder if it was associated with both physical activity at the 3-month interview and depressive symptoms at the 12-month interview (using chi-square analysis) and changed the estimate of the association by $\geq 10\%$ in the modeling stage using backwards deletion.[48] Fisher's exact test p values were reported for chi-square analysis when available. It was determined *a priori* that depressive symptoms at 3 months postpartum would be included as a covariate in all models, as previous history of depression is a major risk factor for PPD[11] and is expected to be associated with previous activity.[49] Confounding assessment was done separately for each physical activity domain.

Exact logistic regression modeling with the Monte Carlo option was used to calculate odds ratios (ORs) and 95% confidence intervals (CIs). Regression models were calculated using 528 women who had complete data for exposures, outcome, and covariates (22 of the 550 women participating at 12 months postpartum were missing covariate data). MVPA, total and domain-specific, was dichotomously coded (none, any) for analysis. Heckman modeling[50,51] was used to determine if there was selection bias in our final model sample compared to the women eligible for the PIN Postpartum Study. After considering pregnancy sociodemographics and depressive symptoms as potential selection factors, marital status and depressive symptoms at 24–29 weeks' gestation were determined to be selection factors, measures that predict selection into the final sample. As some women were missing data on depressive symptoms during pregnancy, the Heckman modeling used 470 uncensored observations. Because of lack of precision of the MET-hours/week analysis, domain-specific MVPA in absolute intensity is not reported.

Results

Sample characteristics

Of the 550 mothers participating in the PIN Postpartum Study at 12 months postpartum, only 35 (6%) reported having elevated depressive symptoms. EPDS scores ranged from 0 to 23, and the median score was 4. Among these women, the majority (79%) were white, 13% were black, and 9% were of another race. Almost two thirds (63%) of the participants were at least 30 years of age, 13% were <25 years of age; the majority of the women were college educated (63% attended college) and married (85%). A low proportion of women (24%) had incomes that met the WIC eligibility criteria. Nearly half the women participating had just given birth to their first child (48%), and the majority were breastfeeding at 3 months postpartum (68%). Differences in these variables and the other potential confounders by depressive symptoms status are shown in Table 1. Those with high depressive symptoms were more likely to be younger, black or other race, unmarried, less educated, of lower income, and smokers. These women were also more likely to have fair or poor sleep quality, have less partner support, and not breastfeed at 3 months postpartum.

Almost one third (32%) of the mothers did not participate in any MVPA at 3 months postpartum. The median of total MVPA in hours/week was 1.3 (with an interquartile range [IQR] of 0–4.25). There were few differences in physical activity levels by depressive symptoms. The median for total MVPA for women with low depressive symptoms was 1.3 (0–4) hours/week; for those with elevated depressive symptoms, the median was 1.6 (0–7.3). The median value for all domain-specific values of MVPA was 0 for both groups. Women with elevated depressive symptoms spent a lower proportion of their total MVPA in the recreational domain (36% vs. 54%, $p=0.04$) and a somewhat greater proportion in the adult and child care domain (31% vs. 19%, $p=0.09$) than women with low levels of depressive symptoms. The mean proportion of total MVPA hours spent in each domain by depressive symptoms status is shown in Figure 1. Results of chi-square analysis of dichotomous MVPA by depressive symptoms status are presented in Table 2.

Physical activity associations with depressive symptoms

Results from crude and adjusted regression models of the associations between MVPA, measured in hours/week, at 3 months postpartum and depressive symptoms at 12 months postpartum are presented in Table 3. In general, similar associations were found with the crude and adjusted models. There was a tendency toward increased odds of having elevated depressive symptoms with participation in work, adult and child care, and indoor household MVPA. Women participating in work MVPA had two times the odds of having elevated depressive symptoms. For care and indoor household MVPA, the adjusted ORs (95% CIs) were 2.66 (1.03-8.11) and 2.72 (0.96-10.18), respectively. There was no relationship between either recreational or outdoor household MVPA with depressive symptoms at 12 months postpartum. Although the adjusted model for total MVPA suggested a stronger association than the crude model, both failed to reach statistical significance. We also examined the role of aggregate, nonelective MVPA (all nonrecreational activities) in hours/week and found that women with any participation at 3 months postpartum had more than two times the odds of having elevated depressive symptoms at 12 months postpartum (OR 2.61, 95% CI 1.12-6.11). When examining the association between total MVPA in absolute intensity (MET-hours/week) and depressive symptoms, null results were found when adjusted for depressive symptoms at 3 months postpartum, maternal age, and partner social support (OR 1.01, 95% CI 0.38-2.65).

Table 1. Characteristics of Women Enrolled in Postpartum Phase of Pregnancy, Infection, and Nutrition Study with Data from 12-Month Home Interview by Depressive Symptoms Status (N=550)

		EPDS[a]		
	Total n *(%)*	*< 13* (n=*515*) n *(%)*	*≥ 13* (n=*35*) n *(%)*	*Chi-square* (p *value*)
Age at 3-month interview (years)				28.91 (<0.0001)
≤ 24	72 (13)	58 (11)	14 (40)	
25–29	132 (24)	121 (24)	11 (31)	
30–34	195 (35)	188 (37)	7 (20)	
35+	151 (27)	148 (29)	3 (9)	
Race				17.20 (0.0002)
White	433 (79)	415 (81)	18 (51)	
Black	69 (13)	58 (11)	11 (31)	
Other	48 (9)	42 (8)	6 (17)	
Marital status at 3-month interview[b]				22.49 (<0.0001)
Married	467 (85)	447 (87)	20 (57)	
Unmarried	83 (15)	68 (13)	15 (43)	
Education at 3-month interview (years)				24.94 (<0.0001)
≤12	202 (37)	197 (38)	5 (14)	
13–16	266 (48)	251 (49)	15 (43)	
17+	82 (15)	67 (13)	15 (43)	
Working at 3-month interview[b]				0.002 (1.0000)
Yes	265 (48)	248 (48)	17 (49)	
No	285 (52)	267 (52)	18 (51)	
Income at 3-month interview (% of poverty line)[b,c]				11.10 (0.0025)
≤185	133 (24)	117 (23)	16 (52)	
>185	413 (76)	396 (77)	17 (48)	
Parity at 3-month interview				0.62 (0.7325)
1	265 (48)	248 (48)	17 (49)	
2	198 (36)	184 (36)	14 (40)	
3+	87 (16)	83 (16)	4 (11)	
Body mass index at 3-month interview (kg/m^2)[d]				5.68 (0.1280)
<18.5	3 (1)	3 (1)	0 (0)	
18.5–24.9	267 (49)	253 (49)	14 (40)	
25–29.9	149 (27)	142 (28)	7 (20)	
30+	130 (24)	116 (23)	14 (40)	
Breastfeeding at 3-month interview				9.21 (0.0100)
Still breastfeeding	372 (68)	356 (69)	16 (46)	
Stopped breastfeeding	137 (25)	121 (24)	16 (46)	
Never breastfed	41 (7)	38 (7)	3 (9)	
Smoking at 3-month interview[b]				18.48 (0.0003)
Yes	48 (9)	38 (7)	10 (29)	
No	502 (91)	477 (93)	25 (71)	
Sleep quality at 3-month interview[b]				21.22 (<0.0001)
Fair/Poor	235 (43)	207 (40)	28 (80)	
Good/Excellent	315 (57)	308 (60)	7 (20)	
Partner support at 3-month interview[e]				18.65 (<0.0001)
A lot	373 (70)	361 (72)	12 (38)	
Some	130 (24)	115 (23)	15 (47)	
Not much/None	29 (5)	24 (5)	5 (16)	
Depressive symptoms at 3-month interview[b]				111.75 (<0.0001)
EPDS <13	515 (94)	497 (97)	18 (51)	
EPDS ≥13	35 (6)	18 (4)	17 (49)	

[a]Score on Edinburgh Postnatal Depression Scale (EPDS) < 13 vs. ≥ 13.
[b]Fisher's exact test p value reported.
[c]Missing data on 4 women.
[d]Missing data on 1 woman.
[e]Missing data on 18 women.

The domain-specific MVPA final adjusted models in Table 3 were recalculated, adjusting additionally for MVPA in all the other domains. For example, the model for work MVPA was adjusted for a variable that subtracted the work MVPA from the total MVPA. The conclusions did not change after adjusting for other physical activity domains.

Assessment of selection bias

Heckman regression models are shown in Table 3. Once potential selection bias was taken into account, most of the estimates regressed to the null. The estimates for recreational MVPA and outdoor household MVPA became slightly

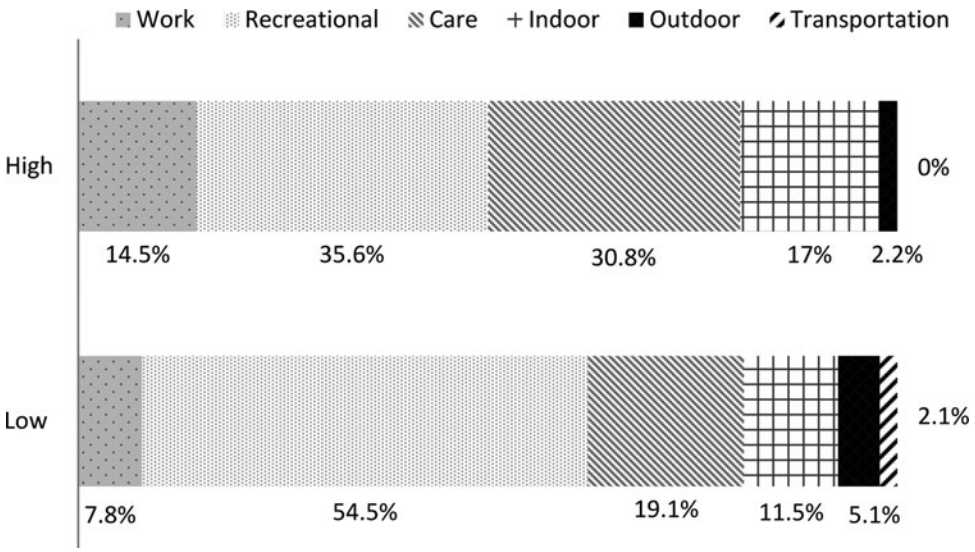

FIG. 1. The mean proportions of total moderate to vigorous physical activity in hours/week at 3 months postpartum spent in each domain by 12-month Edinburgh Postnatal Depression Scale (EPDS) symptoms status (low, EPDS < 13; high, ≥ 13) among women enrolled in the postpartum phase of the Pregnancy, Infection, and Nutrition Study ($n = 550$).

stronger, but the rest became weaker. The estimates for adult and child care MVPA and indoor household MVPA changed most as a result of considering the selection factors of marital status and depressive symptoms at 24–29 weeks' gestation; both OR estimates were nearly halved. The estimate for work MVPA was slightly weaker and became significant (OR 1.73, 95% CI 1.01-2.97).

Discussion

In this prospective study of mothers followed through 12 months postpartum, we found that the association between MVPA and postpartum depressive symptoms varied according to the domain/type of physical activity. There was some evidence of increased odds of having elevated depressive symptoms as a result of participation in any MVPA. Women who participated in adult and child care, indoor household, and work MVPA at 3 months postpartum were more likely to have elevated depressive symptoms at 12 months postpartum. There was no association between recreational and outdoor household MVPA and depressive symptoms.

Our results differ from previously published research in that recreational MVPA, or any other domain of MVPA, was

Table 2. Frequencies and Chi-Square Statistics (with Fisher's Exact *p* Values) of 3-Month Postpartum Moderate to Vigorous Physical Activity by 12-Month Postpartum Depressive Symptoms Status Among Women Enrolled in Postpartum Phase of Pregnancy, Infection, and Nutrition Study ($N = 550$)

		EPDS[a]		
	Total n *(%)*	*< 13* (n = *609)* n *(%)*	*≥ 13* (n = *43)* n *(%)*	*Chi-square* (p *value)*
Total MVPA				0.65 (0.7122)
None	176 (32)	166 (32)	10 (29)	
Any	374 (68)	349 (68)	25 (71)	
Work MVPA				3.54 (0.0809)
None	492 (89)	464 (90)	28 (80)	
Any	58 (11)	51 (10)	7 (20)	
Recreational MVPA				0.08 (0.8619)
None	286 (52)	267 (52)	19 (54)	
Any	264 (48)	248 (48)	16 (46)	
Adult and child care MVPA				4.17 (0.0466)
None	410 (75)	389 (76)	21 (60)	
Any	140 (25)	126 (24)	14 (40)	
Indoor household MVPA				8.34 (0.0069)
None	447 (81)	425 (83)	22 (63)	
Any	103 (19)	90 (17)	13 (37)	
Outdoor household MVPA				0.04 (1.0000)
None	514 (93)	481 (93)	33 (94)	
Any	36 (7)	34 (7)	2 (6)	

[a]Score on EPDS < 13 vs. ≥ 13.
MVPA, moderate to vigorous physical activity; EPDS, Edinburgh Postnatal Depression Scale.

Table 3. Odds Ratios and 95% Confidence Intervals from Exact Logistic Regression and Heckman Analysis of Association Between Total and Domain-Specific Physical Activity (Hours/Week) at 3 Months Postpartum and Depressive Symptoms at 12 Months Postpartum Among Women Enrolled in Pregnancy, Infection, and Nutrition Postpartum Study ($N=528$)

		Crude model		*Final adjusted model*		*Heckman selection model*[a]	
	n	*OR*	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*
Total MVPA (hours/week)[b]							
None	168	1.00	–	1.00	–	1.00	–
Any	360	1.15	0.50-2.89	2.00	0.71-6.75	1.39	0.86-2.28
Work MVPA (hours/week)[c]							
None	476	1.00	–	1.00	–	1.00	–
Any	52	1.87	0.52-5.47	1.95	0.46-7.13	1.73	1.01-2.97
Recreational MVPA (hours/week)[d]							
None	272	1.00	–	1.00	–	1.00	–
Any	256	0.76	0.33-1.67	1.19	0.44-3.14	1.39	0.89-2.17
Adult and child care MVPA (hours/week)[e]							
None	392	1.00	–	1.00	–	1.00	–
Any	136	2.18	0.94-5.64	2.66	1.03-8.11	1.42	0.91-2.22
Indoor household MVPA (hours/week)[f]							
None	430	1.00	–	1.00	–	1.00	–
Any	98	2.18	0.89-5.77	2.72	0.96-10.18	1.36	0.86-8.04
Outdoor household MVPA (hours/week)[g]							
None	494	1.00	–	1.00	–	1.00	–
Any	34	1.01	0.11-4.57	0.91	0.08-4.66	0.89	0.32-2.45

[a]Heckman selection model includes data on 470 total observations due to missing data on pregnancy depressive symptoms.
[b]Adjusted for depressive symptoms at 3 months postpartum, smoking, age, partner support.
[c]Adjusted for depressive symptoms at 3 months postpartum, marital status, sleep quality.
[d]Adjusted for depressive symptoms at 3 months postpartum, age, partner support, sleep quality.
[e]Adjusted for depressive symptoms at 3 months postpartum, sleep quality.
[f]Adjusted for depressive symptoms at 3 months postpartum, sleep quality.
[g]Adjusted for depressive symptoms at 3 months postpartum, smoking.
CI, confidence interval; OR, odds ratio.

not associated with a decrease in the odds of depressive symptoms. Nine of the ten previous studies of physical activity and depressive symptoms in postpartum women found that physical activity participation improves depressive symptoms.[15–18,20–24] Seven of these ten studies were intervention trials.[15–21] Though most of the studies examined the effects of physical activity on depression over time, one study examined the acute impact of physical activity on depressive symptoms.[18] Interventions were varied, including walking with a stroller, regular supervised exercise sessions, and home-based exercise training and support. Both intervention and observational studies focused on walking or recreational activity and did not address differences by physical activity domain. Two of the nonintervention studies were cohorts of pregnant women who were followed into postpartum. Herring et al.[23] found that women with PPD walked significantly less than women without antenatal depression or PPD. Haas et al.[24] found that women who were inactive postdelivery were 1.62 times more likely to have elevated depressive symptoms in comparison to women participating in >2 hours/week of activity. Craike et al.[22] found a significant inverse association between leisure time MVPA and depressive symptoms in a prospective cohort of Australian women with infants aged 3–19 months. Daley et al.[19] reported the only study to find no effect of an exercise trial on depressive symptoms, but the authors state that the study was not powered to determine such an effect.

Few studies have addressed the association between physical activity domain and depression. We found no studies using postpartum women that have done so, but there has been some research among nonpregnant women. McKercher et al.[52] compared the association between physical activity and depression among young men and women and found that leisure activity was associated with decreased prevalence of major depression, and work activity was associated with increased prevalence among women. No associations were found among men. Teychenne et al.[53] investigated how the association between physical activity and depressive symptoms differed by domain among 1501 Australian women. They found that women participating in >3.5 hours of leisure time physical activity per week had lower odds of depressive symptoms but no significant association in any other domain (work, transportation, or domestic). These studies demonstrate that domain can influence physical activity-depression associations.

To date, there has been little explanation as to why the association between physical activity and depression may differ by domain. It has been suggested that it may be due to adverse, unfavorable, or unhealthy conditions in which the activity typically is performed.[54] For example, those with high levels of work activity may be conducting a great deal of strenuous activity over long hours on the job, and those performing household activities may be performing repetitive tasks.[54,55] The benefits of physical activity may be countered

by these adverse conditions. Another possible explanation is that different types of activity may serve as stressors or burdens that may contribute to the development of depressive symptoms. We suspect that performing involuntary physical activity (i.e., to perform housework or as part of a job) may be stressful, therefore contributing toward elevated depressive symptoms rather than alleviating them. Individuals who perform these involuntary activities may also have different profiles than those who do not. For example, women active in transport may not be able to afford a vehicle, and those taking care of adults may have other financial burdens.[55] These women may have different life circumstances, personal characteristics, and stressors that may cause depressive symptoms than those who do not perform these activities.

There is evidence that specific activity domains may be stressful or burdensome, which may explain why we saw such large increases in odds of depressive symptoms related to adult and child care and indoor household MVPA and overall nonelective MVPA. Performing housework and being a housewife have both been identified as risk factors for depression[56,57]; performing housework has been found to be associated with increased perceived stress.[58] A study of postpartum women found that women who took care of handicapped or ill relatives were four times more likely to have major depressive symptoms.[59] A study of Swedish adults found that although the number of hours spent doing domestic work was not associated with anxiety or depression, participation in burdensome domestic work was associated with significantly increased odds of anxiety/depression.[60] Our study's findings of increased odds of having elevated depressive symptoms with indoor household, adult and child care, and nonelective MVPA is supported by these other studies.

We also considered that change in MVPA could be associated with depressive symptoms. Mothers with elevated depressive symptoms at 12 months postpartum had higher MVPA levels at 3 months postpartum. It is possible that women with elevated depressive symptoms are more likely to experience declines in MVPA over the postpartum period, whereas mothers with low depressive symptoms experience stable or increasing MVPA levels. A decline in MVPA may be associated with an increase in depressive symptoms. Unfortunately, we do not present these estimates because of poor precision.

Limitations and strengths

The results of this study must be considered within the context of its limitations. First, a diagnosis of depression can only be make through clinical assessment. The EPDS is a self-report scale that assesses depressed mood and symptoms. However, performing clinical assessments on participants in population studies is costly and timely; therefore, depression screening tools frequently are used. The EPDS has been found to have satisfactory sensitivity and specificity and positive predictive value.[7,32] The EPDS was designed with the purpose of identifying women who are depressed after childbirth and is a widely used screening tool for PPD.[7,32,61]

Physical activity measurement also relied on a self-report tool, which can create recall issues. However, as the assessment asked about the past week, problems with recall may be limited. The questionnaire asked women to consider the frequency, duration, and intensity of all forms of physical activity by domain, which may contribute to better recall. Self-report methods are frequently used to assess physical activity and have been determined to be an acceptable method to assess physical activity with a number of advantages.[62] The physical activity questionnaire showed evidence of concurrent validity when compared to a structured diary and accelerometry and test-retest reliability.[26] Another concern is that physical activity was assessed only during the past week; physical activity behavior can change from week to week, and the reported values may not be representative of usual behavior. This may be an important consideration for the early postpartum when women are likely developing new daily routines.

Precision was of concern in this study. The reporting of elevated depressive symptoms at 12 months postpartum was low in this sample (6%). Many women also reported no total or domain-specific MVPA, and the variation in levels of MVPA was low. This resulted in wide confidence intervals for the regression analysis.

There may be a concern of selection bias in our sample. The 688 women participating in the PIN Postpartum Study differed from the 480 eligible, nonparticipating women by being older, more educated, more affluent, more likely to be married, more likely to be white, of lower BMI at 3 months postpartum, and having lower depressive symptoms during pregnancy. There were no differences between participating women and those who were invited to participate in the study but declined. The rho for selection bias (the correlation between the error terms of the selection model and the final adjusted model) of the Heckman model was significant only for work MVPA; the estimates, once taking into account marital status and pregnancy depressive symptoms, changed by up to 63%. Therefore, we presented both the exact logistic regression and Heckman logistic regression estimates. Most conclusions made did not differ by model used, but there was large attenuation of the estimates of adult and child care and indoor household MVPA. Generalizability of the results may be an issue. Analysis using data from previous PIN cohorts also found that less educated, younger, African American, and parous women and women with higher pregnancy risk profiles were more likely to be underrepresented in the study.[63,64]

Despite these limitations, there are several strengths of this study. The prospective cohort design of the PIN Postpartum Study provided us with the opportunity to examine the association with physical activity early in the postpartum period with later depressive symptoms. There was a 9-month gap between assessments. This is beneficial for an investigation of depression, as it is a chronic condition and length of exposure might need to be considerable to have an impact. Data collection was extensive; a variety of factors related to the health of new mothers was assessed. This enabled us to control for a number of potential confounders. However, there is still the possibility of residual confounding. Although we examined many factors to determine if they confounded the association between physical activity and depressive symptoms, there are known (i.e., life events) and unknown factors that were not examined. Another strength is that both physical activity and depressive symptoms were assessed using reliable and valid assessment tools.[7,26,32] The physical activity assessment was comprehensive, collecting data on duration, frequency,

intensity, and domain. Previous studies of the association between physical activity and depressive symptoms among postpartum women have investigated only walking or recreational activity.

Conclusions

Previous work has indicated that recreational physical activity may be a useful tool for preventing and controlling depression during the postpartum, but our study does not support those findings. Our study found no benefit on the odds of depressive symptoms from recreational MVPA and found that active postpartum women may actually have increased odds of being at risk for depression, especially those who participate in adult and child care and indoor household MVPA. Multiple studies are needed assessing depressive symptoms at a given time point because previous studies vary with their assessments and etiology may differ during different periods. Future studies examining associations between postpartum physical activity and depressive symptoms should explore differences by physical activity domain. There is also a need for investigations of models and mechanisms that could explain why the physical activity-depression association may differ by domain.

Acknowledgments

The Pregnancy, Infection, and Nutrition Postpartum Study was supported by National Institutes of Health grants from the National Institute of Child Health and Human Development (HD37584, HD39373), the National Institute of Diabetes and Digestive and Kidney Diseases (DK61981, DK56350), the National Cancer Institute (RO1CA109804), and the General Clinical Research Center (RR00046). The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH. We thank Drs. David Savitz and John Thorp, Principal Investigators of the PIN3 Study, for their support of this analysis, and Chyrise Bradley, Kathryn Carrier, Diane Kaczor, and Fang Wen for their assistance.

Disclosure Statement

No competing financial interests exist.

References

1. Greden JF. The burden of recurrent depression: Causes, consequences and future prospects. J Clin Psychiatry 2001;62:5–9.
2. Lopez AD, Mathers CD. Measuring the global burden of disease and epidemiological transitions: 2002–2030. Ann Trop Med Parasitol 2006;100:481–499.
3. Burke KC, Burke JD, Rae DS, Regier DA. Comparing age at onset of major depression and other psychiatric disorders by birth cohorts in five U.S. community populations. Arch Gen Psychiatry 1991;48:789–795.
4. Vesga-Lopez O, Blanco C, Keyes K, Olfson M, Grant BF, Hasin DS. Psychiatric disorders in pregnant and postpartum women in the United States. Arch Gen Psychiatry 2008;65:805–815.
5. Eberhard-Gran M, Tambs K, Opjordsmoen S, Skrondal A, Eskild A. A comparison of anxiety and depressive symptomatology in postpartum and non-postpartum mothers. Soc Psychiatry Psychiatr Epidemiol 2003;38:551–556.
6. O'Hara MW, Zekoski EM, Phillips LH, Wright EJ. Controlled prospective study of postpartum mood disorders: Comparison of childbearing and nonchildbearing women. J Abnorm Psychol 1990;99:3–15.
7. Gaynes BN, Gavin N, Meltzer-Brody S, et al. Perinatal depression: Prevalence, screening accuracy, and screening outcomes. Evidence Report/Technology Assessment No. 119. (Prepared by the RTI-University of North Carolina Evidence-based Practice Center, under contract No. 290-02-0016.) AHRQ Publication No. 05-E006-2 Rockville, MD: Agency for Healthcare Research and Quality, 2005.
8. U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Mental Health. Depression. NIH Publication No. 07-3561. 2007. Available at www.nimh.nih.gov/health/publications/depression/nimhdepression.pdf Accessed February 20, 2010.
9. Lusskin SI, Pundiak TM, Habib SM. Perinatal depression: Hiding in plain sight. Can J Psychiatry 2007;52:479–88.
10. Lee DTS, Chung TKH. Postnatal depression: An update. Best Pract Res Clin Obstet Gynaecol 2007;21:183–191.
11. Marcus SM. Depression during pregnancy: Rates, risks, and consequences. Can J Clin Pharamacol 2009;16:e15–e22.
12. Logsdon MC, Wisner KL, Pinto-Foltz MD. The impact of postpartum depression on mothering. JOGN Nurs 2006;35:652–658.
13. Appolonio KK, Fingerhut R. Postpartum depression in a military sample. Mil Med 2008;173:1085–1091.
14. Teychenne M, Ball K, Salmon J. Physical activity and likelihood of depression in adults: A review. Prev Med 2008;46:397–411.
15. Heh S-S, Huang L-H, Ho S-M, Fu Y-Y, Wang L-L. Effectiveness of an exercise support program in reducing the severity of postnatal depression in Taiwanese women. Birth 2008;35:60–64.
16. Armstrong K, Edwards H. The effectiveness of a pram-walking exercise programme in reducing depressive symptomatology for postnatal women. Int J Nurs Pract 2004;10:177–194.
17. Armstrong K, Edwards H. The effects of exercise and social support on mothers reporting depressive symptoms: A pilot randomized controlled trial. Int J Ment Health Nurs 2003;12:130–138.
18. Koltyn KE, Schultes SS. Psychological effects of an aerobic exercise session and a rest session following pregnancy. J Sports Med Phys Fitness 1997;37:287–291.
19. Daley AJ, Winter H, Grimmett C, McGuinness M, McManus R, MacArthur C. Feasibility of an exercise intervention for women with postnatal depression: A pilot randomised controlled trial. Br J Gen Pract 2008;58:178–183.
20. May A. Using exercise to tackle postnatal depression. Health Visit 1995;68:146–147.
21. Da Costa D, Lowensteyn I, Abrahamowicz M, et al. A randomized clinical trial of exercise to alleviate postpartum depressed mood. J Psychosom Obstet Gynaecol 2009;30:191–200.
22. Craike MJ, Coleman D, MacMahon C. Direct and buffering effects of physical activity on stress-related depression in mothers of infants. J Sport Exerc Psychol 2010;32:23–38.
23. Herring SJ, Rich-Edwards JW, Oken E, Rifas-Shiman SL, Kleinman KP, Gillman MW. Association of postpartum depression with weight retention 1 year after childbirth. Obesity 2008;16:1296–1301.

24. Haas JS, Jackson RA, Fuentes-Afflick E, et al. Changes in health status of women during and after pregnancy. J Gen Intern Med 2004;20:45–51.
25. Siega-Riz AM, Herring AH, Carrier K, Evenson KR, Dole N, Deierlein A. Sociodemographic, perinatal, behavioral, and psychosocial predictors of weight retention at 3 and 12 months postpartum. Obesity 2009;18:1996–2003.
26. Evenson KR, Wen F. Measuring physical activity in pregnant women: Validity and reliability of a structured one-week recall questionnaire. Int J Behav Nutr Phys Act 2010;7:21.
27. Borg G, Linderholm H. Perceived exertion and pulse rate during graded exercise in various age groups. Acta Med Scand 1974;472:194–206.
28. Pollock M, Gaesser G, Butcher J, et al. American College of Sports Medicine position stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc 1998;30:975–991.
29. Ainsworth BE, Haskell WL, Leon AS, et al. Compendium of physical activities: Classification of energy costs of human physical activities. Med Sci Sports Exerc 1993;25:71–80.
30. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: An update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(Suppl 9): S498–516.
31. Pregnancy, Infection, and Nutrition Study. PIN3 physical activity, 2007. Available at www.cpc.unc.edu/projects/pin/design_pin3/docs_3/PIN-MET-Table-080207.pdf Accessed August 20, 2009.
32. Cox JL, Holden JM, Sagovsky R. Detection of postnatal depression: Development of the Edinburgh Postnatal Depression Scale. Br J Psychiatry 1987;150:782–786.
33. Abraham S, Taylor A, Conti J. Postnatal depression, eating, exercise, and vomiting before and during pregnancy. Int J Eat Disord 2001;29:482–487.
34. Brown WJ, Burton NW, Heesch KC. Physical activity and health in mid age and older women. Canberra, Australia: The Office for Women, Department of Families, Community Services, and Indigenous Affairs, 2007.
35. Baker L, Ostwalt K. Screening for postpartum depression in a rural community. Community Ment Health J 2008;44:171–180.
36. Bowen A, Muhajarine N. Antenatal depression. Can Nurse 2006;102:27–30.
37. Belza B, Warms C. Physical activity and exercise in women's health. Nurs Clin North Am 2004;39:181–193.
38. de Castro Toledo Guimares LH, de Carvalho LB, Yanaguibashi G, do Prado GF. Physically active elderly women sleep more and better than sedentary women. Sleep Med 2008;9: 488–493.
39. Dorheim SK, Bondevik GT, Eberhard-Gran M, Bjorvatn B. Sleep and depression in postpartum women: A population-based study. Sleep 2009;32:847–855.
40. Goodwin RD. Association between physical activity and mental disorders among adults in the United States. Prev Med 2003;36:698–703.
41. Ning Y, Williams MA, Dempsey JC, Sorenson TK, Frederick IO, Luthy DA. Correlates of recreational physical activity in early pregnancy. J Matern Fetal Med 2003;13:385–393.
42. Pippins JR, Brawarsky P, Jackson RA, Fuentes-Afflick E, Haas J. Association of breastfeeding with maternal depressive symptoms. J Womens Health 2006;15:754–762.
43. Ryan D, Milis L, Misri N. Depression during pregnancy. Can Fam Physician 2005;51:1087–1093.
44. Sanchez-Villegas A, Ara I, Guillén-Grima F, Bes-Rastrollo M, Varo-Cenarruzabeitia JJ, Martínez-Gonzáles MA. Physical activity, sedentary index, and mental disorders in the SUN Cohort Study. Med Sci Sports Exerc 2008;40:827–834.
45. Wise LA, Adams-Campbell LL, Palmer JR, Rosenberg L. Leisure time physical activity in relation to depressive symptoms in the Black Women's Health Study. Ann Behav Med 2006;32:68–76.
46. U.S. Department of Agriculture. Food and Nutrition Service. Special supplemental nutrition program for Women, Infants and Children (WIC): Income eligibility guidelines. Fed Regist 2009;74:9780–9782.
47. U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. The evidence report. NIH Publication No. 98-4083. September 1998. Available at www.nhlbi.nih.gov/guidelines/obesity/ob_gdlns.pdf Accessed February 20, 2010.
48. Rothman KJ, Greenland S. Modern epidemiology, 2nd ed. Baltimore: Lippincott-Raven, 1998:256–257.
49. Roshanaei-Moghaddam B, Katon WJ, Russo J. The longitudinal effects of depression on physical activity. Gen Hosp Psychiatry 2009;31:306–315.
50. Heckman JJ. Dummy endogenous variables in a simultaneous equation system. Econometrica 1978;46:931–959.
51. Heckman JJ. Sample selection bias as a specification error. Econometrica 1979;47:153–161.
52. McKercher CM, Schmidt MD, Sanderson KA, Patton GC, Dwyer T, Venn AJ. Physical activity and depression in young adults. Am J Prev Med 2009;36:161–164.
53. Teychenne M, Ball K, Salmon J. Associations between physical activity and depressive symptoms in women. Int J Behav Nutr Phys Act 2008;5:27–38.
54. Abu-Omar K, Rütten A. Relation of leisure time, occupational, domestic, and commuting physical activity to health indicators in Europe. Prev Med 2008;47:319–323.
55. Jurakić D, Pedišić Z, Greblo Z. Physical activity in different domains and health-related quality of life: A population-based study. Qual Life Res 2010;19:1303–1309.
56. Glass J, Fujimoto T. Housework, paid work, and depression among husbands and wives. J Health Soc Behav 1994;35: 179–191.
57. Marchesi C, Bertoni S, Maggini C. Major and minor depression in pregnancy. Obstet Gynecol 2009;113:1292–1298.
58. Asztalos M, Wijndaele K, De Bourdeaudhuij I, et al. Specific associations between types of physical activity and components of mental health. J Sci Med Sport 2009;12:468–474.
59. Garcia-Esteve L, Navarro P, Ascaso C, et al. Family caregiver role and premenstrual syndrome as associated factors for postnatal depression. Arch Womens Ment Health 2008;11: 193–200.
60. Molarius A, Berglund K, Eriksson C, et al. Mental health symptoms in relation to socioeconomic conditions and lifestyle factors—A population-based study in Sweden. BMC Public Health 2009;20:302.
61. Pogany A, Peteresen M. What are the best screening instruments for PPD? JAAPA 2007;20:34–38.
62. Dale D, Welk GJ, Matthews CE. Methods for assessing physical activity and challenges for research. In: Welk GJ, ed.

Physical activity assessments for health-related research. Champaign, IL: Human Kinetics Publishers, 2002.
63. Savitz DA, Dole N, Kaczor D, et al. Probability samples of area births versus clinic populations for reproductive epidemiology studies. Paediatr Perinat Epidemiol 2005;19: 315–322.
64. Savitz D, Dole N, Williams J, et al. Determinants of participation in an epidemiologic study of preterm delivery. Paediatr Perinat Epidemiol 1999;13:114–125.

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