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The association between physical activity and maternal sleep during the postpartum period

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Abstract

Background—Physical activity is associated with improved sleep quality and duration in the general population, but its effect on sleep in postpartum women is unknown.

Methods—We examined cross-sectional and longitudinal associations between hours/week of self-reported domain-specific and overall moderate to vigorous physical activity (MVPA) and sleep quality and duration at 3- and 12-months postpartum among a cohort of 530 women in the Pregnancy, Infection, and Nutrition Postpartum Study.

Results—MVPA was not associated with sleep quality or duration at 3-months postpartum. At 12-months postpartum, a one hour/week increase in recreational MVPA was associated with higher odds of good (vs. poor) sleep quality (odds ratio, OR=1.14; 95% confidence interval, CI, 1.03–1.27) and a one hour/week increase in child/adult care MVPA was associated with lower odds of good (vs. poor) sleep quality (OR=0.93; 95% CI=0.88–0.99). A one hour/week increase in child/adult care MVPA (OR=1.08, 95% CI=1.00–1.16) was associated with higher odds of long sleep duration and one hour/week increases in indoor household (OR=1.09, 95% CI=1.01–1.18) and overall MVPA (OR=1.04, 95% CI=1.01–1.07) were associated with higher odds of short (vs. normal) sleep duration. Comparing 3-months postpartum to 12-months postpartum, increased work MVPA was associated with good sleep quality (OR=2.40, 95% CI=1.12–5.15) and increased indoor household MVPA was associated with short sleep duration (OR=1.85, 95% CI=1.05–3.27) as measured at 12-months postpartum.

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Conclusions—Selected domains of MVPA and their longitudinal increases were associated with sleep quality and duration at 12-months postpartum. Additional research is needed to elucidate whether physical activity can improve postpartum sleep.

Keywords

postpartum; pregnancy; cohort; longitudinal; leisure activity

INTRODUCTION

Sleep disruption and deprivation occur frequently among postpartum women. In 2007, approximately 42% of postpartum women in the United States reported rarely or never having a good night's sleep and 84% reported experiencing sleep problems at least a few nights per week up to 6 months following delivery [1]. The National Sleep Foundation recommends that adults obtain 7 to 9 hours of sleep per day [2]. However, postpartum women report, on average, as little as 4 hours of total daily sleep [3]. Newborn sleep and feeding patterns are the most frequently reported causes of postpartum sleep disturbances [3,4], with less sleep and more day-to-day variability reported during the first weeks after delivery [5–7]. Poor sleep is associated with substantial weight retention [8], fatigue [9], impaired psychomotor performance [10], and an increased risk of depression or other perinatal mood disorders [11, 12] during the postpartum period (up to one year following delivery).

Despite the high frequency of sleep problems and their adverse health effects among postpartum women, very few evidence-based strategies have been recommended to improve maternal sleep following pregnancy. Previous studies have suggested that modifying newborn feeding and sleep methods [11, 12] or educating women about postpartum sleep and how to adapt to and manage sleep disruptions [13, 14] are useful methods for improving sleep. In the general population, sleep medications are used to treat insomnia and lengthen sleep duration, but they may not be recommended for postpartum women who are breastfeeding [15] and may limit the mother's ability to respond to infant needs [16]. Therefore, other strategies are needed to promote maternal sleep. One potential strategy is regular participation in physical activity. Physical activity has been found to improve sleep quality and duration among adults in the general population [17, 18], but its effect on sleep among postpartum women is unknown.

To overcome this gap in the literature and to inform the development of recommendations for improving sleep following pregnancy, our objective was to examine the association between overall and domain-specific moderate to vigorous physical activity (MVPA) and sleep quality and duration at 3- and 12-months postpartum among a cohort of North Carolina women enrolled in the Pregnancy, Infection, and Nutrition (PIN) Postpartum Study. We also sought to examine the association between the change in MVPA (from 3 to 12 months) and sleep quality and duration at 12-months postpartum.

METHODS

Study Population

The third phase of the PIN Study (PIN3) recruited pregnant women at less than 20 weeks' gestation seeking prenatal care at clinics associated with the University of North Carolina Hospitals. Trained staff identified women through review of medical charts of new prenatal patients. Women were excluded if they were non-English speaking, under the age of 16 years, carrying multiple gestations, not planning to continue care or deliver at the study hospital, or did not have a telephone from which they could complete the phone interviews. Recruitment occurred from 2001 to 2005, with the last birth occurring in December 2005. The PIN Postpartum Study collected data prospectively from a subset of PIN3 participants who delivered between October 2002 and December 2005. Women who continued to live in the study area and had not become pregnant again were invited to participate in 3- and 12-month home visits for data collection from 2003–2007. Information about dropouts and assessment of selection bias can be found elsewhere [19–21]. The study website (www.cpc.unc.edu/pin) provides details about the protocols.

There were 2006 women who participated in the PIN3 study. Of these women, 1169 were eligible for the Postpartum Study, 938 were invited to participate, and 688 agreed to participate and completed an in-home interview at 3-months postpartum (mean time from birth to interview was 3.9 months, range: 2.9 to 5.5). After excluding women who became pregnant between the two postpartum time points (n=45), those who moved out of the recruitment area (n=73), and those who had medical complications or were lost to follow-up (n=20), there were 550 women who participated in the home visit at 12-months postpartum (mean time from birth to interview was 13.2 months, range: 11.9 to 17.9). We further excluded 20 women with more than one pregnancy who had participated in the PIN3 and PIN Postpartum studies for a second or third time to remove correlated observations. Our final sample included 530 women who completed interviews at both 3- and 12-months postpartum. This study was approved by the Institutional Review Board at the University of North Carolina at Chapel Hill, and each participant provided informed consent prior to participation in the studies.

Measures

Self-reported physical activity—Physical activity was measured using an interviewer-administered questionnaire designed to assess any activity in the past week, with evidence for validity and reliability reported elsewhere [22]. The test-retest reliability was assessed among 109 pregnant women who completed the questionnaire twice over the telephone within a 48-hour time period. Using Landis and Koch's classification [23], the measures displayed substantial agreement, with intraclass correlation coefficients ranging from 0.56 to 0.84 [22]. The criterion validity of the questionnaire was assessed among 177 pregnant women who kept a structured diary and wore an accelerometer for one week. At the end of the week, these women completed the interviewer-administered physical activity questionnaire for comparison. Moderate to substantial agreement was displayed when comparing the questionnaire and diary (Spearman correlation coefficients ranged from 0.47–0.69); lower agreement was observed when comparing the questionnaire (scored using

perceived intensity in hours/week) and accelerometer (coefficients ranged from 0.16–0.34) [22].

The questionnaire assessed the frequency and duration of all MVPA in which the woman participated, including activity done at work (e.g., lifting, carrying objects or people), for recreation (e.g., walking for exercise, swimming), transportation (e.g., walking to work or to the store), child and adult care (e.g., playing with children, pushing a stroller or wheelchair), and both indoor (e.g., scrubbing floors, mopping) and outdoor (e.g., gardening, mowing) household activities. The activity intensity was self-reported using a modified Borg scale [24] to capture the participant's perception of intensity. The physical activity questionnaire was administered during the in-home interviews at 3- and 12-months postpartum and provided an estimate of the total number of minutes or hours in the past week of MVPA using activities that were reported as "somewhat hard" or "hard or very hard". For this study, physical activity was coded as a continuous variable and was classified as total hours of overall (across all domains) and domain-specific MVPA per week. The change in MVPA from 3 to 12 months was categorized as no change, increased, or decreased; the latter two categories corresponded to any hours/week change in MVPA.

Sleep quality and duration—Sleep quality and duration were measured at 3- and 12-months postpartum during the in-home interviews. To assess sleep quality in the past month, women were asked: "How would you describe the quality of your sleep most nights?" Four response options were classified into two categories at each time point: poor sleep quality (poor and fair) and good sleep quality (good and excellent). To assess sleep duration in the past month, women were asked; "How many hours of sleep do you usually get each 24 hours?" Response options included ≤3, 4, 5, 6, 7, 8, and ≥9 hours. Similar to previous studies, we classified the responses into three categories at each time point: short sleep (<7 hours), normal sleep (7–8 hours), and long sleep duration (≥9 hours) [25–31]. In this study, core questions about sleep were developed by Jenkins et al. [32], while others were constructed as exploratory for this research.

Covariates—Self-reported race and Hispanic ethnicity (categorized as non-Hispanic white, non-Hispanic black, other non-Hispanic race, and Hispanic) and education were assessed once during pregnancy. Women reported their age, marital status, current employment status, number of children less than 18 years old in the household, and current breastfeeding practices during in-home interviews at 3- and 12-months postpartum. Body mass index (BMI) was constructed based on height and weight measured at both interviews and was categorized according to the Institute of Medicine's (1990) recommendations in effect during the study period [33]. Depressive symptoms (measured by the Edinburgh Postnatal Depression Scale, EDPS) [34, 35], anxiety (measured by the State Anxiety Inventory, STAI) [36] and perceived stress (measured by the 10-item Cohen Perceived Stress Scale, PSS) [37] were assessed at both interviews.

Statistical Analysis

We conducted descriptive analyses to examine participant characteristics at 3- and 12-months postpartum. At each time point, logistic regression models were used to estimate

odds ratios (OR) for the association between MVPA and sleep quality (good vs. poor) and baseline-category logit models (i.e., multinomial logistic regression with one fixed baseline category) were used to estimate odds ratios for the association between MVPA and sleep duration (long vs. normal and short vs. normal). Separate models were examined for each domain of activity and for overall activity. To assess confounding, the change-in-estimate approach was used to identify the appropriate adjustment sets of covariates for each domain of activity. Potential confounders included age, race/ethnicity, education, marital status, current employment, BMI, current breastfeeding, number of children less than 18 years old in the household, depressive symptoms, anxiety, perceived stress, and time from delivery to interview. Confounders were selected if they were associated with both MVPA and sleep quality or duration and changed one or more of the OR estimates by at least 10%. For this cross-sectional analysis, adjustment for the covariates did not alter any of the estimates by ≥10%, thus only unadjusted estimates are reported.

Logistic regression and baseline-category logit models were also used to estimate ORs for the association between the change in MVPA (from 3 to 12 months) and sleep quality and duration at 12-months postpartum. Separate models were examined for each domain of activity and for overall activity. The change-in-estimate approach was used to identify the appropriate adjustment sets of covariates and potential confounders included those that were also assessed in the cross-sectional analysis. For this longitudinal analysis, different adjustment sets were identified for each domain of MVPA and for overall MVPA (as reported in the tables).

RESULTS

Study population

A total of 688 women enrolled in the PIN Postpartum Study and participated at 3-months postpartum, of which 137 were excluded from further participation because they did not meet the eligibility criteria. We compared these women (n=137) to those who were included in the final sample (n=530). A higher proportion of excluded women were younger, non-Hispanic black, less educated, unmarried, overweight or obese, and not currently breastfeeding, as compared to women in the final sample ($p<0.05$ for all associations).

Among the 530 postpartum women who met the eligibility criteria between 2005 and 2007, most were aged 30 and older, non-Hispanic white, college educated, married, employed, had normal weight, were currently breastfeeding, had one child less than 18 years old in the household, and reported good or excellent sleep and normal sleep duration at 3-months postpartum (Table 1). The proportion of women with these characteristics was similar at 12-months postpartum, with the exception of current breastfeeding status, where a lower proportion reported breastfeeding at 12 months. On average, women reported few depressive symptoms and low levels of anxiety and stress at both time points.

Physical activity and sleep quality

There were no significant cross-sectional associations observed between MVPA and sleep quality at 3-months postpartum (Table 2). At 12-months postpartum, child/adult care and

recreational MVPA were associated with sleep quality such that a one hour/week increase in child/adult care MVPA was associated with a 7% decrease in the odds of reporting good (vs. poor) sleep and a one hour/week increase in recreational MVPA was associated with a 14% increase in the odds of reporting good sleep. Other domains of activity and overall MVPA were not significantly associated with sleep quality at 12-months postpartum.

The change in MVPA from 3 to 12 months was associated with sleep quality at 12-months postpartum only for work MVPA, such that increased involvement in work MVPA was associated with higher odds of reporting good (vs. poor) sleep quality (Table 3). The change in other domains of activity and overall MVPA was not significantly associated with sleep quality as measured at 12-months postpartum.

Physical activity and sleep duration

There were no significant cross-sectional associations observed between MVPA and sleep duration at 3-months postpartum (Table 4). At 12-months postpartum, child/adult care, indoor household, and overall MVPA were associated with sleep duration such that a one hour/week increase in child/adult care MVPA was associated with an 8% increase in the odds of reporting long (vs. normal) sleep duration and one hour/week increases in indoor household and overall MVPA were associated with 9% and 4% increases, respectively, in the odds of reporting short (vs. normal) sleep duration. Outdoor household, recreational, transportation, and work MVPA were not significantly associated with sleep duration at 12-months postpartum.

The change in MVPA from 3 to 12 months was associated with sleep duration at 12-months postpartum only for indoor household MVPA (Table 5). Increased involvement in this domain of activity was associated with short (vs. normal) sleep duration. The change in other domains of activity and overall MVPA was not significantly associated with sleep duration as measured at 12-months postpartum.

DISCUSSION

To date, no prior epidemiologic studies have examined the association between physical activity and sleep during the postpartum period. We found that self-reported child/adult care and recreational MVPA were weakly associated with sleep quality; child/adult care was weakly associated with long sleep duration and indoor household and overall MVPA were weakly associated with short sleep duration, only at 12-months postpartum, among a cohort of postpartum women in North Carolina. No cross-sectional associations were observed at 3-months postpartum. The change in MVPA between 3- and 12-months postpartum was associated with sleep quality and duration at 12-months postpartum such that increased work MVPA was associated with good sleep quality and increased indoor household MVPA was associated with short sleep duration.

Two studies examined the association between physical activity and sleep among pregnant women [38, 39] and several studies examined this association in the general population [40]. Borodulin et al. [38] found that self-reported physical activity was not associated with sleep quality in late pregnancy, but selected domains of activity (e.g., work activity) were

associated with sleep duration. Loprinzi et al. [39] did not find any strong associations between objectively measured physical activity and various sleep characteristics during pregnancy, with the exception of difficulty finishing a meal because of being tired which was less likely to occur among those who engaged in higher amounts of physical activity. This study did not examine sleep quality or duration. Several epidemiologic studies of physical activity and sleep among adults in the general population found self-reported exercise to be associated with less reports of insufficient sleep and fewer sleep disturbances and disorders [40].

Our results are similar to the studies among pregnant women, but in contrast to the studies among adults in the general population, in that we observed only a few associations between physical activity and sleep among postpartum women. Like pregnancy, the postpartum period is a time when women experience physiological and lifestyle changes that likely have an immediate effect on their involvement in physical activity and sleep quality and patterns, particularly during the first few months since delivery. This may explain why we did not observe any strong associations between MVPA and sleep at 3-months postpartum. The non-significant findings may also be due to a floor effect from the low participation in MVPA. At 12-months postpartum, we observed stronger cross-sectional associations between MVPA and sleep. While recreational MVPA was associated with good sleep quality, involvement in child/adult care was associated with worse sleep quality. The latter is likely due to the increased demands of caring for a more active infant. In addition, the associations we observed between short sleep duration and indoor household and overall MVPA may be due to the limited amount of time a woman has available to sleep because of her participation in MVPA. In contrast, the association between child/adult care MVPA and longer sleep duration is unclear. To our knowledge, no prior studies have found an association between physical activity and longer sleep duration, thus more research is needed to better explain this association.

For the change in MVPA, our results suggest that women who report more MVPA from their jobs are more likely to have better sleep. Additional information on the types of jobs, time of day, and hours worked would be helpful for better understanding the association between work MVPA and sleep quality. Similar to the cross-sectional association observed for indoor household MVPA, the longitudinal increase in these activities from 3- to 12-months postpartum that was associated with short sleep duration at 12-months postpartum may be due to the demands of keeping up with household tasks that take time away from getting a normal amount of sleep.

Strengths and limitations

To our knowledge, this is the first study to examine the association between physical activity and sleep during the postpartum period. The strengths of this study include the prospective cohort design and the use of a validated and detailed physical activity questionnaire. Due to the prospective design and the collection of similar information at two time points, we were able to examine the longitudinal association between the change in MVPA and sleep at 12-months postpartum, thus allowing us to establish a temporal sequence between MVPA and sleep and minimize the potential for reverse causality. Also, by assessing sleep behaviors

later during the postpartum period, we were able to observe behaviors that were less likely to be affected by newborn sleep and feeding as would be expected early in the postpartum period.

This study has limitations. Measures of MVPA and sleep quality and duration were self-reported and may be misclassified due to errors in recall. These measures also reflect different recall periods (i.e., one week recall for physical activity and one month recall for sleep). In addition, while the study protocol aimed to interview women at 3- and 12-months postpartum, the acceptable window varied with a wider range at 12-months postpartum. We assessed the potential for confounding by time between interview dates, but it did not alter any of the estimates by ≥10%. Although we had physical activity and sleep measures at two postpartum time points, more frequent assessments of behaviors would allow for detection of more precise patterns. This study lacked information on infant sleep patterns. Infant sleep is associated with maternal sleep disruptions during the postpartum period [3, 4] and may be associated with a mother's ability to participate in MVPA. Thus, residual confounding by infant sleep, as well as other unmeasured confounders, may have weakened the associations that were observed. The generalizability of this study may be limited, as the women were recruited from one clinic in central North Carolina. Participation in MVPA, reported sleep quality and duration, and the observed associations between these measures may differ from those in the general population. Also, the women were not necessarily representative of the original pregnancy cohort due to attrition and exclusion for having a subsequent pregnancy before 12-months postpartum or other factors, thus selection bias may affect our results. Confirmation of these findings in larger population-based cohorts of postpartum women is needed.

CONCLUSION

This study addresses the potential for improved sleep quality and duration from participation in MVPA during the postpartum period. Although physical activity was not associated with sleep during the early postpartum period, associations with good sleep quality and both short and long sleep duration were observed during the later postpartum period. In addition, positive associations were observed between the longitudinal increase in selected domains of MVPA and good sleep quality and short sleep duration at one year postpartum. Additional research is needed to better understand if physical activity can improve sleep and subsequently reduce the potential for adverse health effects from impaired and insufficient sleep during the postpartum period. This research should also explore whether sedentary behavior is associated with sleep quality and duration.

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Table 1

Participant characteristics at 3- and 12-months postpartum (n=530)

	3-Months Postpartum		12-Months Postpartum	
	n	%	n	%
Age, years				
≤24	70	13.2	56	10.6
25–29	127	24.0	112	21.1
30–34	188	35.5	181	34.2
35+	145	27.4	181	34.2
Race & Hispanic ethnicity (assessed only once during pregnancy)				
Non-Hispanic white	408	77.4		
Non-Hispanic black	66	12.5		
Non-Hispanic other	29	5.5		
Hispanic	24	4.6		
Missing	3			
Education (assessed only once during pregnancy)				
Less than high school	18	3.4		
High school graduate	63	11.9		
Some college	87	16.4		
College graduate	362	68.3		
Marital status				
Married	449	84.7	449	84.7
Not married	81	15.3	81	15.3
Employment status				
Yes	279	52.6	334	63.0
No	251	47.4	196	37.0
Body mass index				
Underweight (<19.8 kg/m^2)	20	3.8	51	9.9
Normal weight (19.8–26.0 kg/m^2)	278	52.6	262	50.9
Overweight (26.1–29.0 kg/m^2)	84	15.9	75	14.6
Obese (>29.0 kg/m^2)	147	27.8	127	24.7
Missing	1		15	
Current breastfeeding status				
Yes	355	67.0	135	25.5
No	175	33.0	395	74.5
Number of children <18 years old in the home				
1	248	46.8	254	47.9
2	199	37.6	196	37.0
≥3	83	15.7	80	15.1
Sleep quality				
Poor or Fair	225	42.4	201	37.9
Good or Excellent	305	57.6	329	62.1

	3-Months Postpartum		12-Months Postpartum	
	n	%	n	%
Sleep duration				
Short (≤6 hours)	183	34.5	143	27.0
Normal (7–8 hours)	294	55.5	333	62.8
Long (≥9 hours)	53	10.0	54	10.2
	Mean	SD	Mean	SD
Psychosocial characteristics				
Depressive symptoms (possible range: 0 to 30)	5.48	4.12	4.95	4.18
Anxiety (possible range: 20 to 80)	29.83	8.89	30.37	9.60
Perceived stress (possible range: 0 to 40)	13.32	5.95	13.52	6.25
MVPA (hours per week)				
Child/adult care	0.94	3.65	1.04	3.14
Indoor household	0.47	1.72	0.56	2.85
Outdoor household	0.15	0.74	0.26	1.34
Recreational	1.41	2.65	1.25	2.13
Transportation	0.06	0.29	0.10	0.96
Work	0.27	1.44	0.20	1.15
Overall (all domains)	3.30	5.48	3.40	5.79

Abbreviations: SD, standard deviation; MVPA, moderate to vigorous physical activity

Table 2

Odds ratios for the cross-sectional associations between physical activity and sleep quality at 3- and 12-months postpartum (n=530)

	3-Months Postpartum		12-Months Postpartum	
	Good vs. Poor Sleep Quality		Good vs. Poor Sleep Quality	
	OR[a]	95% CI	OR[a]	95% CI
Child/adult care MVPA	0.96	0.91, 1.01	0.93	0.88, 0.99
Indoor household MVPA	0.93	0.84, 1.03	0.92	0.84, 1.00
Outdoor household MVPA	1.02	0.81, 1.29	0.97	0.85, 1.10
Recreational MVPA	1.04	0.97, 1.11	1.14	1.03, 1.27
Transportation MVPA	1.69	0.83, 3.42	0.79	0.54, 1.16
Work MVPA	0.99	0.87, 1.11	1.00	0.86, 1.17
Overall MVPA (all domains)	0.99	0.96, 1.02	0.97	0.94, 1.00

Abbreviations: OR, odds ratio; CI, confidence interval; MVPA, moderate to vigorous physical activity (as a continuous variable measured in hours per week)

[a]Separate models were examined for each domain of activity and for overall activity. No covariates were found to alter any of the estimates by ≥ 10%, thus only unadjusted estimates are reported.

Table 3

Odds ratios for the longitudinal associations between the change in physical activity (from 3- to 12-months postpartum) and sleep quality measured at 12-months postpartum (n=530)

	Good vs. Poor Sleep Quality at 12-Months Postpartum	
	OR[a]	**95% CI**
Child & adult care MVPA[b]		
Increase (n=114)	0.82	0.51, 1.33
No change (n=319)	1.00	reference
Decrease (n=97)	0.85	0.51, 1.41
Indoor household MVPA[c]		
Increase (n=76)	0.71	0.41, 1.23
No change (n=378)	1.00	reference
Decrease (n=76)	0.80	0.46, 1.40
Outdoor household MVPA[d]		
Increase (n=40)	1.03	0.50, 2.12
No change (n=460)	1.00	reference
Decrease (n=30)	1.02	0.43, 2.39
Recreational MVPA[e]		
Increase (n=166)	1.39	0.89, 2.19
No change (n=199)	1.00	reference
Decrease (n=165)	1.06	0.68, 1.66
Transportation MVPA[f]		
Increase (n=21)	0.68	0.28, 1.64
No change (n=483)	1.00	reference
Decrease (n=26)	2.07	0.82, 5.25
Work MVPA[g]		
Increase (n=44)	2.40	1.12, 5.15
No change (n=440)	1.00	reference
Decrease (n=46)	0.97	0.49, 1.92
Overall MVPA[h] (all domains)		
Increase (n=227)	1.01	0.61, 1.66
No change (n=94)	1.00	reference
Decrease (n=209)	0.85	0.51, 1.41

Abbreviations: OR, odds ratio; CI, confidence interval; MVPA, moderate to vigorous physical activity (as a continuous variable measured in hours per week)

[a] Separate models were examined for each domain of activity and for overall activity

[b] Adjusted for number of children <18 in the household, anxiety, perceived stress

[c] Adjusted for race/ethnicity, education, perceived stress

[d] Adjusted for age, perceived stress

[e] Adjusted for education

[f] Adjustment for covariates did not alter the estimates by ≥10% for transportation MVPA. Only unadjusted estimates are reported.

[g] Adjusted for race/ethnicity, body mass index, perceived stress

[h] Adjusted for age

Table 4

Odds ratios for the cross-sectional associations between physical activity and sleep duration at 3- and 12-months postpartum (n=530)

	3-Months Postpartum			
	Short vs. Normal Sleep		Long vs. Normal Sleep	
	OR[a]	95% CI	OR[a]	95% CI
Child/adult care MVPA	1.03	0.98, 1.08	0.99	0.90, 1.10
Indoor household MVPA	1.00	0.90, 1.11	0.97	0.81, 1.17
Outdoor household MVPA	0.90	0.69, 1.17	0.74	0.39, 1.41
Recreational MVPA	0.95	0.88, 1.03	1.00	0.90, 1.11
Transportation MVPA	1.11	0.60, 2.09	1.09	0.41, 2.92
Work MVPA	1.04	0.92, 1.18	1.04	0.87, 1.26
Overall MVPA (all domains)	1.00	0.97, 1.04	0.99	0.94, 1.05
	12-Months Postpartum			
	Short vs. Normal Sleep		Long vs. Normal Sleep	
	OR[a]	95% CI	OR[a]	95% CI
Child/adult care MVPA	1.05	0.98, 1.12	1.08	1.00, 1.16
Indoor household MVPA	1.09	1.01, 1.18	0.89	0.66, 1.21
Outdoor household MVPA	0.97	0.83, 1.13	0.97	0.77, 1.22
Recreational MVPA	0.99	0.91, 1.09	1.01	0.89, 1.15
Transportation MVPA	1.20	0.89, 1.60	0.44	0.06, 3.40
Work MVPA	1.08	0.93, 1.26	0.48	0.12, 1.89
Overall MVPA (all domains)	1.04	1.01, 1.07	1.02	0.97, 1.07

Abbreviations: OR, odds ratio; CI, confidence interval; MVPA, moderate to vigorous physical activity (as a continuous variable measured in hours per week)

[a] Separate models were examined for each domain of activity and for overall activity. No covariates were found to alter any of the estimates by ≥ 10%, thus only unadjusted estimates are reported.

Table 5

Odds ratios[a] for the longitudinal associations between the change in physical activity (from 3- to 12-months postpartum) and sleep duration measured at 12-months postpartum (n=530)

	Short vs. Normal Sleep at 12-Months Postpartum		Long vs. Normal Sleep at 12-Months Postpartum	
	OR[a]	95% CI	OR[a]	95% CI
Child & adult care MVPA[b]				
Increase (n=114)	1.61	0.97, 2.67	1.47	0.72, 2.98
No change (n=319)	1.00	reference	1.00	reference
Decrease (n=97)	1.13	0.65, 1.95	0.72	0.30, 1.74
Indoor household MVPA[c]				
Increase (n=76)	1.85	1.05, 3.27	1.48	0.64, 3.39
No change (n=378)	1.00	reference	1.00	reference
Decrease (n=76)	0.70	0.37, 1.32	0.70	0.28, 1.74
Outdoor household MVPA[d]				
Increase (n=40)	0.63	0.27, 1.46	1.25	0.45, 3.50
No change (n=460)	1.00	reference	1.00	reference
Decrease (n=30)	1.84	0.77, 4.43	2.89	0.96, 8.70
Recreational MVPA[e]				
Increase (n=166)	0.72	0.43, 1.18	1.56	0.77, 3.16
No change (n=199)	1.00	reference	1.00	reference
Decrease (n=165)	1.02	0.63, 1.64	1.11	0.51, 2.40
Transportation MVPA[f]				
Increase (n=21)	1.57	0.63, 3.93	0.51	0.06, 3.98
No change (n=483)	1.00	reference	1.00	reference
Decrease (n=26)	0.83	0.32, 2.16	1.07	0.30, 3.80
Work MVPA[g]				
Increase (n=44)	0.77	0.36, 1.67	0.27	0.06, 1.24
No change (n=440)	1.00	reference	1.00	reference
Decrease (n=46)	0.78	0.38, 1.63	0.28	0.06, 1.25
Overall MVPA[h] (all domains)				
Increase (n=227)	0.80	0.47, 1.38	1.02	0.45, 2.30
No change (n=94)	1.00	reference	1.00	reference
Decrease (n=209)	0.70	0.40, 1.23	0.84	0.36, 1.97

Abbreviations: OR, odds ratio; CI, confidence interval; MVPA, moderate to vigorous physical activity (as a continuous variable measured in hours per week)

[a] Separate models were examined for each domain of activity and for overall activity

[b] Adjusted for number of children <18 in the household, anxiety, perceived stress

[c] Adjusted for race/ethnicity, education, perceived stress

[d] Adjusted for age, perceived stress

[e] Adjusted for education

[f] Adjustment for covariates did not alter the estimates by ≥10% for transportation MVPA. Only unadjusted estimates are reported.

[g] Adjusted for race/ethnicity, body mass index, perceived stress

[h] Adjusted for age