Association between sleep quality and physical activity in postpartum women

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ABSTRACT

Objective: To describe sleep quality and sleep duration in primiparous women 6 months postpartum and to determine whether sleep quality is associated with 24-hour physical activity assessed using triaxial wrist accelerometry and a novel analytic technique, functional data analysis (FDA).
Methods: Six months postpartum, participants wore a triaxial wrist accelerometer for 7 days and completed the Pittsburgh Sleep Quality Index (PSQI). We categorized sleep quality as good (score ≤5) or poor (>5). Data were summarized as vector magnitude of accelerations net of local gravity, or "Euclidean Norm Minus One" (ENMO, mg), in 5-second epochs. Using FDA, we modeled ENMO as a continuously changing, functional outcome predicted by sleep quality. We also compared mean total ENMO per 24-hour day, mean minutes of moderate to vigorous physical activity (MVPA) and of light activity/day, and mean minutes of MVPA in 10-minute bouts/day by sleep quality.
Results: Of 365 women that completed the PSQI, 215 (59%) reported poor sleep quality. Two hundred ninety-six women completed both the PSQI and valid accelerometry. With the exception of one brief period around noon, sleep quality was not significantly associated with 24-hour physical activity according to FDA. Women with poor sleep quality had slightly greater total mean activity, minutes of light activity, and minutes of MVPA per day, but no difference in minutes of MVPA in at least 10-minute bouts.
Conclusion: Poor sleep quality is common 6 months postpartum. We identified no clinically significant differences in physical activity metrics between women with good and poor quality sleep.

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Introduction

Physical activity during the postpartum period has many health benefits, such as improving sleep quality, reducing gestational weight gain, improving mood, and decreasing risk for depressive symptoms.[1] The demands of childrearing, however, can interfere with the postpartum woman's pursuit of healthful physical activity.[2] Research suggests that physical activity levels at 3 and 12 months postpartum are below recommended levels such that women are not enjoying the benefits of physical activity at this transitional period.[3]

Sleep is disrupted and redistributed in the postpartum period. Whether assessed subjectively or objectively, women in the postpartum period are more likely to have interrupted, fragmented, and lower-quality sleep.[4–6] Understanding factors, such as sleep quality, that may promote physical activity engagement during postpartum would help guide recommendations for those who are underactive and could provide health intervention targets for the problem of inactivity among postpartum women.

Sleep duration and quality are related to physical activity levels in various populations. Moderate to vigorous physical activity (MVPA) is associated with shorter time to fall asleep, greater time in deep sleep, and less daytime sleepiness.[1] One pilot trial found that a light-intensity exercise program done 3 times per week improved sleep in the postpartum period.[7] Although there are numerous

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reports concluding that higher levels of physical activity improve sleep, fewer examine whether those with better sleep quality are more likely to be physically active. In older women, there is support for both a bidirectional relationship between sleep and objective assessment of physical activity and a unidirectional relationship between sleep and physical activity.[8,9]

Based on a comprehensive literature search, the 2018 Physical Activity Guidelines Advisory Committee concluded that there is insufficient evidence to understand the association between physical activity and the quality of sleep postpartum and recommended observational studies to explore the associations between physical activity and sleep quality in postpartum women.[10] We contend that understanding the other direction of relationship, that is, between sleep and physical activity, may also be fruitful in postpartum women given that poor sleep is common in this population.[11] If poor sleep quality is found to be associated with less physical activity, then interventions focused on sleep quality in postpartum women may help to achieve the goal of reducing inactivity in this population.

We identified no studies assessing the association between sleep quality and physical activity using objectively assessed activity in the later postpartum period. In addition to sparse information about the association between sleep quality and physical activity in postpartum women, most information to date has focused on moderate to vigorous physical activity in at least 10-minute bouts and on mean activity averaged over a day. However, the recently updated Physical Activity Guideline no longer recommends a focus on 10-minute bouts of activity, as total moderate to vigorous activity, as well as light-intensity activity, has been shown to have important health benefits regardless of bout length.[12] There is also increasing attention to describing total activity that includes both light-intensity and MVPA over a 24-hour period in populations that tend to have more irregular and sporadic activity.[13] We therefore focused our analysis on total activity, which incorporates all intensities.

The aims of this cross-sectional study are (1) to describe sleep quality and sleep duration in a group of primiparous women 6 months after vaginal birth and (2) to determine whether sleep quality is associated with overall 24-hour physical activity, assessed using conventional methods as well as a novel analytic technique, functional data analysis (FDA) of vector magnitude of accelerations over an average day. This type of analysis can delineate whether the effect of sleep quality on physical activity varies at different time points in the course of a 24-hour day.

Methods

This is an ancillary study to an ongoing cohort study. Methods for the primary study have been published.[14] This study was approved by institutional review boards at the participating sites, and all participants completed written informed consent. Women were included in the primary study if they were 18 years or older, pregnant in the third trimester with their first child, planning vaginal delivery, English or Spanish speaking, without medical problems that precluded physical activity, and living within a 60-mile radius of the study site. Because the purpose of the primary study is to better understand how certain postpartum factors including physical activity impact pelvic floor health 1 year after vaginal childbirth, women that delivered by cesarean birth or preterm were subsequently excluded after delivery. We are continuing to follow the remaining population for 1 year postpartum. Pertinent to the current analysis, at 5-7 months postpartum (hereafter referred to as 6 months), participants were asked to wear a wrist-worn accelerometer for 7 days and also to complete the Pittsburgh Sleep Quality Index (PSQI).[15] Participants also completed comprehensive study questionnaires at enrollment, during the third trimester, at 8 weeks postpartum, and at 1 year

postpartum; they did not complete these more comprehensive questionnaires at 6 months postpartum.

The PSQI, validated in both English and Spanish, consists of 19 items that measure 7 different aspects of sleep: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleeping medication, and daytime dysfunction due to sleepiness. Respondents are asked to reflect on their sleep characteristics over the past month. Each item is weighted on a 0-3 interval scale, and the items are summed to obtain a global PSQI score, with values ranging from 0 to 21. Consistent with previous reports, we dichotomized sleep quality as good ($\leq$5) or poor (>5).[15] In addition to the PSQI, participants also completed an activity checklist summarizing types of activities performed based on the Bone Loading History Questionnaire, designed to assess loads applied to the hip and spine during various activity types.[16]

Study staff delivered a triaxial accelerometer (Actigraph GT9X LINK; Actigraph, Inc, Pensacola, FL) to participants at 6 months postpartum and asked them to wear it on the nondominant wrist for 24 hours per day over 7 days. Detailed accelerometry procedures are summarized elsewhere.[17] Briefly, accelerometers were initialized using ActiLife 6.13.0 software (Pensacola, FL) to collect data at 80 Hz, to begin data collection at midnight, and to display date and time so that the device would serve as a watch. Accelerometers did not display any physical activity parameters. Study staff retrieved the devices, downloaded the acceleration data, and converted them to raw files for further processing. At least 4 days of wear, with at least 1 weekend day, and at least 10 hours of wear on weekdays and 8 hours of wear on a weekend day were required for adequate accelerometry.[18] We used GGIR V1.5-21, an R package designed to process multiday raw accelerometer data and applied quality control measures as per van Hees et al.[19]

Physical activity measurement by accelerometry has advanced recently to express the intensity of movement using vector magnitude of accelerations in short intervals of time such as 5-second "epochs".[20] Euclidean Norm Minus One (ENMO) is a summary metric for acceleration data and represents the vector magnitude of 3 axial measures minus the contribution of gravity (1 g). The greater the intensity of movement and duration of activity in the summed 5-second epochs are, the greater the ENMO value is. Based on Bakrania et al[21] and Hildebrand et al,[22] ENMO values between 25.8 and 100.6 mg correspond to light activity and values >100.6 mg correspond to MVPA.

We compared demographics and relevant medical history between groups categorized by good vs poor sleep quality. We compared continuous variables between groups using independent-samples t tests with pooled variances, Satterthwaite test when variances were unequal based on the folded F test, or the Wilcoxon rank sum test when variables were not consistent with normality, and categorical variables using χ^2 tests or Fisher exact tests, as appropriate.

For the primary analysis of the effect of sleep on physical activity, we used FDA. Plotting physical activity over the entire course of a 24-hour day can provide confidence bands for the effects of sleep quality on physical activity continuously over a 24-hour period. To perform FDA,[23] we summarized and plotted ENMO in each of the 17,280 5-second epochs of an average day. We excluded 1 woman with anomalous, implausibly high values of ENMO. Using the FDA methodology and R package fda, we modeled ENMO as a continuously changing, functional outcome that was predicted by the dichotomous variable of good or poor sleep quality based on a single administration of the PSQI. Modeling proceeded using B-splines to produce a smoothed representation of the data and generalized cross-validation to identify tuning parameters.[23] The software produced pointwise 95% confidence bands at each and every available 5-second epoch during the day, allowing the effect of sleep quality to vary over the 24-hour
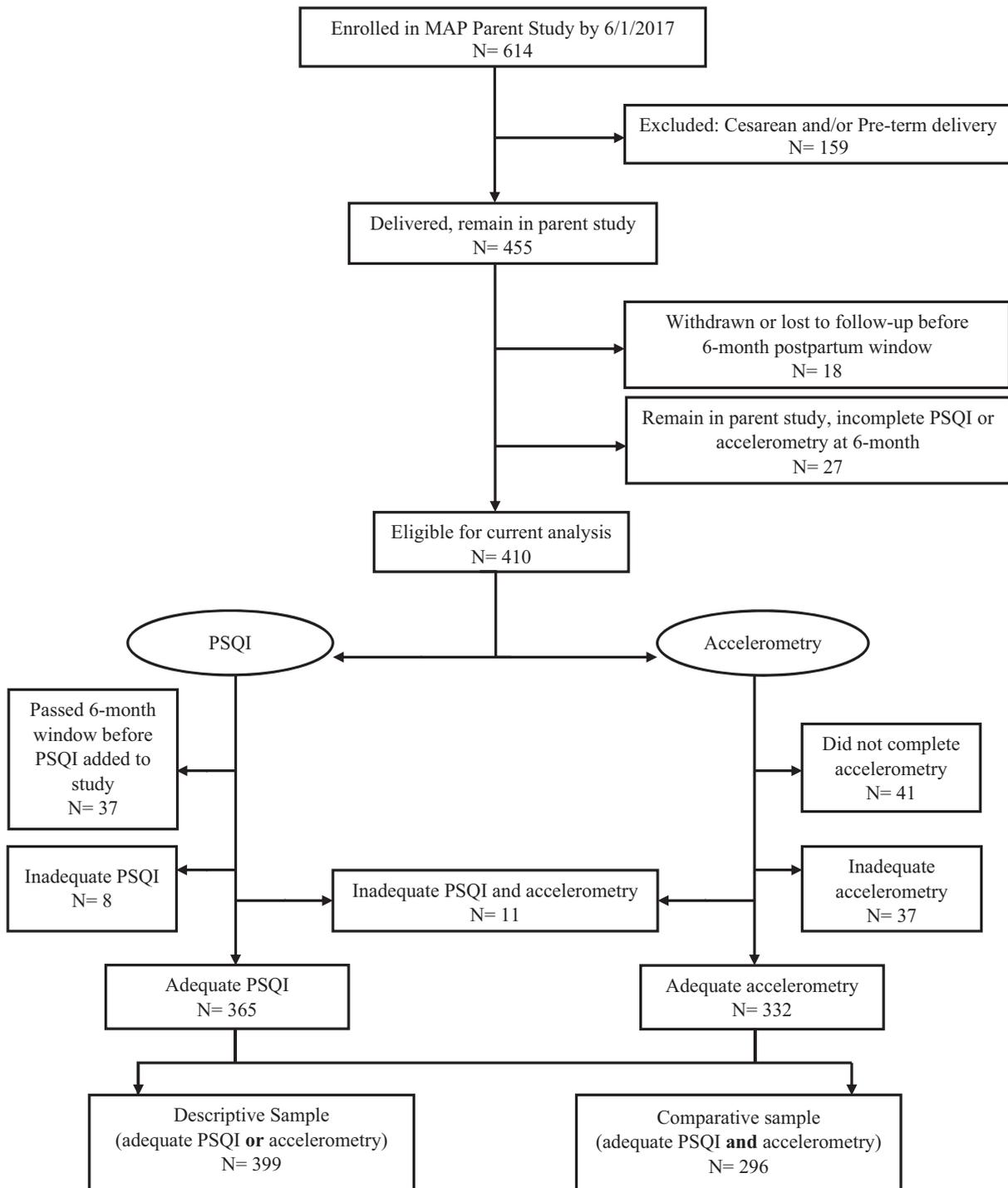
Fig. 1. Participant flow from enrollment to the 6-month postpartum period.

period, with tests for significant effects of sleep quality by a permutation F test for functional data.[23]

In addition to the FDA analysis, as secondary outcomes, we also compared total mean ENMO averaged over all epochs in the entire week of accelerometry, total mean minutes per day of light activity, total mean minutes per day of MVPA, and mean minutes per day of MVPA constrained to occur in at least 10-minute bouts between participants with good sleep vs poor sleep quality. For example, minutes per day and per week of MVPA were calculated as the total duration of epochs where ENMO exceeded 100.6 mg. MVPA in 10-minute bouts has been used widely to assess the health benefits of physical

activity. Although recently released updated physical activity guidelines no longer include the restriction of MVPA to 10-minutes bouts, as total MVPA confers similar health benefits, we included this analysis to enable better comparisons between our results and the extant literature.[1]

We plotted each total mean ENMO and total mean minutes of MVPA vs total PSQI score and calculated the Pearson or Spearman correlation coefficient as appropriate.

We compared the analysis data set to participants in the parent study who did not have valid accelerometry at 6 months postpartum or who did not complete the PSQI using similar methods. Statistical

Table 1
Baseline characteristics

	N = 399
Age at enrollment (y), mean ± SD	27.9 ± 5.1
Ethnicity	
Non-Hispanic	316 (79.2%)
Hispanic/Latina	83 (20.8%)
Race	366 (91.7%)
White/Caucasian	
Asian/Asian American	18 (4.5%)
Black/African American	6 (1.5%)
American Indian/Alaskan Native	3 (0.8%)
Native Hawaiian/Pacific Islander	2 (0.5%)
Do not wish to identify	4 (1.0%)
Education	
Less than 12th grade	15 (3.8%)
Completed high school or equivalent	56 (14.0%)
Some college/associate degree	87 (21.8%)
Completed 4 y of college or more	241 (60.4%)
Months since delivery, mean ± SD	7.2 ± 0.9
BMI at 8 wk (kg/m^2)	
<25	199 (51.2%)
25-<30	116 (29.8%)
>30	74 (19.0%)
Diabetes	12 (3.0%)
Hypertension	5 (1.2%)
Work status at 8 wk	
Working full time (at least 30 h/wk)	34 (8.9%)
Working part time	19 (5.0%)
Work status at 1 y (n = 313)	
Full time	158 (50.5%)
Part time	59 (18.9%)
Breastfeeding at 8 wk	338 (88.3%)
Breastfeeding at 1 year (n = 313)	143 (45.7%)
Health rating at 8 wk	
Excellent	80 (20.9%)
Very good	145 (37.9%)
Good	127 (33.2%)
Fair	28 (7.3%)
Poor	3 (0.8%)

Presented as n (%), except as otherwise noted.
Except where otherwise stated, N = 399. At the time of analysis, 313 women had reached the 1-year endpoint for the primary study.

Table 2
Results of the PSQI at 6 months postpartum

Scale	n = 365
Overall results	
PSQI total score	
Median [IQR]	6 [4-9]
Range	[0-17]
Number of minutes to fall asleep, median [IQR]	15 [10-30]
Hours of actual sleep, mean ± SD	6.9 ± 3.0
Poor sleep quality (PSQI total >5)	215 (58.9%)
Good sleep quality (PSQI total ≤5)	150 (41.1%)
Subscale results	
Duration of sleep	
≥7 h sleep per night	120 (32.9%)
6-7 h sleep per night	98 (26.8%)
5-6 h sleep per night	81 (22.2%)
<5 h sleep per night	66 (18.1%)
Sleep disturbance	
No sleep disturbance	17 (4.7%)
Low sleep disturbance	291 (79.7%)
Medium sleep disturbance	56 (15.3%)
High sleep disturbance	1 (0.3%)
Sleep latency	
No sleep latency	136 (37.3%)
Low sleep latency	117 (32.0%)
Medium sleep latency	89 (24.4%)
High sleep latency	23 (6.2%)
Day dysfunction due to sleepiness	
No effect on daily work	93 (25.5%)
Low effect on daily work	203 (55.6%)
Medium effect on daily work	61 (16.7%)
High effect on daily work	8 (2.2%)
Sleep efficiency	
Sleep hours ≥85% of time in bed	165 (45.2%)
Sleep hours 75%-84% of time in bed	91 (24.9%)
Sleep hours 65%-74% of time in bed	54 (14.8%)
Sleep hours ≤64% of time in bed	55 (15.1%)
Overall sleep quality	
Very good sleep quality	46 (12.6%)
Fairly good sleep quality	215 (58.9%)
Fairly bad sleep quality	89 (24.4%)
Very bad sleep quality	15 (4.1%)
Need medications to sleep	
Not during the past month	342 (93.7%)
Less than once a week	14 (3.8%)
Once or twice a week	3 (0.8%)
Three or more times a week	6 (1.6%)

tests were performed at the conventional 5% significance level. All analyses were performed in SAS v 9.4 (Cary, NC), except that FDA analysis was conducted using R package fda.

Results

Study population

Study participants included 399 women that completed the PSQI and/or 6-month accelerometry. Of these, 365 completed the PSQI, 332 had adequate accelerometry data, and 296 had both a complete PSQI and adequate accelerometer data. Figure 1 demonstrates participant flow from enrollment in the parent study to the analytic sample for this analysis. There were no statistically significant differences in age, race, and work status between women in the study population (N = 399) and enrolled participants that completed neither adequate accelerometry nor the PSQI (n = 56); however, noncompleters were more likely to self-identify as Hispanic and less likely to have graduate-level education than the study population (P < .001 for both). The same findings were noted in comparing women that completed both adequate accelerometry and the PSQI (n = 296) vs enrolled participants that did not (n = 159).

Characteristics of the full cohort are summarized in Table 1. The mean age of the cohort was 27.9 (SD 5.1) years, and mean time since delivery was 7.2 (SD 0.9) months. The cohort was predominantly White/Caucasian race (91.7%), non-Hispanic ethnicity (79.2%), educated (60% completed 4 years of college or more),

nonobese (19% body mass index [BMI] >30), and healthy (3% had diabetes, 1.2% had hypertensive disorders). We did not include questions on work status and breastfeeding on the questionnaire completed by participants at 6 months postpartum, but women completed these questions at 8 weeks and 1 year postpartum. At 8 weeks postpartum, 8.9% of the cohort were working at least 30 hours per week and 88% were breastfeeding. At 1 year postpartum, 50% of 313 respondents that had completed the 1-year visit were working at least 30 hours per week and 46% were breastfeeding.

Sleep quality

The time period in which sleep was assessed preceded the accelerometry assessment in 268 women, whereas in 11 women, the 2 assessments overlapped in time and, in 16, the sleep assessment followed accelerometry. Table 2 summarizes PSQI results. Two hundred fifteen of 365 women (59%) reported poor sleep quality, as indicated by a PSQI total score >5. The median PSQI score was 6 (interquartile range [IQR] 4-9, range 0-17). Mean sleep duration was 6.9 hours (SD 3.0) per night. One hundred twenty (33%) reported sleeping 7 or more hours per night, and 66 (18%) reported less than 5 hours per night. A considerable proportion of women reported medium or high sleep disturbance (16%), medium or high

Table 3
Participant characteristics according to sleep quality

	Good sleep quality (≤5) n = 150	Poor sleep quality (>5) n = 215	P
Age at enrollment (y), mean ± SD[a]	27.7 ± 5.1	28.1 ± 5.1	.678
Ethnicity			.825
Hispanic/Latina	30 (20.0%)	41 (19.1%)	
Non-Hispanic/Latina	120 (80.0%)	174 (80.9%)	
Race			.107
White/Caucasian	135 (90.0%)	199 (92.6%)	
American Indian/Alaskan Native	1 (0.7%)	2 (0.9%)	
Asian/Asian American	6 (4.0%)	11 (5.1%)	
Black/African American	5 (3.3%)	0 (0%)	
Native Hawaiian/Pacific Islander	2 (1.3%)	0 (0%)	
Do not wish to identify	1 (0.7%)	3 (1.4%)	
Education			.717
Less than 12th grade	6 (4.0%)	8 (3.7%)	
Completed high school or equivalent	18 (12.0%)	30 (13.9%)	
Some college/associate degree	29 (19.3%)	50 (23.3%)	
Completed 4 y of college or more	97 (64.7%)	127 (59.1%)	
BMI at 8 wk (kg/m²), mean ± SD Missing = 9	25.3 ± 4.4	26.4 ± 5.6	.094
Diabetes	1 (0.7%)	10 (4.7%)	.029
Hypertension Missing = 1	4 (2.3%)	1 (0.5%)	.074
Work status full or part time at 8 wk Missing = 12	16 (10.9%)	31 (15.1%)	.288
Work status full or part time at 1 y[b] Missing = 74	80 (69.5%)	122 (69.3%)	.964
Health rating at 8 wk (missing = 12)			.019
Excellent	37 (25.2%)	37 (18.0%)	
Very good	60 (40.8%)	74 (35.9%)	
Good	46 (31.3%)	71 (34.5%)	
Fair	4 (2.7%)	21 (10.2%)	
Poor	0 (0%)	3 (1.5%)	

[a] Unless otherwise specified, missing responses to a specific variable = 0.
[b] Still in study flow.

sleep latency (31%), medium or high day dysfunction at work due to sleepiness (19%), and suboptimal sleep efficiency (30% sleep less than 75% of their time in bed sleeping). Overall, 28% rated their sleep quality as fairly bad or very bad, although 93.7% denied using sleeping-aid medication in the past month.

Compared to women reporting good sleep quality, those reporting poor sleep quality were of similar age, ethnicity, race, and education (Table 3). There were no differences in work status or breastfeeding at 8 weeks and 1 year postpartum. Women reporting poor sleep quality had a nonsignificantly higher BMI (26.4 vs 25.3 kg/m², P = .094) and were more likely to have diabetes, generally gestational (4.7% vs 0.7%, P = .029).

Relationships between sleep quality and physical activity

Results from the FDA analysis are summarized in Figure 2. As can be seen in this figure, activity rises between early morning and noon-time, drops somewhat, and then rises again, tapering off over the afternoon and evening. Women with good quality sleep had less activity at 3:00 AM, noon, and 8:00 PM; however, of all 5-second epochs analyzed, this was statistically significant only briefly around noon.

Total activity intensity, as reflected by the mean total ENMO averaged over all 5-second epochs per day, was slightly *lower* in women with good sleep quality (26.8 mg for good sleep vs 28.4 for poor sleep, P = .015). This is reflected by slight decreases in both total light activity and total MVPA in women with good sleep quality (Table 4). However, median MVPA in 10-minute bouts was similar between groups (2.0 [IQR 0-8.4; range 0-103.6] min/d for good and 2.1 [IQR 0-10.0; range 0-60.1) min/d for poor sleep quality; P = .839). The types of activities that participants reported doing for at least 10 minutes per week were also similar between women with good and poor sleep quality (Table 5.) When evaluating the PSQI score as a continuous variable instead of a dichotomized variable (good vs poor sleep), the score was not correlated with total mean ENMO (Fig. 3) or with total mean MVPA (Fig. 4). In addition, we evaluated the effect of 2 sleep quality subscales, duration of sleep and day dysfunction due to sleepiness, and found no association between either subscale (dichotomized as >7, 6-7 hours vs 5-6, <5 hours, and no/low effect vs medium/high effect, respectively) and mean total ENMO (data not shown).

Discussion

More than half of our population of women at 6 months postpartum reported poor sleep quality. We found no clinically meaningful differences between sleep quality and physical activity either throughout the day as analyzed by FDA or according to activity intensity and type. FDA enables studying the effects of sleep quality on physical activity continuously over an entire 24-hour day. Thus, one can evaluate whether, for example, women with good sleep quality have greater total activity during certain morning hours, perhaps reflecting sufficient energy to exercise compared to women with poor sleep quality. In our population of primiparous women 6 months postpartum, we found essentially no associations between sleep quality and total activity over the course of 24 hours, except for a very brief period around noon when women with poor quality sleep had greater activity than women with good quality sleep. Although values for total activity (expressed as ENMO), total minutes of MVPA, and total minutes of light activity were all slightly greater in women with poor sleep quality, the differences seen were small. We also assessed MVPA in 10-minute bouts, the amount of sustained activity associated with many health outcomes, but found no difference by sleep quality.

One study suggested that specific types of physical activity, but not greater amounts of MVPA, were associated with improved sleep quality 1 year postpartum.[24] Longitudinal data are sparse. A cohort study in college-aged students demonstrated a bidirectional but indirect relationship between sleep quality and physical activity, and the relationship was reliant on emotional factors.[25] Another study of older women found no reciprocal associations between MVPA and sedentary time and total sleep time and sleep efficiency, assessed using wrist accelerometry.[26] We designed our study to examine one direction of effect that has been understudied: that of sleep on physical activity. In our study, the vast majority of women assessed their sleep quality before their accelerometry wear period, and therefore, our study is not well suited to explore the opposite direction of effect. Future prospective cohort studies of postpartum women will be valuable in further understanding the bidirectional nature of this association, as well as the role both sleep and physical activity play temporally in the genesis of postpartum mood disorders.

Although women with poor sleep quality had slightly greater total ENMO per day, total minutes of MVPA per day, and total minutes of light activity per day, the FDA revealed that this difference was significant for total ENMO only for a very brief time point around noon. These marginally statistically significant results do not correspond to clinical significance. Indeed, the direction of effect does not lead
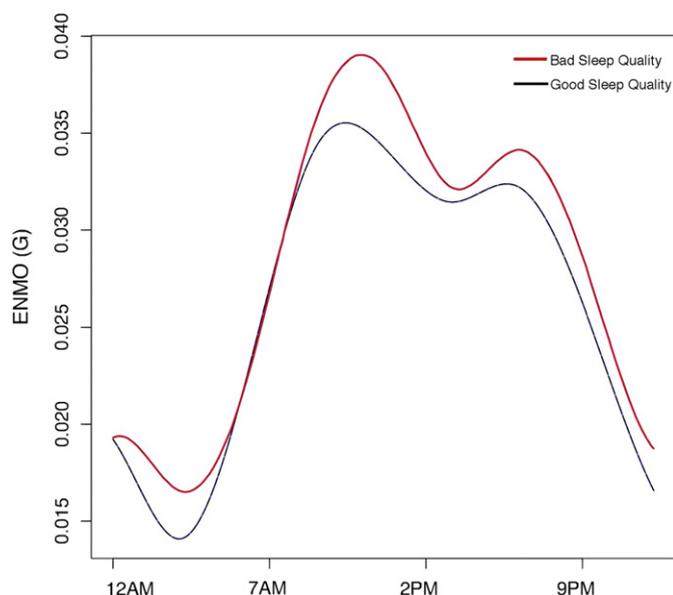
Fig. 2. FDA results. This regression function demonstrates the difference in ENMO (in mg assessed in 5-second epochs over the course of 24 hours) for women with good sleep, beyond the ENMO for women with poor quality sleep. The differences throughout the day, analyzed by permutated *F* tests in 5-second epochs throughout an average 24-hour period, reached statistical significance only briefly around noon .

to a promising clinical intervention—that is, one would not recommend striving for worse sleep quality to increase MVPA or light activity by 10 minutes per day. Good sleep quality does not appear to be leading to more purposeful exercise in this population, which may simply reflect the fact that new mothers have changing priorities and less time to devote to exercise.

The association between sleep and self-rated health that we observed has been reported in different populations, including young adults and nurses.[27–29] Whether a general self-rating of health in early postpartum can predict longer-term maternal sleep outcomes is worthy of follow-up, especially given the feasibility of this assessment.

By assessing physical activity using objective measures and sleep quality using a validated instrument, this study helps to address a gap in the literature about sleep and physical activity in postpartum women. The proportion of participants still eligible after delivery that adequately completed either the PSQI or accelerometry, 399 of 455 (88%), is high, although the proportion that completed both adequately was lower, 296 of 455 (65%). Participants that did not complete 1 or both of these study instruments were of similar age as those that did but were more likely to be Hispanic and less likely to have completed higher education levels. Thus, our results may not be generalizable to other populations. As we excluded women that delivered by cesarean birth, our results may also not apply to those women. Study participants completed comprehensive questionnaires at 8 weeks and 1 year postpartum, but at 6 months completed only the PSQI and a physical activity questionnaire, and therefore, we do not have contemporaneous data about potentially important factors such as current breastfeeding or work status. However, we found no differences between sleep quality at 6 months and breastfeeding or work status at either 8 weeks postpartum or,

Table 4
Physical activity metrics according to sleep quality

n = 295	Good sleep quality n = 119	Poor sleep quality n = 176	P
Total ENMO/d[a]			.015
Mean (SD)	26.8 (6.1)	28.4 (6.3)	
Median (IQR)	26.0 (22.5-30.3)	28.2 (24.3-32.6)	
Range	(12.8-49.0)	(14.3-49.4)	
Total minutes of MVPA/d[b]			.023
Mean (SD)	82.4 (30.4)	91.1 (34.6)	
Median (IQR)	78.1(62.3-99.9)	90.2 (65.0-111.9)	
Range	(27.7-174.5)	(22.1-210.5)	
Minutes of MVPA in at least 10-min bout/d			.839
Mean (SD)	7.2 (14.5)	7.1 (10.7)	
Median (IQR)	2.0 (0-8.4)	2.1 (0-10.0)	
Range	(0-103.6)	(0-60.1)	
Total minutes light activity/d[c]			.057
Mean (SD)	328.5 (94.6)	339.1 (99.3)	
Median (IQR)	334.0 (299.4-376.3)	359.9 (301.7-398.7)	
Range	(0-623.0)	(0-516.6)	

  [a] Reflects all activities averaged over a 24-hour period.
  [b] Includes all activities with ENMO value >100.6 mg.
  [c] Includes all activities with ENMO value between 25.8 and 100.6 mg.

Table 5
Types of activities reported by women according to sleep quality

Type of activity, ≥10 min/wk	Good sleep quality n (%) n = 119	Poor sleep quality n (%) n = 176	P
Heavy lifting or work			
Yes	50 (42.4%)	77 (44.5%)	.718
No	68 (57.6%)	96 (55.5%)	
Hard running or exertion			
Yes	32 (27.1%)	40 (22.7%)	.406
No	86 (72.9%)	135 (77.1%)	
Bouncing/easy running			
Yes	61 (51.7%)	88 (50.0%)	.776
No	57 (48.3%)	88 (50.0%)	
Activities not involving bouncing, jumping, exertion, or lifting			
Yes	93 (78.8%)	141 (80.6%)	.713
No	25 (21.2%)	34 (19.4%)	

Some numbers do not add up to total because of missing data.
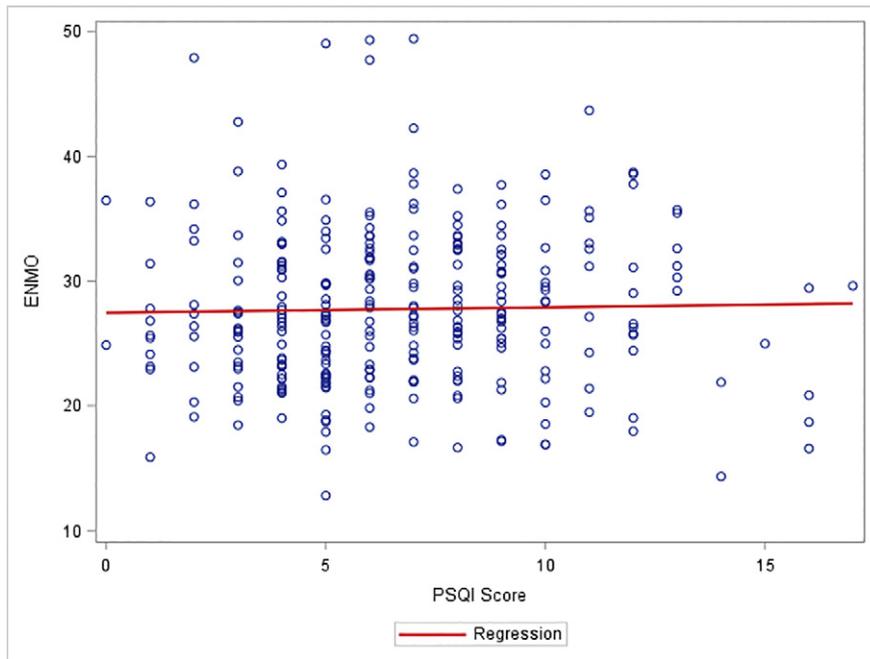
Fig. 3. Relationship between total PSQI score and mean total physical activity (expressed as ENMO) over 24 hours.

among participants who had completed the 1-year evaluation at the time of this analysis, 1 year. We chose the PSQI because it has been validated in both English and Spanish and has been used extensively, including in postpartum women. However, it may not adequately reflect sleep quality in postpartum women because it was not specifically designed for use in this population.

Although one of the main strengths of this study is the objective assessment of physical activity with accelerometry, this tool lacks information on the context (ie, recreation vs household activity), which at least one other study has found related to postpartum sleep quality.[24] However, we found no difference between sleep quality and the types of activities participants reported engaging in. It is possible that the trends in increased activity during the night in women with poor sleep quality are due to responding to more demands made by their babies, but given that accelerometry cannot accurately identify specific activities, this is speculative only.

Another strength of this study is the use of FDA, which has the capability to allow the effects of good sleep on physical activity to vary at different times of day. It should be noted that our analysis used the average day, not the entire week in detail, primarily because participants did not have the identical numbers of days of data required by the FDA method. The analysis also did not differentiate weekend vs
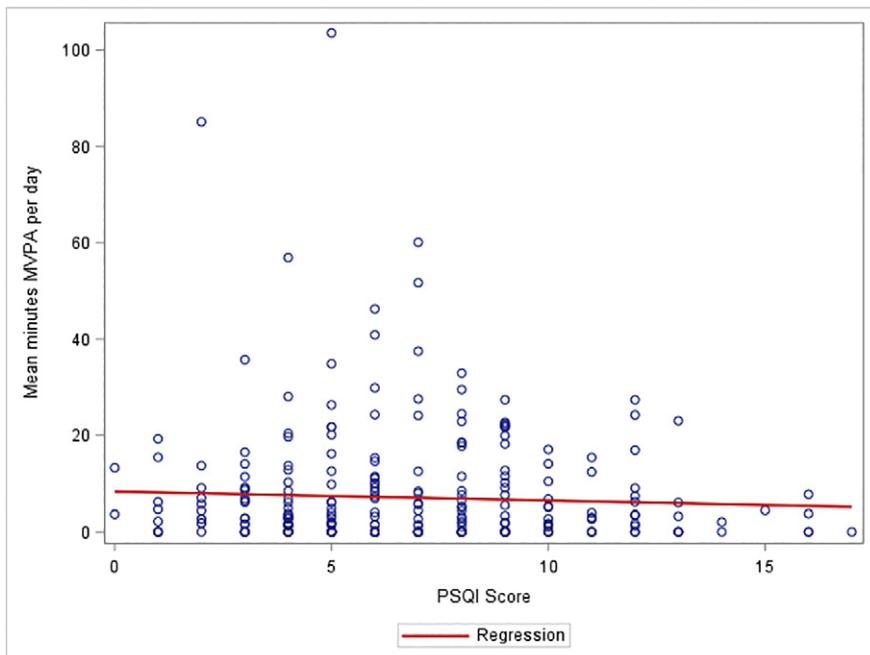

Fig. 4. Relationship between total PSQI score and mean total minutes of moderate/vigorous physical activity over 24 hours.

weekday days. A key computational limitation of FDA is that it used considerable resources on a high-performance computer cluster, especially to identify some of the tuning parameters in the analysis. This may impact the utility of this type of analysis in future studies.

In conclusion, this study found that most primiparous women at 6 months postpartum after a vaginal delivery report poor sleep but that poor sleep was not associated with objectively measured periodic physical activity levels. Future studies may find activity level differences by accounting for the context in which sleep and activity are disrupted, redistributed, and moderated in the unique postpartum time period.

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