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Exercise during Early Pregnancy is Associated with Greater Sleep Continuity

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Abstract

Pregnant women report disturbed sleep beginning in early pregnancy. Among non-pregnant populations, exercise has been associated with improved sleep; however, research in pregnant samples has been equivocal. We examined whether varying degrees of exercise were associated with better nocturnal sleep among pregnant women during early gestation. Self-reported sleep and exercise and objective sleep were collected during early gestation: T1 (10–12 wk), T2 (14–16 wk), and T3 (18–20 wk) from 172 pregnant women. Exercise was categorized into three time-varying groups: 0 metabolic equivalent minutes per week [MET-min/wk], 1 to <500 MET-min/wk, or 500 MET-min/wk. Linear mixed-effects models were employed to test hypotheses.

A significant main effect for Time ($F(2,254)=9.77$, $p<0.0001$) and Time*Exercise group interaction were observed for actigraphic sleep efficiency (aSE) ($F(4,569)=2.73$, $p=0.0285$). At T2, women who reported 500 MET-min/wk had higher aSE than those who reported 0 MET-min/wk. Significant main effects for Exercise Group and Time were observed for actigraphic wake after sleep onset ($aWASO$) ($F(2,694)=3.04$, $p=0.0483$ and $F(2,260)=3.21$, $p=0.0419$). $aWASO$ was lowest for those reporting 1 to < 500 MET-min/wk ($t(701) = 2.35$, adjusted $p = .0489$) and $aWASO$ decreased from T1 to T3 ($t(258)=2.53$, adjusted p -value=0.036). Lastly, there was a main effect for Time for the PSQI ($F(2,689)=52.11$, $p<0.0001$), indicating that sleep quality improved over time. Some level of exercise among pregnant women appears to be more advantageous than no exercise at all. Moderate exercise, while still unclearly defined, may be a worthwhile adjunct treatment to combat sleep disturbances during pregnancy.

INTRODUCTION

Sleep in pregnancy is often disturbed, with sleep complaints manifesting as early as 10 weeks gestation (Okun, 2013). Most often these complaints are comprised of frequent

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nocturnal awakenings, symptoms of insomnia, and poor sleep quality (Facco, Kramer, Ho, Zee, & Grobman, 2010; Okun, 2013). These sleep disturbances have been correlated with increased risk for adverse pregnancy outcomes including preterm birth (Okun, Schetter, & Glynn, 2011), glucose intolerance (Facco et al., 2010), and gestational hypertension (Williams et al., 2010). Based on these associations, we contend that improvements in sleep could result in better pregnancy outcomes.

Though a traditional treatment for sleep disturbance, medications are not a viable option in pregnancy because they may be teratogenic (Nodine & Matthews, 2013; Okun, Ebert, & Saini, 2014). Thus, non-pharmacological treatments are critically needed to improve or offset the substantial sleep disturbance reported among pregnant women. Recently there has been an increased emphasis on understanding the benefits of incorporating positive health behaviors to modify health (Bauer, Briss, Goodman, & Bowman, 2014; Okorodudu, Bosworth, & Corsino, 2014; Rad, Bakht, Feizi, & Mohebi, 2013; Yaffe et al., 2014). Specifically, incorporation of exercise for the management of sleep disturbance has received a great deal of attention (Buman, Hekler, Bliwise, & King, 2011; Irish et al., 2014; King et al., 2008; Kline et al., 2013; Kline et al., 2014).

Numerous public health agencies suggest 150 minutes of moderate- to vigorous-intensity exercise per week for optimal health in adults. Various studies in non-pregnant populations consistently support the hypothesis that exercise improves sleep quality and continuity (Irish, Kline, Gunn, Buysse, & Hall, 2014; Youngstedt, O'Connor, & Dishman, 1997). In studies focused on older adults, exercise training has resulted in reduced sleep latency, fewer sleep disturbances, reduced daytime sleepiness, and subjectively reported improvements in daytime functioning (King et al., 2008; Li et al., 2004). Taken together, these data indicate that habitual exercise confers positive benefits on sleep parameters, particularly among non-pregnant cohorts.

There are few studies on the effects of exercise on sleep in pregnant women. Cross-sectional studies have noted mixed findings, with one reporting a significant relationship between exercise and sleep (Goodwin, Astbury, & McMeeken, 2000), but most others finding no association (Borodulin et al., 2010; Loprinzi, Fitzgerald, & Cardinal, 2012; Yucel SC, Yucel u, Gulhan I, & Ozeren M, 2012). Two brief exercise interventions have observed significant reductions in insomnia symptoms (Tella BA, Sokunbi OG, Akinlami OF, & Afolabi B, 2010) and increased sleep continuity (Beddoe, Lee, Weiss, Kennedy, & Yang, 2010). A shortcoming of all of these studies is the limited assessment period. Most were retrospective and used varying methodologies, which limits generalization of their findings. As a result, these studies do not accurately describe normal/usual exercise and sleep behaviors in pregnant populations.

According to the American Congress of Obstetricians and Gynecologists (ACOG), pregnant women should participate in moderate-intensity exercise for 30 minutes per day on most, if not all, days of the week (The American College of Obstetricians and Gynecologists, 2011). To explore the potential health benefits of meeting these recommendations, the present study sought to examine the relationship between exercise and sleep in pregnant women using concurrent and prospective assessments of exercise and sleep. We first sought to describe the

prevalence and frequency of exercise behavior in early pregnancy. We then sought to evaluate whether varying degrees of exercise based on public health recommendations, were differentially associated with sleep. We hypothesized that women who met current ACOG recommendations for exercise would have better sleep quality and efficiency, as depicted by lower Wake After Sleep Onset (WASO), higher Sleep Efficiency (SE), and greater Total Sleep Time (TST), compared to women who either did not meet ACOG guidelines or who did not exercise at all during the study period.

METHODS

Participants

This is a secondary analysis of a larger study assessing sleep early in pregnancy and its association with pregnancy outcomes (Okun et al., 2013; Okun, Tolge, & Hall, 2014). Participants were recruited during early (~10–14 weeks) pregnancy, from self-referral, physician referrals, local advertisements or via participation in University research registries. Exclusion criteria included self-report of psychopathology, sleep disorders, or current pharmacological/therapeutic treatment for psychopathology. In addition, women with preexisting diabetes, HIV or uterine abnormalities were excluded. Physiological screening for sleep-disordered breathing or restless legs syndrome/periodic limb movements during sleep were not conducted. The University of Pittsburgh Institutional Review Board granted approval for this study. All participants provided written informed consent prior to participation.

Study Protocol and Procedure

Upon enrollment, current health status, health behaviors, and socio-demographic information were collected. Data were collected for three 2-week periods during the following weeks of gestation: 10–12 (T1), 14–16 (T2), and 18–20 weeks (T3). The specific time frame was chosen based on our published conceptual model that perturbations in sleep within the first 20 weeks of gestation could negatively impact inflammatory processes conferring an increased risk for adverse pregnancy outcomes (Okun, Roberts, Marsland, & Hall, 2009). To augment enrollment, women were allowed to enroll at 14 weeks (T2). Hence, enrollment in the study occurred at T2 for 24 participants. Given the statistical analyses utilized, we included data from participants with at least 2 of the 3 time points.

Sleep Assessment—Participants completed the Pittsburgh Sleep Diary (Monk et al., 1994) each day during 3 two-week periods. Immediately before bed each night, participants recorded information about the previous day (e.g., caffeine use, exercise, naps); upon awakening, participants recorded information about the prior night's sleep. In addition, participants wore a wrist actigraph (Actiwatch 64; Philips Respironics, Bend, OR) continuously during the two-week periods on the non-dominant wrist. Participants were asked to press an event marker button on the watch when they tried to go to sleep and when they got out of bed to begin their day. The Actiwatch captures wrist movement data; sleep/wake status was estimated from movement data in 1-minute epochs using the medium-sensitivity wake threshold (40 counts) in Actiware (v. 5.0) software. On download, each record was visually inspected for collection quality (i.e., correct number of days and watch

removals). The Auto Interval option was set to identify one primary Rest Interval per 24-h period, using event markers as anchor points. This method saves processing time but does not eliminate the need for some manual editing. Periods of time where the watch was not worn during the protocol were excluded from the record prior to export. The assessment periods enabled collection of all sleep patterns for the entire time period, often including irregularities due to illness, travel, “on call” nights, etc. All available days with data were included in the descriptive analyses. The average number of data collection days for the whole cohort at each time point was 13.6 days (97% compliance for both diary and actigraphy).

Sleep measures derived from both sleep diary and actigraphy included (a) *wake after sleep onset* (WASO; the amount of time awake after the onset of sleep); (b) *sleep efficiency* (SE; the amount of time spent asleep divided by the amount of time spent in bed); (c) *sleep onset latency* (SOL; the number of minutes to fall asleep); and (d) *total sleep time* (TST; the total number of minutes slept across the night). Sleep variables were averaged across each single week of a two-week period, producing two mean values per time period. These two values were considered repeated measures for each time period, and they were treated as continuous variables in our analyses. Sleep diary measure abbreviations are preceded by “*d*” and actigraphy measure abbreviations are preceded by “*a*”. To assess habitual sleep quality at the end of each 2-week period, participants completed the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI is an 18-item self-report questionnaire that assesses seven items including indices of sleep continuity and daytime functioning that has been validated in many populations, including pregnancy (Jomeen J & Martin C.R., 2007) (Qiu et al., 2016). For the present study, the PSQI was modified to assess sleep “over the past 2 weeks” instead of the usual timeframe of “over the past month”.

Exercise Assessment—Participants recorded their daily exercise behavior in the sleep diary. Each day, participants reported whether they engaged in exercise and, if so, indicated the start time, end time, and type of activity. We then assigned each reported activity a Metabolic Equivalent (MET) value according to *The Compendium of Physical Activities* (Ainsworth et al., 2011). A MET provides an estimate of the energy cost of a given physical activity, expressed as a ratio of the active metabolic rate relative to the resting metabolic rate (e.g., a MET value of 3.0 would equate to an energy cost that is approximately three times higher than resting energy costs). To obtain a measure of each ‘dose’ of exercise, we multiplied each recorded activity’s MET value by the duration of that activity (i.e., MET-minutes). All the MET-min were then summed for the entire day to obtain daily MET-min. Daily MET-min were then summed across each recording week to find MET-minutes per week. Although participants wore Actiwatchs, they were not used for physical activity assessment since daytime activity data from these devices have poor agreement with more widely accepted forms of objective physical activity monitoring (e.g., hip-worn accelerometry) (Lambiase, Gabriel, Chang, Kuller, & Matthews, 2014; Cellini, McDevitt, Mednick, & Buman, 2016).

Women were categorized into three groups based upon their self-reported exercise habits at each weekly time point, which allowed for this categorization to vary over time. Women

were classified as being inactive (0 MET-min/wk), insufficiently active (1 to <500 MET-mins/wk), or sufficiently active (≥ 500 MET-min/wk). Women exercising ≥ 500 MET-mins per week were considered to have met ACOG guidelines, as 500 MET-min/wk approximates 150 min/wk of moderate-intensity exercise.

Covariates

Covariates consisted of age, body mass index (BMI), marital status, income, and race, each provided by participants at the beginning of study involvement. Age and BMI were treated as continuous variables, whereas marital status, income, and race were treated as categorical variables. Marital status was categorized into 3 groups (married/living with partner, separated/divorced, and never married), income was categorized into 4 groups (< \$20K, \$20–50K, \$50–100K, and > \$100K), and race was categorized into 3 groups (Caucasian, African American, and Other). All were chosen because they have a known association with sleep and/or exercise habits (Borodulin et al., 2010; Okun et al., 2014; Uijtdewilligen et al., 2014; Uijtdewilligen et al., 2015). We chose to include age even though it has not been a significant covariate in other reports/analyses of this cohort (Okun et al., 2013; Okun et al., 2014). We did not include parity as it is evenly distributed in our cohort and has not been a statistically significant covariate (Ebert, Wood, & Okun, 2015).

Statistical Analyses

Descriptive statistics were used to characterize the sample and evaluate distributions of sleep outcome variables. Missing data were minimal: 2 women had less than 10 days of diary data collection at T1 (N=5 days), 2 different women at T2 (N=8 days), and 2 different women at T3 (N=8 and 9 days, respectively). For actigraphy, 4 women had less than 10 days at T1 (3, 8, 7 and 8 days, respectively), 1 woman at T2 (9 days), and 1 at T3 (9 days). Skewed sleep variables were transformed to produce approximately normally distributed values. A natural-logarithmic transformation was used for both diary and actigraphic measures of SE and a square-root transformation was employed for both diary and actigraphic measures of WASO. Linear mixed-effects models were utilized to investigate the effects of time and exercise on sleep measures. Each sleep outcome was analyzed in a separate model. Main effects for time period and exercise group, as well as covariates (age, BMI, race, marital status, income), were treated as fixed effects in the models. To investigate whether the relationship between exercise and sleep varied as a function of time, an interaction term between time period and exercise group was added to the models. A random subject effect was also included to account for repeated measurements made on the same participants. In order to capture more week-to-week variability in sleep outcomes due to exercise and time effects, additional analyses were performed using modifications of the primary statistical models. In addition to exercise group, period and the group-by-period interaction, the models also included the fixed effects REP (which represents the repeated measurement number within each categorical time period (levels T1, T2 and T3), Group-by-REP, REP-by-period, and Group-by-REP-by-period interactions. Inference was still based on exercise group and period; most results and conclusions stayed approximately the same after modifying the models. These models were fit through maximum likelihood estimation in SAS version 9.3 (Proc Mixed, SAS Institute, Cary, NC, USA). To test whether the effects of time period, exercise group, and the interaction between time period and exercise group had significant effects on sleep

outcomes, F-tests were conducted at the 0.05 level of significance. Post hoc analyses were employed using a Bonferroni adjustment to account for multiple comparisons.

RESULTS

Participants

Participant characteristics are presented in Table 1. Participants (N = 172) were approximately 29 years of age, with 69% reporting being married or living with their partner. The racial breakdown was consistent with the Greater Pittsburgh area: 72.3% Caucasian and 24.7% African-American. The average BMI was 26.72 ± 6.00 ; however, 38 participants (22.1%) were obese as defined by a BMI $\geq 30 \text{ kg/m}^2$. A diverse household income was noted: About 20% had an annual income of $<\$20,000$, whereas almost 19% had annual incomes greater than \$100,000. There was also a range of educational attainment. For instance, approximately 26% had earned a post-graduate degree. We had 9 women attrit from the study, but these were entirely due to miscarriages. This number is in line with the estimated 10–20% that occur within the first 12 weeks gestation.

The earliest collected sleep variables for the entire cohort and by exercise group are presented in Table 2. As expected, there were group shifts during the study period. Interestingly, the majority (N=88 (51%)) of the women remained in a single exercise category throughout the study. There were 59 (34%) women who switched between 2 exercise categories, and 25 (15%) women who moved among 3 exercise categories. In addition to the total weekly dose of exercise that was quantified by MET-min/wk, we also evaluated the frequency of exercise bouts, regardless of the number of MET-min/wk. Out of all weekly observations in our study for which participants indicated some exercise, 88% reported exercising ≥ 4 days per week, and 63% reported exercising on all 7 days. More specifically, among the participants who met ACOG guidelines ($\geq 500 \text{ MET-min/wk}$), 82% reported exercising ≥ 4 days per week, and 54% indicated exercising on all 7 days. Figure 1 shows the number of participants in each group at each of the six weeks, and the average weekly MET-minutes.

Exercise and Actigraphic and Diary Sleep

When investigating aSE , the main effect for Exercise Group was not significant ($F(2,671)=1.42$, $p = 0.24$); however, a significant main effect for Time was observed ($F(2,254)=9.77$, $p < 0.0001$). Specifically aSE increased between T1 and T3 ($t(253) = 4.15$, adjusted $p = .0001$), and from T2 to T3 ($t(250) = 3.41$, adjusted $p = .0024$) (Table 3). In addition, a significant Exercise Group*Time interaction was observed ($F(4,569)=2.73$, $p=0.0285$). Post-hoc investigation of the interaction effect revealed that, during T2, sufficiently active women ($\geq 500 \text{ MET-min/wk}$) exhibited a higher aSE than inactive women (0 MET-min/wk) ($t(688) = 2.47$, adjusted $P = .0417$).

When fitting the linear mixed model to $aWASO$, we observed significant main effects for Exercise Group ($F(2,694)=3.04$, $p=0.0483$) and for Time ($F(2,260)=3.21$, $p=0.0419$). Mean $aWASO$ was significantly lower in insufficiently active women compared to inactive women ($t(701) = 2.35$, adjusted $p = .0489$). Mean $aWASO$ was significantly lower at T3 compared to

T1 ($t(258) = 2.53$, adjusted $P = .0360$) (Table 3). There was no significant interaction between Exercise Group and Time ($F(4, 260) = 1.11$, $p = .349$). We observed no significant Exercise Group, Time, or Group-by-Time interactions for $aSOL$, $aTST$, or any of the diary-based sleep measures (dSE , $dWASO$, $dSOL$, $dTST$).

Exercise and PSQI-assessed Sleep

We found a significant main effect for Time ($F(2,689)=52.11$, $p < 0.0001$). PSQI scores decreased significantly from T1 to T2 ($t(695) = -8.02$, adjusted $p < 0.001$) and from T1 to T3 ($t(693) = -9.5$, adjusted $p < 0.001$) indicating an improvement in habitual sleep quality (Table 3). Neither the main effect of Exercise Group on PSQI scores nor the Exercise Group* Time interaction effect on PSQI scores was significant.

DISCUSSION

The goal of this study was to examine whether varying amounts of exercise in early pregnancy are associated with better nocturnal sleep. It was hypothesized that women who met ACOG exercise recommendations would have better sleep, as measured by self-report and actigraphy, compared to women who did not meet these recommendations. Results partially supported the hypotheses in that women who exercised in early pregnancy reported better sleep continuity at 16 weeks, as reflected by higher actigraphy-assessed SE. Additionally, among the women who were insufficiently active, mean $aWASO$ was significantly lower than women who did not exercise at all. Contrary to our hypotheses, we did not observe a significant benefit of regular physical activity with regards to the sleep variables assessed.

Minimal significant associations were observed between the amount of exercise and sleep. Interestingly, our only significant association was restricted to actigraphy-assessed SE and WASO, as we did not observe any associations with diary-reported sleep. Our findings are in contrast to the extant literature on exercise and sleep in non-pregnant populations, which has typically found the strongest relationships between exercise and self-reported sleep (Youngstedt & Kline, 2006). For instance, King and colleagues found that older adults who exercised 5 days/week had improvements in self-reported nocturnal disturbances, SOL, and feeling rested in the morning, but few improvements in PSG-assessed sleep were observed (King et al., 2008). However, our results are consistent with the literature that has considered physical activity and sleep in pregnant women (Borodulin et al., 2010; Tella BA et al., 2010). For example, Borodulin and colleagues found weak associations between modes of physical activity and sleep duration and quality in late pregnancy (Borodulin et al., 2010). It should be noted that they collected recalled information via telephone interviews, whereas our data were collected prospectively.

The fact that associations were limited to SE and WASO, is consistent with existing literature that suggests that exercise may impact sleep continuity more than sleep duration (Kline et al., 2013). It is unclear as to why only women who were “insufficiently active” had the highest SE compared to the other two groups, and why it was only observed for actigraphy-assessed sleep. We postulate that in early pregnancy, modest levels of exercise may improve sleep better than high levels of exercise. It is also unclear as to whether some

(or all) women initiated exercise once pregnant or if they maintained a habitual exercise routine. Further evaluation of this association is needed to make definitive interpretations and recommendations. However, there are data to suggest that the greatest health-benefits of physical activity, are typically observed when transitioning from being inactive to insufficiently active (Haskell, 1994). Future interventions should examine dose-response effects and timing of exercise in early pregnancy. While recent data suggest that pregnant women show discrepancies in self-report sleep data compared to objectively-assessed sleep data (Wilson, Fung, Walker, & Barnes, 2013; Herring et al., 2013), it is fairly well understood that self-report, actigraphy and PSG assess “different” constructs (Tryon, 2004) and that discrepancies are often observed. The type of improvement in sleep (e.g. better sleep quality vs. less WASO) will likely dictate which measurement of sleep is best.

We found that certain aspects of sleep (i.e., *a*WASO, *a*SE, and PSQI-assessed sleep quality), improved over time. These findings are in line with the majority of reports on sleep during pregnancy that there is a “U” shaped curve with sleep being poor in first trimester, improving in the second, and worsening again in the third (Borodulin et al., 2010; Guendelman et al., 2012; Soltani et al., 2012). This is not surprising given that pregnant women, especially in early pregnancy, report multiple self-reported nocturnal disruptions, for instance, to void the bladder, contend with nausea or handle physical discomfort (Challis & Lye, 2003). Each of these circumstances can result in long periods of time spent awake at night, impair sleep efficiency, and reduce sleep quality.

Our largely nonsignificant findings notwithstanding, our results are unique in that this is the first study that we are aware of that has examined the relationship between exercise and sleep over multiple timepoints within early pregnancy. Borodulin and colleagues (Borodulin et al., 2010) had women recall physical activity and sleep duration and quality at 27–30 weeks. They found that physical activity was not significantly associated with sleep duration or sleep quality, although the type of activity (e.g., household vs. leisure, indoor vs. outdoor) was important. Likewise, a study by Beddoe and colleagues (Beddoe et al., 2010) evaluated a mindfulness meditation/yoga intervention on sleep in women who were 12–32 weeks pregnant. Among the women who were randomized to the experimental condition, they found an improvement in actigraphy-assessed SE, awakenings and WASO. Interestingly, the greatest benefit was observed for women who enrolled in the second trimester versus those in the third trimester. The timing of exercise initiation in pregnancy may also be another future consideration. Additionally, confronting women’s beliefs about exercise during pregnancy could be an important factor in timing of initiation of exercise. Interestingly, it has been shown that women are more likely to exercise if they believe it is beneficial during pregnancy, and it is the physician who has the greatest influence over these beliefs (Krans et al., 2005). Considerations about women’s beliefs about the efficacy of exercise for improvement of health in pregnancy should be considered in future studies.

Limitations and Strengths

There are some limitations to the current study that need to be acknowledged. First, we relied on self-reported exercise behavior. Although it was a daily recollection of exercise, reporting of exercise is subject to error (Tomaz, Lambert, Karpul, & Kolbe-Alexander,

2014). Future studies should use a validated and more objective measure of activity. We did not have reliable pre-pregnancy information on sleep or exercise. While we asked about exercise and sleep habits, it was not clear if the participants answered with reference to pre-pregnancy status or in the first several weeks of pregnancy. Thus, we did not utilize those data. Assessment of behaviors prior to becoming pregnant would help delineate whether exercise behavior changes in pregnancy or remains the same. However, Loprinzi and colleagues note that even rigorous measurement of exercise using hip-worn accelerometers does not guarantee a better understanding of the relationship between exercise and another health related variable, such as depression (Loprinzi et al., 2012; Loprinzi, Fitzgerald, Woekel, & Cardinal, 2013). Moreover, the reliance on sleep diary input resulted in an inability to presume that missing values for exercise data in the sleep diaries indicated zero activity. It is possible that the participant simply forgot to record it. Therefore, to be more conservative in our results, the only observations that were included in statistical models were those women reporting exercise data (0 or otherwise). Furthermore, the reliance on self-reported exercise resulted in a handful of occasions where categorization of exercise intensity was difficult to establish (e.g., the metabolic demands of walking through a mall or doing yard work). Additionally, there were some significant outliers within the sample, as some participants were uniquely active for pregnancy (e.g., marathon or competitive weight training). Although these could obscure the relationship between exercise and sleep, the generalizations would be diminished if we removed these participants. Another issue to consider is the significant variability in exercise within and between subjects. Adherence to a regular exercise regimen was not strictly observed by all the women in this study, which adds complexity to the analyses. Some women maintained a regular exercise routine throughout the study period while others were intermittent. Hence, it may not be as simple as stating that exercise does or does not affect sleep in early pregnancy. Additional consideration of the effects of consistent versus inconsistent exercise levels on sleep variables of the group, as opposed to its effect on a single individual, is needed

Due to feasibility with this specific large observational study, polysomnography was not used, despite being considered the gold-standard for sleep assessment. The use of concurrent diary and actigraphy comprehensively assesses sleep, while also reducing the participant burden and overall cost of observation (Martin & Hakim, 2011; Ustinov & Lichstein, 2013; Lemola, Ledermann, & Friedman, 2013). This was deemed the most efficient and least intrusive form of measurement for the population. Also, while we did screen for self-reported sleep disorders (e.g., sleep-disordered breathing, restless legs syndrome) at enrollment, we did not clinically evaluate the participants. This can be deemed a limitation as it is well appreciated that pregnant women experience higher rates of sleep disorders.

This study has several strengths. One significant strength is the concurrent objective and subjective measures of sleep that spanned 6 weeks. The parallel collection of multiple sleep measures is important for reliability and consistency due to increasing evidence that subjectively reported sleep variables can differ greatly from their objectively measured counterparts (Martin & Hakim, 2011; McCall & McCall, 2012; Okun et al., 2013; Tryon, 2004). The demographic distribution of this sample is another strength. This cohort consisted of women with a wide range of exercise habits, from those who never reported any exercise to those who exercised daily. Moreover, the demographic representation of our

cohort matches that of the Greater Pittsburgh area in relation to education and income (<http://quickfacts.census.gov/qfd/states/42/4261000.html>). Finally, this is one of the only studies to focus on the relation between exercise habits and sleep of women during early gestation. Early gestation constitutes a multifaceted stage of pregnancy. Several behaviors, including exercise and sleep, can influence biological pathways involved in normal as well as pathological pregnancies (Duncombe et al., 2006; Goodwin et al., 2000; Juhl et al., 2008; Okun et al., 2009).

Conclusion

To summarize, we sought to demonstrate whether exercise behavior was associated with better sleep in pregnant women. Women who were insufficiently active had slightly better actigraphy-assessed SE and actigraphy-assessed WASO compared to those who reported no exercise. Interestingly, we found no association between sufficient exercise and sleep quality in our sample. However, it should be noted that women who exercised had better sleep overall (albeit nonsignificant), both subjectively and objectively. The bi-directional nature of exercise and sleep need to also be considered. It is likely that women who are better sleepers may engage in more exercise. Further examination of these relationships is warranted due to the frequency of disturbed sleep complaints in this population and need for effective and safe methods to improve sleep and pregnancy/delivery outcomes. The well-established benefits of exercise in all populations will continue to make the proposal of exercise as an intervention for maternal sleep disturbance a relevant matter for the future.

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Figure 1:
Average MET-min/week by Exercise Group.

Table 1.

Participant Demographics at Enrollment (10 –14 weeks gestation)

	Total Cohort N= 172	Inactive (0 MET-min) n=71	Insufficiently Active (1-<500 MET-min) n=40	Sufficiently Active (≥ 500 MET-min) n=61
Age, yr	29.27 ± 4.88	28.48 ± 4.71	30.32 ± 5.17	29.51 ± 4.80
BMI, kg/m²	26.72 ± 6.00	27.85 ± 6.56	26.85 ± 6.26	25.20 ± 4.70
Marital Status				
Married	112 (65.12)	40 (56.34)	31 (77.50)	41 (67.21)
Living with partner	27 (15.7)	10 (14.08)	6 (15.00)	11 (18.03)
Separated/Divorced/ Widowed	2 (1.16)	2 (2.82)	0 (0)	0 (0)
Never Married	31 (18.02)	19 (26.76)	3 (7.50)	9 (14.75)
Income				
(<\$20K)	35 (20.35)	19 (26.76)	8 (20.00)	8 (13.11)
(\$20K-\$50K)	37(21.51)	20 (28.17)	5 (12.50)	12 (19.67)
(\$50K-\$100K)	56 (32.56)	17 (23.94)	17 (42.50)	22 (36.07)
(>\$100K)	33(19.19)	11 (15.49)	9 (22.50)	13 (21.31)
Do not know/wish to answer	11(6.4)	4 (5.63)	1 (2.50)	6 (9.84)
Education				
High School Graduate	24 (13.96)	8 (11.27)	6 (15.00)	10 (16.40)
Technical or trade school/Some college	38 (22.09)	27 (38.02)	5 (12.50)	6 (9.84)
College degree	47 (27.33)	19 (26.76)	8 (20.00)	20 (32.79)
Some post-graduate work	18 (10.47)	7 (9.86)	4 (10.00)	7 (11.48)
Post Graduate degree	45 (26.16)	10 (14.08)	17 (42.50)	18 (29.51)
Race^a				
Caucasian	120(69.77)	45 (63.38)	32 (80.00)	43 (70.49)
African American	41(23.84)	22 (30.99)	6 (15.00)	13 (21.31)
Other	7 (4.07)	3 (4.23)	1 (2.50)	3 (4.92)

Data are displayed as Mean ± SD or N (%)

^aNo race data on 4 participants

Table 2.Average Sleep Variables Collected at Initial Visit[^]

	Total Cohort N=172	Inactive (0 MET-min) n=71	Insufficiently Active (1-<500 MET-min) n=40	Sufficiently Active (≥ 500 MET-min) n=61
Actigraphy				
Sleep Onset Latency (min)	12.3 ± 10.07	13.6 ± 11.50	13.0 ± 11.00	10.3 ± 7.03
Wake after Sleep Onset (min)	71.3 ± 55.86	74.9 ± 58.08	73.4 ± 57.70	65.8 ± 52.48
Sleep Efficiency (%)	75.3 ± 10.82	73.7 ± 11.29	75.7 ± 10.45	76.9 ± 10.41
Total Sleep Time (min)	314.0 ± 117.77	304.6 ± 118.00	325.4 ± 113.50	317.5 ± 121.47
Sleep Diary				
Sleep Onset Latency (min)	20.8 ± 16.48	25.2 ± 19.03	19.2 ± 13.32	16.7 ± 13.96
Wake After Sleep Onset (min)	26.0 ± 20.82	29.5 ± 23.07	24.7 ± 17.63	23.0 ± 19.70
Sleep Efficiency (%)	90.6 ± 6.23	89.0 ± 6.96	91.4 ± 4.70	91.9 ± 5.88
Total Sleep Time (min)	457.9 ± 57.61	446.6 ± 63.02	474.1 ± 54.99	460.4 ± 50.28
PSQI	5.0 ± 2.64	6.4 ± 2.63	5.5 ± 1.97	5.3 ± 2.97

[^] Baseline data may have been derived from T2 (14–16 weeks) as that was their enrollment

Table 3.

Significant Sleep Variables by Time and Exercise Group

	10–12 weeks	14–16 weeks	18–20 weeks
Actigraphy WASO (min)			
Inactive (0 MET-min) n=71	88.1 ± 62.14 N = 71	82.4 ± 50.59 N = 81	73.2 ± 48.15 N = 84
Insufficiently Active (1-<500 MET-min)	82.5 ± 67.18 N = 40	74.0 ± 48.45 N = 28	62.5 ± 40.91 N = 34
Sufficiently Active (≥ 500 MET-min)	75.2 ± 58.94 N = 61	67.5 ± 48.15 N = 63	64.6 ± 32.53 N = 54
Actigraphy SE %			
Inactive (0 MET-min)	73.8 ± 12.79	75.3 ± 9.60	77.7 ± 8.95
Insufficiently Active (1-<500 MET-min)	76.4 ± 11.76	78.0 ± 8.63	80.9 ± 8.13
Sufficiently Active (≥ 500 MET-min)	75.9 ± 12.00	78.4 ± 9.59	78.9 ± 8.30
PSQI			
Inactive (0 MET-min) n=71	6.3 ± 2.64	5.1 ± 2.73	4.9 ± 2.58
Insufficiently Active (1-<500 MET-min)	5.6 ± 1.98	4.3 ± 2.06	4.2 ± 2.33
Sufficiently Active (≥ 500 MET-min)	5.4 ± 2.97	4.6 ± 2.58	4.0 ± 2.41