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The Impact of Physical Activity on Sleep during Pregnancy: A Secondary Analysis

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Abstract

Disturbed sleep is independently associated with adverse pregnancy outcomes. The primary aim of this research which tested Pender's Model of Health Promotion was to evaluate the contribution of physical activity (PA) to sleep parameters in pregnant women, with pre-pregnant body mass index (BMI) as a confounder. Sleep and physical activity data were drawn from a parent study in which 29 sedentary women in the second trimester were enrolled in an 8-week PA intervention pilot study and randomly assigned to intervention or control group. Steps per day, as measured by pedometer, and sleep parameters (sleep onset latency [SOL], wake time after sleep onset [WASO], sleep duration, and sleep quality), obtained from sleep diaries, were used to evaluate the daily interaction between PA levels and sleep. Hierarchical linear modelling (HLM) was used for analysis, as data were nested within persons. Pre-pregnant BMI contributed negatively to PA levels ($p=0.003$). PA levels were positively predictive ($p=0.037$) of sleep onset latency (SOL) and negatively predictive ($p=0.01$) of sleep quality, demonstrating a negative effect of PA on sleep during pregnancy when measured daily. These results confirm results from the only other published study that looked at daily measures, but contradict findings from other studies that evaluated the PA level-sleep relationship over a week or month. Both PA and sleep are modifiable factors that affect pregnancy outcomes. Further studies are needed to understand the complex relationship between PA, sleep, and weight in pregnancy.

Keywords: Pender's health promotion model; Pregnancy; Physical activity; Maternal obesity; Sleep

Introduction

Disturbed sleep, characterized as insomnia, is difficulty falling asleep and/or staying asleep, even when a person has the chance to do so [1]. Insomnia can be acute or chronic (at least 3 nights per week for at least 3 months), can be caused by other sleep disorders (e.g., restless leg syndrome or obstructive sleep apnea) or primary [1].

Disturbed sleep is known to negatively impact many aspects of human health, including cognitive functioning, mood, inflammatory and healing processes, glucose metabolism, and overall quality of life [2-5]. During pregnancy, disturbed sleep is independently associated with various adverse health outcomes, including gestational hypertension, preeclampsia, glucose intolerance, depressed mood, anxiety, inflammatory markers, longer labor, and operative birth [6-10].

Women's sleep patterns change with pregnancy [11]. Generally, sleep quality declines and sleep duration is shorter during pregnancy with shortest sleep duration in late pregnancy [11]. Table 1 describes select sleep parameters. Sleep quality, sleep onset latency (SOL), sleep efficiency, daytime dysfunction, and wake time after sleep onset (WASO) are worse in pregnancy compared to pre-pregnancy and worsen with increasing gestation [12-14]. The potential health risks associated with pregnancy-related sleep disturbances are particularly evident when obesity is present, but can occurs independent of maternal obesity [15].

This study focused on the impact of physical activity on sleep during pregnancy. Physical activity is broadly defined as "any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level" [16]. Physical activity in the context of health research refers to activity that enriches health. In the non-pregnant population, acute and long term physical activity has been associated with improvement in sleep quality, increased slow wave (deeper) sleep, as well as decreased SOL [3,17-19]. There have been few published studies evaluating the association between physical activity and sleep in pregnancy [20-22]. Borodulin and colleagues [20] reported a weak association between physical activity, as measured by a telephone questionnaire, and improved sleep duration and sleep quality in women in the third trimester. This large study (N=1295) assessed data on timing, intensity and type of exercise (Pregnancy Physical Activity Questionnaire [PPAQ]). BMI was not reported, and data was collected over the second and third trimesters. Yet concurrent sleep and physical activity data were not consistently collected. Kolu and colleagues[21], using secondary analysis of active (n=80) and less-active (n=258) pregnant Finnish women at high risk for gestational diabetes (GDM), collected data twice during pregnancy, using the PPAQ for PA information and a self-reported Likert scale for measurement of sleep quality. Active women in Kolu's study [21] described higher quality sleep. Lindseth and Vari [22], while comparing a self-report PA diary with pedometer, reported that the daytime physical activity as measured by pedometer, negatively impacted nocturnal sleep duration in pregnant women (N=94). This study was limited by the lack of demographic and ethnic diversity and the self-reported sleep duration as one item of the physical activity diary.

Using a sleep diary, the present study measured four standard sleep parameters, sleep duration, SOL, WASO, and sleep quality [1]. Sleep impacts pregnancy outcomes and women with high BMI are more prone to disturbed sleep and are less likely to be physically active in pregnancy than normal weight women [23,24]. Since most women are generally less active than recommended during pregnancy [25-27], minimal increases may improve sleep significantly. This research examines the contribution of physical activity to sleep during pregnancy with BMI as confounder within the context of Pender's Health Promotion Model [28].

Pender's Health Promotion Model (Figure 1), a heuristic theory that integrates variables shown to impact health behavior [28], was the theoretical framework guiding this study. The health behavior of participating in physical activity was hypothesized to impact sleep, a measure of health in this study. Socio-cognitive factors, self-efficacy, social support, and understanding benefits of physical activity, was thought to be important factors contributing to physical activity [29,30]. Finally, BMI and gestational age were personal factors hypothesized to impact physical activity. Several studies in pregnancy have found these factors to impact exercise during pregnancy [31-33].

Objectives

The specific aims of the study were to: 1) evaluate the contribution of daily physical activity to nocturnal sleep parameters, specifically sleep duration, SOL, WASO, and sleep quality in pregnant women with pre-pregnant BMI category as a confounder and 2) explore associations between pre-pregnant BMI and self-efficacy; social support for physical activity during pregnancy; and perception of importance and effect of physical activity.

Methodology

This study was conducted in a south-western state in the United States of America (USA) and was a secondary analysis of a larger parent study examining implementation of a novel pregnancy exercise program, My Baby, My Move [34].

Parent study: context for the current study

Data were drawn from a pilot study funded by the Centers for Disease Control (CDC, 1K01DP001127-01, Leiferman). The parent program, called My Baby My Move, was designed as a randomized, controlled external pilot study with the intervention consisting of 8, 90-minute weekly sessions with a didactic component (e.g., educational sessions on exercise prescription, setting goals, obtaining social support) as well as an experiential component (i.e., walking, fitness ball, and yoga) at a community center. The control group had similar access to written and internet resources as the intervention group. The study was approved through Colorado Multiple Institutional Review Board (COMIRB #08-1237).

Sample

Participant recruitment for the parent study took place for 4 weeks in the fall of 2010 in university clinics, which included resident, faculty obstetrician, and faculty nurse-midwifery clinics and in the surrounding community by way of flyers. The 29 participants were sedentary, English-speaking women, aged 18-46 years with a singleton pregnancy. Participants resided in in a large metropolitan area and were between 13 and 28 weeks' gestation at the time of study enrolment. Sedentary was defined as less than 120 minutes of moderate activity per week prior to pregnancy determined by a brief screening questionnaire; 120 minutes per week was determined to be enough less than the recommended minimum of 150 minutes per week of activity for pregnant women to be considered "sedentary" [35]. Recruitment of sedentary participants was purposeful because the parent study included a physical activity intervention. Women were excluded if they were identified by the healthcare provider as having a high-risk pregnancy and/or if they were advised to avoid exercise. "High-risk" conditions are absolute contraindications as stated by the American Congress of Obstetricians and Gynecologists [26] and include, but are not limited to, heart disease, incompetent cervix, placenta previa after 26 weeks gestation, and multiple gestation.

Forty women were needed for a well-powered study, 20 per group, for detectable ß of 0.80 at alpha=0.05 and 80% power. The sample size was limited because this was a secondary data analysis, and as shown in the power analysis above, that means only a relatively large effect would be detectable. [36,37]. Permuted-block randomization was utilized with an allocation ratio of 1:1.

Procedure

Data collection was consistent with the parent program. Specifically, participants completed the consent form and baseline survey, including demographic and health behavior questionnaires, during an orientation week. Participants were also instructed in use of the pedometer and completion of the sleep diary at orientation. After baseline assessment, participants were randomly assigned to the control group (n=14) and the intervention group (n=15).

All 29 participants wore pedometers and recorded in their sleep diaries at two time points; just after baseline survey and 8-weeks later. The pedometer was worn for 3 consecutive days and the sleep diary was recorded for 7 days, overlapping with the pedometer use. Pedometer use for 3 days has been determined to be sufficient time to estimate activity [38] and the 7-day sleep diary is a standard collection time for sleep [39].

Variables and their measures

Sleep parameters: Four sleep parameters (Table 1) were measured by a standard sleep diary. The daily sleep diary is a self-reported measure of a participant's sleep and wake times and related information. The diary was completed every morning and consisted of eleven questions regarding one's sleep the previous night. Sleep diaries have been validated as accurate when compared to actigraphy and polysomnography in diverse populations [40] and are used commonly in sleep research with pregnant women [41-44].

The Pittsburgh Sleep Quality Index (PSQI) [45] is a 19-item self-rated questionnaire that assesses subjective sleep quality, latency, duration, and disturbances, sleep medication usage and daytime dysfunction in the last month. A global PSQI score>5 indicates poor sleep quality. The PSQI has shown internal consistency and reliability [43,46].

It was administered at baseline for descriptive purposes only since the primary objective of this study was to evaluate daytime PA on subsequent night's sleep.

Sleep parameter	Definition
Sleep duration or total sleep time (TST)	The number of minutes between switching off the lights and waking less the time it took to get to sleep and the number of minutes of wakefulness during the night

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Sleep onset latency (SOL)	The number of minutes that it takes to transition from full wakefulness to sleep
Sleep quality	The subjective assessment given by the participant of how restorative and undisturbed her sleep was
Wake after sleep onset (WASO)	The number of minutes awake after first falling asleep and finally waking in the morning

Table 1: Sleep parameters and definitions.

Physical activity: Physical activity was evaluated as steps per day as measured by the Yamax CW-701 Digiwalker Pedometer. The steps per day were then grouped with that night's sleep parameters to evaluate how physical activity correlated to sleep. The pedometer is a reliable measure of activity during pregnancy [47].

Personal factors: The personal factors included pre-pregnant BMI (defined as BMI just prior to current pregnancy) and were obtained from medical records for all but 3 participants. For the later 3 participants, pre-pregnant BMI was obtained from self-reported height and weight. Pre-pregnant BMIs were grouped by Institute of Medicine categories of underweight (BMI<18.5 kg/m^2), normal weight (BMI 18.5-25.9 kg/m^2), overweight (BMI 26-29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2). Gestational age (age of gestation in weeks as per last menstrual period or early ultrasound), age (maternal age at time of delivery) and parity (number of living biological children) were also obtained from medical records. Marital status and income were self-reported in baseline questionnaire.

Self-efficacy, social support, behavioral skills: The Physical Activity Self-Efficacy Questionnaire [48], a 5-item measure of self-efficacy for physical activity during pregnancy via a 5-point Likert scale to rate confidence that one will exercise in different situations (e.g. when feeling tired) with demonstrated an internal consistency of 0.76 [48]. The Social Support for Exercise Scale [49], a 10-item, 6-point Likert scale measure, assesses social support for physical activity during pregnancy and focuses on one's sense of support by friends and family to participate in physical activity, with Cronbach's α of 0.79 and 0.78 respectively (friends, family). The Importance and Effects of Physical Activity, part of the San Diego Health and Exercise Survey [50] is a 10-item, 5-point Likert scale questionnaire that focuses on belief in the positive effects of physical activity (e.g. If I participate in regular physical activity I will improve my health or reduce my risk of disease) and the importance of these effects (e.g. It is important that I improve my health).

Data analysis

Data were entered into the hierarchical linear modeling program (HLM 6: SSI, Inc., Skokie, IL) and SPSS program (SPSS version 19: IBM, Inc., Armonk, NY). In order to determine similarities or differences between the groups at the pre-intervention phase, correlations were done on the personal factors (pre-pregnant BMI, age, marital status, parity, and income).

Aim 1-impact of physical activity on sleep: Hierarchical linear modeling (HLM) was used to analyze the daily data from the pedometer and the sleep diary. Four hierarchical linear models were run, one for each sleep parameter; sleep duration, SOL, WASO, sleep quality. The data were approximately normally distributed. Of 870 possible data (29 participants, each with 6 data points of both 4 sleep measures and steps per day), this study had 36 missing data (4%). HLM is a statistical method that accounts for data that are clustered or hierarchical. HLM is flexible with regard to missing data and unequal time between measures, which occurred in this study [51]. With this research data were clustered within participants over time, and compared between groups (intervention and control). Analyses of change in sleep parameters through the pregnancy and level of sleep parameters related to physical activity level were investigated with HLM.

Each participant had six grouped (physical activity with sleep) data points, three days at the beginning of the study and three days again about eight weeks later after the physical activity intervention. Level one data included within-person data on each sleep parameter (SOL, WASO, sleep duration, sleep quality) as separate dependent variables and time as independent variable (Hp1, see Figure 1 for a schematic of the HLM analysis). Physical activity was a dependent variable when looking at the change in physical activity over time, with the parent program added as a possible mediator (Hp2, Figure 1). As well, daily physical activity's effect on nightly sleep parameters was assessed (Hp3, Figure 1). The possible confounders of pre-pregnant BMI and gestational age were added to the level two variables.

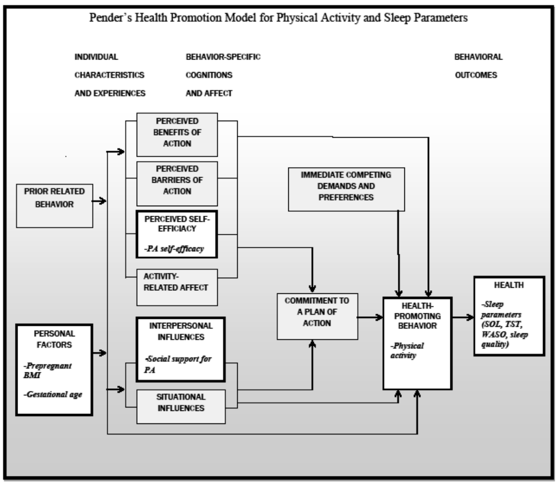

Figure 1: Research variables within Pender's Health Promotion Model.

Aim 2- pre-pregnancy BMI and personal and social factors: The correlations of pre-pregnant BMI with self-efficacy and social support for physical activity and of pre-pregnant BMI with understanding of importance and effect of physical activity were analyzed using Pearson Product Moment Correlation (Pearson *r*).

Results

Sample characteristics

The sample was diverse particularly with regards to ethnicity, age, income level, and parity (Table 2). Fifty-nine percent (n=17) of participants had a pre-pregnant BMI in the overweight or obese category (Table 3).

There was no statistical difference between the control and intervention groups in pre-pregnant BMI, age, marital status, parity, and income. Correlation analysis of pre-intervention measures of

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primary variables (daily steps and sleep parameters [sleep duration, WASO, SOL, sleep quality]) also revealed no significant difference between groups.

Variables	**Mean (range)**	**Standard deviation**
Age	30.6 (20-40)	5
	Frequency	Percent
Ethnicity*		
Caucasian	17	58.6
African American	6	20.7
American Indian	1	3.4
Asian or Pacific Islander	3	10.3
Hispanic/Latina	4	13.8
Marital status		
Single	8	27.6
Divorced or separated	1	3.4
Married	20	69
Number of children		
0	11	37.9
1	10	34.5
2	6	20.7
3	1	3.4
≥ 4	1	3.4
Income (yearly)		
<$10,000	1	3.4
$10,000-$19,999	2	6.9
$20,000-$34,999	5	17.2
$35,000-$49,999	8	27.6
≥ $50,000	11	37.9
Don't know	2	6.9
Education		
Completed H.S./GED	5	17.5
Some college	8	27.6
College degree	10	34.5
Beyond college	6	20.7
*Some participants chose more than one option; Key: H.S./GED=high school (12^{th} grade)		

Table 2: Description of sample- Demographics.

Variables	**Frequency**	**Percent**	**Mean (range)**	**Standard deviation**
Pre-pregnant BMI (Body mass index)			26.7 (16.1-55.1)	7.4
Pre-pregnant BMI by category: Underweight	1	3.4		
Normal weight	11	37.9		
Overweight	10	34.5		
Obese	7	24.1		
Gestational age at baseline (in weeks)			22.8 (12.1-31.1)	5.4

Table 3: Description of sample–Biophysical (n=29).

Physical activity levels were generally low at baseline due to purposeful recruitment of sedentary women and stayed well below recommendations for physical activity when assessed eight weeks later. By pedometer, the average number of steps per day for all participants throughout the pregnancy was 5,241. PSQI results indicate that about 38% of participants were poor sleepers at baseline and this increased to about 59% by the end of the study.

Predictors of physical activity

Daily physical activity, as measured by pedometer, did not change over time in these second trimester women, the majority of whom moved into the third trimester by study's end (Hp2 in Figure 2, p=0.469). Physical activity was not predicted by gestational age, parity, assignment to the PA intervention group, or level of compliance with the PA intervention, but it was negatively predicted by pre-pregnant BMI (Hp2b in Figure 2, Table 4, p<0.05).

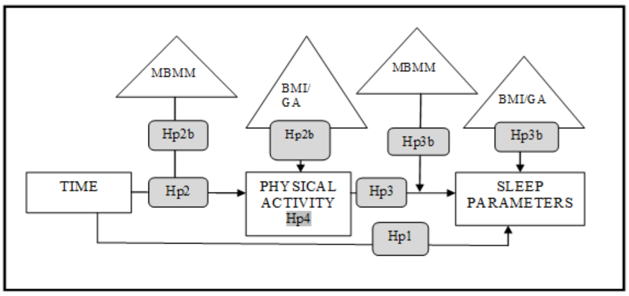

Figure 2: Schematic of primary hypotheses for hierarchical linear modelling, Hp=Steps for primary hypotheses; MBMM=Intervention; BMI=Body mass index; GA=Gestational age.

Hypothesis	**T-ratio**	***p* value**	***β* value**
Time PA	0.725	0.469	114.23
Moderators:			
MBMM assignment	-0.726	0.469	-223.38

MBMM compliance	0.443	0.658	155.45
Confounders:			
BMI level	-3.357	0.003*	-1310.77
Gestational age	-0.987	0.333	-75.42
PA=Physical Activity; MBMM=My Baby, My Move intervention; BMI=Body Mass Index *p<0.05			

Table 4: Physical activity over time.

Aim 1- impact of physical activity on sleep within the context of pre-pregnant BMI: None of the four sleep parameters evaluated changed significantly over time during pregnancy (Hp1 in Figure 2). Only sleep quality and SOL were predicted by physical activity (Hp3 in Figure 2). SOL was positively predicted by level of physical activity (p<0.05) (Table 5) and sleep quality was negatively predicted by level of physical activity (p<0.05) (Table 6).

Hypothesis	T-ratio	*p* value	*β* value
Time SOL	-0.968	0.335	-0.000973
PA SOL	2.102	0.037*	0.000001
Moderators:			
MBMM compliance	-1.259	0.210	-0.000001
Covariates:			
BMI	0.127	0.900	0.000276
Gestational age	0.475	0.638	0.000155
SOL=Sleep Onset Latency; PA=Physical Activity; MBMM=My Baby, My Move intervention; BMI=Body Mass Index; *p<0.05			

Table 5: Statistical results for primary hypotheses - Sleep onset latency.

Higher levels of physical activity predicted increased SOL and worse sleep quality. WASO and sleep duration showed no change in relation to PA level. Pre-pregnant BMI was not associated with any of the sleep parameters.

Hypothesis	T-ratio	*p* value	*β* value
Time SQ	-0.458	0.647	-0.023456
PA SQ	-2.625	0.010*	-0.000045
Moderators:			
MBMM compliance	1.891	0.060	0.000053
Confounders:			
BMI	-1.547	0.134	-0.169270
Gestational age	-1.576	0.127	-0.027686
SQ=Sleep Quality; PA=Physical Activity; MBMM=My Baby, My Move intervention; BMI=Body Mass Index; *p<0.05			

Table 6: Statistical results for primary hypotheses - Sleep quality.

	Effects of PA	Importance of PA	Prepreg. BMI
Effects of PA Pearson correlation Sig. (2-tailed)		0.054 0.780	-0.547 0.002*
Importance of PA Pearson correlation Sig. (2-tailed)			-0.019 0.924
PA=Physical Activity; BMI=Body Mass Index ; **p*<0.01 (2-tailed)			

Table 7: Correlations of pre-pregnant BMI with effects and importance of physical activity.

Aim 2- pre-pregnant BMI and self-efficacy and social support for physical activity during pregnancy and importance and effect of physical activity: The secondary hypotheses were partially supported. No associations were found between self-efficacy or social support for physical activity and pre-pregnant BMI, nor were age a contributing factor. The understanding of the importance of PA did not differ between BMI categories. Yet, higher pre-pregnant BMI was related to a belief that physical activity did not have a positive effect on health outcomes (Table 7).

Discussion

Physical activity and sleep parameters

The finding that higher activity levels predicted increased SOL and worse sleep quality was consistent with Lindseth and Vari [22], a study comparing the self-report exercise diary, which included sleep duration, with the pedometer and evaluated the physical activity-sleep relationship with daily measures in 94 pregnant women at 14 and 28-weeks' gestation. The authors [22] reported a negative relationship between daily pedometer counts and sleep duration, suggesting more steps are associated with poor sleep. Reaching significance with the limited power of this study could indicate a fairly strong relationship that warrants additional investigation.

Pragmatic reasons for this negative relationship exist, such that timing, type, and intensity of physical activity may matter when it comes to the impact of daily physical activity on sleep. It has been theorized that exercising in the later parts of the day can negatively impact sleep [52,53]. Sleep is partially thermoregulated as it is initiated when core body temperatures drop and awakening tends to occur when body temperatures rise [54]. The slight hyperthermic state after most exercise may inhibit sleep onset if done late in the day, but studies are not conclusive [54]. The association of poorer sleep with more steps could also relate to increased fetal activity following maternal activity, disrupting her sleep. In future research, concurrently recording the type of physical activity, time of day of activity, and intensity while using the pedometer or gathering this information by other methods (e.g. use of accelerometer) would help increase knowledge of daily physical activity's impact on sleep. Lastly, studying fetal movement as a possible confounder may bring some light to the findings.

Pre-pregnant BMI and physical activity

This study supported prior research [55] suggesting that obese and overweight women are less likely to be physically active than normal weight women during pregnancy. Significance was reached even with a small sample size of sedentary pregnant women.

Almost 60% of the participants were overweight or obese. The discomforts of pregnancy, increasing abdominal girth, metabolic dysfunction, and respiratory challenges may present particular barriers to physical activity for overweight and obese women. A better understanding of factors associated with lower activity levels of overweight and obese pregnant women is needed for physical activity programs to effect change for these women.

Pre-pregnant BMI and effects of physical activity

The low physical activity levels of overweight and obese pregnant women in the current study was partially explained by the finding that the overweight and obese women were less likely to believe that physical activity would improve health or result in any positive physical changes. Doubting the health benefits of physical activity may impede uptake of exercise behaviors.

Weir and colleagues' [56] qualitative investigation into the beliefs of overweight and obese pregnant women and physical activity found similar results. The women broadly endorsed a healthy lifestyle in pregnancy, including being active. The study participants understood the benefits to being active during pregnancy for themselves (e.g. easier pregnancy and delivery; feel better), but most did not adopt physical activity during pregnancy [56]. The women saw no benefits for the fetus and were actually concerned that exercise would harm the fetus. Lastly, participants tended to emphasize barriers to physical activity during pregnancy, focusing on physical barriers due to largeness and lack of information.

Pender's Health Promotion Model was invaluable in delineating factors to evaluate. The importance of cognitive beliefs in the initiation or continuation of healthy behavior, such as PA, and how cognitions impact sleep may play an essential role in the physical activity-sleep relationship. In young adults, cognitive beliefs related to exercise, such as feeling active and fit, may be more important to sleep onset and maintenance than actual physical activity [57]. Other behavior-specific cognitions within Pender's Health Promotion Model need to be investigated to help explain differences between obese and normal weight women with regards to physical activity and sleep.

Limitations

The diversity of participants in demographic and personal factors, such as ethnicity and BMI, added to the strength of this study. The use of hierarchical linear modelling (HLM) to analyze data helped to account for issues common in pregnancy research, including longitudinal data that may change over time, due to normal changes of pregnancy, and clustered data points through pregnancy.

Because this was a secondary data analysis, the sample size was limited by the size of the parent study. Therefore, the study could only detect relatively large effects. The physical activity intervention did not improve activity as measured by pedometer, so the recruited sedentary women remained sedentary. This offered limited variability in the physical activity measure of steps per day, which limited ability to find significance in relationships with sleep.

Conclusion

The findings of longer SOL and poorer sleep quality with more steps per day support some prior results and partial support for Pender's Model was evidenced. Additional studies are needed to clarify the impact of daytime physical activity on nocturnal sleep during pregnancy. Future research should delineate the effect of types, timing, and intensity of the activity and of the role of fetal movement on sleep. The results of this study also supported the finding from prior research that pregnant women with higher BMI category are less likely to be physically active. New data from this research suggest that these women were less apt to believe in any health benefits of physical activity during pregnancy, suggesting the potential value of targeted education. A comprehensive understanding of factors associated with lower activity levels in overweight and obese pregnant women is needed for physical activity programs to effect change for these women.

In practice, we need to stress the health benefits of being physically active during pregnancy, especially in overweight and obese women. Motivational interactions with women throughout pregnancy to effect positive health behavior change can have lasting impact for both mother and fetus. As well, the sleep habits of pregnant women need to be evaluated through pregnancy. If a woman is sleeping poorly, snoring, or restless, further testing and/or appropriate referral (cognitive behavior therapy and/or sleep study) should be initiated, as disturbed sleep can negatively impact maternal and fetal health [6,58,59].

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