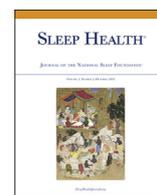


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## Physical activity and sleep quality and duration among Hispanic postpartum women at risk for type 2 diabetes: Estudio PARTO

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### ABSTRACT

**Objectives:** Poor sleep among postpartum women is associated with adverse maternal outcomes. Physical activity (PA) is associated with better sleep. However, few studies have been conducted among postpartum Hispanic women. The objective of this study was to examine the association between PA and sleep quality and duration among postpartum Hispanic women.

**Design:** A cross-sectional analysis using baseline data from Estudio PARTO, an ongoing randomized controlled trial aimed at reducing type 2 diabetes risk among Hispanic women.

**Setting:** Baystate Medical Center, in Western Massachusetts, which serves an ethnically and socioeconomically diverse population.

**Participants:** Hispanic women, at elevated risk for type 2 diabetes, at a mean of 11 weeks (SD = 4.5) postpartum.

**Measurements:** PA was measured with the Pregnancy Physical Activity Questionnaire (PPAQ), and sleep was measured with the Pittsburgh Sleep Quality Index (PSQI).

**Results:** Mean sleep duration was 5.9 hour/night (SD = 1.7) and PSQI score was 6.5 (SD = 3.9). In multivariable logistic models, sports/exercise was associated with lower odds of very poor sleep quality (PSQI >10) (OR = 0.18, 95% CI = 0.05 to 0.69). Sports/exercise (OR = 0.05, 95% CI = 0.01 to 0.26) and vigorous intensity PA (OR = 0.13, 95% CI = 0.04 to 0.42) were associated with lower odds of short (vs normal) sleep duration. There were no statistically significant relationships between PA in any other domain or intensity and sleep quality or duration.

**Conclusions:** Findings can inform interventions designed to improve postpartum sleep via increasing opportunities for exercise among postpartum women.

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### Background

Sleep disturbances are highly prevalent among postpartum women. The National Sleep Foundation reported that nearly half of postpartum women reported never or rarely getting a good night's sleep compared to only 15% of women in general.<sup>1</sup> Poor sleep, defined as poor sleep quality or short sleep duration, is associated with postpartum depression<sup>2</sup> and obesity development.<sup>3</sup> Data from the Child Community Health Network found that sleep quality at 6 months postpartum was inversely associated with depression at 6 and 12

months postpartum.<sup>2</sup> A systematic review of 13 studies found that short sleep duration (<5 h/night) vs normal sleep duration at 6 months postpartum was associated with a two and three-fold increased risk of substantial (>5 kg) postpartum weight retention at 1 and 3 years postpartum, respectively.<sup>4</sup> Postpartum weight retention places women at an increased risk for adverse maternal and fetal outcomes in future pregnancies including pre-eclampsia<sup>5</sup> and gestational diabetes.<sup>6</sup> To promote optimal maternal health, the identification of modifiable risk factors associated with poor sleep during the postpartum period is critical to inform the development of targeted interventions.

Studies in non-postpartum populations have shown that exercise has a beneficial impact on sleep.<sup>7</sup> For example, a meta-analysis of 66

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exercise and sleep interventions in non-postpartum populations found that exercise interventions had a small to moderate effect on improving objective measures of sleep duration (Cohen's  $d = 0.25$ ), and large improvements in self-reported overall sleep quality (Cohen's  $d = 0.74$ ).<sup>7</sup> However, studies examining the relationship between physical activity and sleep among postpartum women are sparse and have primarily been conducted in predominantly non-Hispanic, white populations.

The extent to which physical activity impacts sleep quality and duration may differ by race/ethnicity. For example, findings from the National Health and Nutrition Examination Survey found that self-reported recreational physical activity was positively associated with sleep duration in White, but not in Black or Hispanic participants.<sup>8</sup> Moreover, social and cultural factors such as acculturation and discrimination-related stress are associated with short and long sleep duration in Hispanic populations.<sup>9,10</sup> Therefore, it remains unclear whether physical activity influences sleep in Hispanic women above and beyond cultural or socio-economic factors.

Therefore, the objective of this cross-sectional analysis was to examine the association between domain and intensity-specific physical activity and sleep quality and duration among postpartum Hispanic women.

## Methods

### Study population

Estudio PARTO (Proyecto pAra Reducir diabetes Tipo dOs) (NCT01679210) was a randomized controlled trial that aimed to test the efficacy of a culturally and linguistically modified, individually-tailored lifestyle intervention to reduce risk factors for type 2 diabetes and cardiovascular disease among postpartum Hispanic women with a history of abnormal glucose tolerance during pregnancy. According to a recent systematic review, the highest risk period for the development of type 2 diabetes is within the first 5 years after a pregnancy during which gestational diabetes developed<sup>11</sup>; with 50% of Hispanic women developing type 2 diabetes within 5 years.<sup>12</sup> At each BMI level, Hispanics have a higher prevalence of diabetes than non-Hispanic whites.<sup>13</sup> In addition, Hispanics are the most physically inactive ethnic group in the US and are disproportionately affected by overweight and obesity.<sup>14</sup>

The study was based in the ambulatory obstetrical practices of Baystate Medical Center, a large tertiary care facility in Western Massachusetts, which serves an ethnically and socioeconomically diverse population. A detailed description of the study design is available elsewhere.<sup>15</sup> In brief, eligible women were recruited after routine screening for gestational diabetes mellitus (GDM) (~26.5 weeks gestation). Eligibility criteria included women at elevated risk for developing type 2 diabetes, defined by having an abnormal result (ie, plasma glucose concentration  $\geq 135$  mg/dL) on the routine screen for GDM (24–28 weeks gestation). Hispanic ethnicity was identified via self-report using the fixed category question, “Are you Latina or of Spanish or Hispanic origin or descent? (response options: yes, no)” in the manner of the US Census. The exclusion criteria included women with a (1) history of type 1 or type 2 diabetes, heart disease, or chronic renal disease, (2) contraindications to postpartum participation in the trial's intervention activities, which included engagement in moderate-intensity physical activity and consumption of a low-fat/high-fiber diet (eg, Crohn's disease, ulcerative colitis), or (3) inability to read English or Spanish at a 6th grade level.

Eligible women completed a baseline assessment and were randomized to a Lifestyle Intervention or to a Health & Wellness (control) Intervention. An Introductory Phase (~29 weeks gestation to the time of birth) started prior to the active intervention (~11 weeks postpartum) and served as a run-in period to identify compliant participants.

This is particularly critical for pregnant women as the postpartum transition can be a challenging time when mothers may become overwhelmed with the difficulties of caring for their new infant.

Women who completed the run-in phase, were considered eligible for the Active Phase (6 weeks postpartum–6 months postpartum) of the intervention and then a Maintenance Phase (6 months–12 months postpartum).

The participant flow is described in Fig. 1. Five hundred eighty-five participants were approached and screened for eligibility. Of these, 263 women met the eligibility criteria and were enrolled in the study. Fifty-nine were subsequently excluded prior to randomization because they were no longer interested ( $n = 25$ ),  $>37$  weeks gestation ( $n = 26$ ), or developed other medical contraindications ( $n = 8$ ). The remaining 204 women were randomized. Of these women, 149 (73%) completed the run-in phase and were entered into the Active Phase of the intervention. For the current analysis, we further excluded women missing information on physical activity, sleep quality and sleep duration for a final analytic dataset of 145 (Lifestyle intervention,  $n = 68$ ; Health & Wellness,  $n = 77$ ).

### Sleep quality and duration

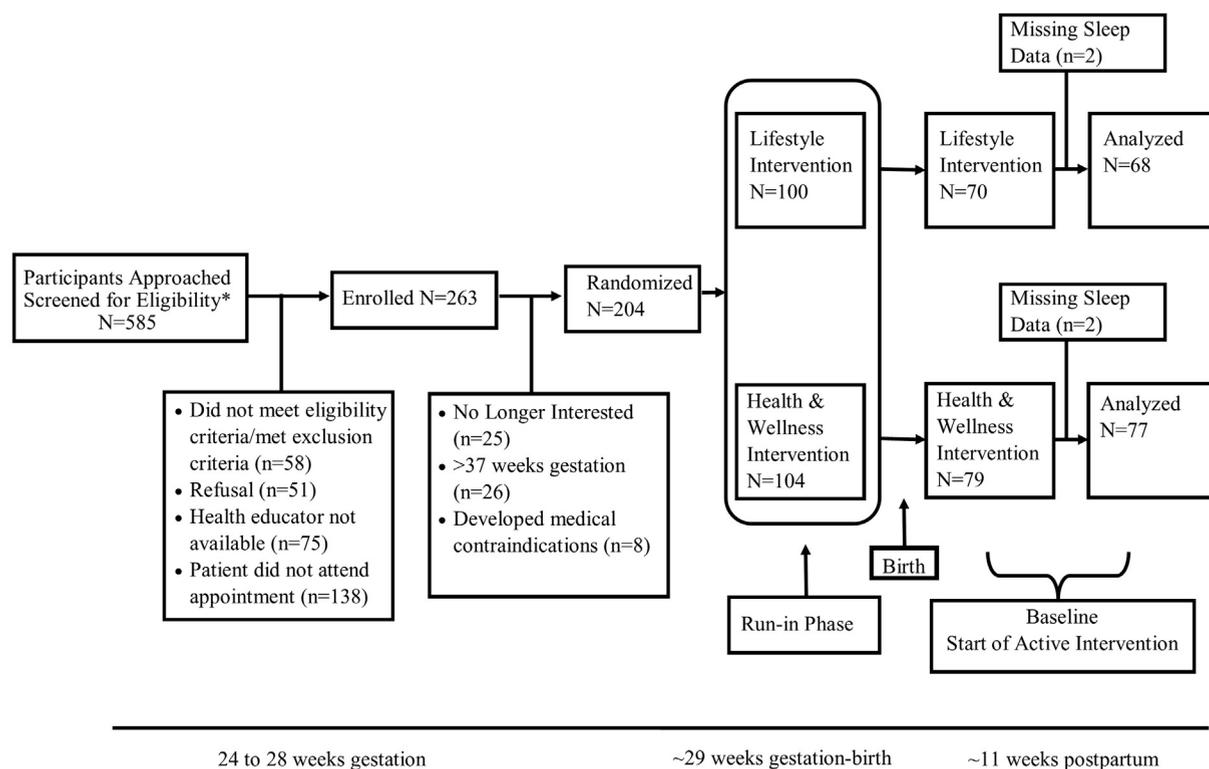
The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality and duration. The PSQI is one of the most commonly used instruments to measure self-reported sleep. The Spanish-language version of the PSQI was found to have good construct validity.<sup>16</sup> The PSQI has seven components (ie, subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction over the last month), each scored on a scale of 0 to 3. The seven components of the PSQI have high internal consistency (Cronbach's  $\alpha = 0.83$ ).<sup>17</sup>

Overall sleep quality is the sum of all components (possible range of 0 to 21), with higher scores indicating worse quality. Sleep quality was treated as both a continuous and dichotomous variable. In terms of the categorical variable, a cut point of  $>5$  has been shown to have high sensitivity (89.6%) and specificity (86.5%) at distinguishing between good and poor sleepers in non-postpartum populations.<sup>17</sup> However, because it is common for postpartum women to experience some sleep disruption after delivery,<sup>18</sup> it may be more appropriate to use a higher threshold to identify relatively worse sleep quality in the postpartum population. Since no standard criteria has been established, using the distribution of the data is an alternative method for categorizing sleep quality. We therefore used the top quartile of the distribution of total PSQI scores ( $>10$ ) to identify women with relatively worse sleep quality. We labeled this group, very poor sleepers.

Sleep duration was assessed by asking women, “How many hours of actual sleep did you get at night?” during the past month. Sleep duration was categorized into three groups: short, normal, and long using thresholds that are consistent with prior research.<sup>19,20</sup> The National Sleep Foundation recommends 7 to 8 h/d of sleep for adults but states that 6 hours/day may be appropriate.<sup>21</sup> Because reductions in total sleep time are common among women in the early postpartum period ( $<3$  months),<sup>18</sup> to be conservative, we classified short sleep duration as getting less than the appropriate duration of sleep ( $<6$  hours/night), which may represent a more realistic target for women in this population. Normal sleep duration was defined as 6 to 8 hours per night. Long sleep duration was defined as sleeping more than recommended levels (ie,  $>8$  hours/night).

### Physical activity assessment

The Pregnancy Physical Activity Questionnaire (PPAQ) is a semi-quantitative instrument, previously validated in this study



\*Eligibility criteria included women at elevated risk for developing type 2 diabetes, defined by having an abnormal result (i.e., plasma glucose concentration  $\geq 135$  mg/dL) on the routine screen for GDM (24–28 weeks gestation) and self-reported Hispanic ethnicity

Fig. 1. Participant flow chart.

population.<sup>22</sup> The PPAQ measures the duration and intensity of time spent in the past month in household/caregiving, occupational, transportation, and sports/exercise activities. The number of minutes spent in each reported activity was multiplied by its metabolic equivalent of task (MET) level and summed to arrive at an estimate of average weekly MET-hours/week.

Each activity was first classified by intensity: light (1.5–<3.0 METs), moderate ( $\geq 3$ –<6.0 METs) or vigorous ( $\geq 6.0$  METs) and the average number of MET-h/wk. expended in each intensity level was calculated. Light intensity and moderate intensity physical activity were categorized into quartiles. Vigorous intensity physical activity was dichotomized into none or some activity due to the fact that few women participated in vigorous activity.

Activities were also classified by domain (household/caregiving, transportation, occupational, and sports/exercise) and the average number of MET-h/wk. spent in each activity domain was calculated. Household/caregiving activities include those performed around the home or when caring for children, other adults, or pets. Transportation activities include walking to go places, not for exercise. Occupational activity includes physical activity as part of work. Sports/exercise includes activities undertaken for fun or exercise.

Household/caregiving and transportation activities were categorized into quartiles. Occupational activity was divided into three groups: none, low (below the median level of occupational activity), and high (above the median). Sports/exercise (ie, activity for fun or exercise) was dichotomized into none or some activity because women reported only a small proportion of their total activity in this domain.

#### Covariates

Demographic and behavioral characteristics including age, the number of adults and children in the household, parity, marital status, living situation (eg, with a spouse or partner), bed sharing (with partner), acculturation, education, annual household income, currently employment status or attending school, and breastfeeding status, current smoking status, and alcohol intake were collected at the time of enrollment via standardized questionnaires.

Clinical characteristics of the pregnancy were abstracted from the medical record and included height, prepregnancy weight, and gestational weight gain. Gestational weight gain was classified as below, within, or above recommendations based on Institute of Medicine guidelines.<sup>23</sup>

Postpartum weight was measured at the onset of the active postpartum phase of the intervention using standardized procedures. BMI was calculated as weight in kilograms (kg) divided by height in meters squared. A total of 17 (12%) participants were missing the first postpartum weight measure, and for these women we imputed missing values using weight at the subsequent postpartum assessment (6 months postpartum). Mean weight at these assessments did not differ significantly among participants with data at both time points.

Acculturation was assessed via language preference for speaking, reading, and writing, generation in the continental US, and with the Psychological Acculturation Scale (PAS).<sup>24</sup> PAS scores between 1 and <3 and 3 or greater were defined as low and high acculturation, respectively.

The Edinburgh Postnatal Depression Scale (EPDS) was used to measure depression symptoms.<sup>25</sup> This 10-item self-reported scale identifies symptoms of depression such as feeling sad or miserable, the inability to cope, and sleep disruption in the past week. The scores range from 0 to 30, with higher scores indicating more depressive symptoms. The scale has acceptable sensitivity (86%) and specificity (78%) for predicting depression.

The State and Trait Anxiety Inventory (STAI) was used to measure both current (ie, state anxiety) and a general propensity to having anxiety (ie, trait anxiety). Scores range between 20 and 40, with higher scores indicating higher anxiety levels. The STAI has been shown to have high reliability and convergent validity.<sup>26</sup> The Spanish version has also demonstrated high validity and internal consistency (Cronbach's  $\alpha = 0.93$ ).<sup>27</sup>

The Perceived Stress Scale (PSS)<sup>28</sup> is a 14-item scale used to assess how often participants experienced stress in the past month. Scores range from 0 to 56, with higher scores indicating more perceived stress. In a general population, the test–retest correlations ranged between 0.55 and 0.85.<sup>28</sup> The Spanish version has also demonstrated high validity and reliability.<sup>29</sup>

### Statistical analysis

We compared the demographic, behavioral, and psychosocial characteristics of both intervention arms to determine the success of randomization and appropriateness of combining both arms using  $\chi^2$  tests or Fisher's Exact tests for categorical variables and Wilcoxon Rank Sum tests or Student *t* tests for continuous variables. Because the active intervention was not initiated until after the baseline postpartum assessment, and there were no statistically significant differences between the intervention arms, we combined both arms for the primary analysis. Spearman rank order correlations were used to examine the correlation between sleep quality, sleep duration, and psychosocial covariates.

For the analysis of sleep quality as a categorical variable, we utilized unadjusted and multivariable logistic regression models to examine the relationship between physical activity by intensity (ie, light, moderate, vigorous) and type (ie, occupational, household/caregiving, transportation, and sports/exercise), and odds of very poor sleep quality. In each model, the lowest category of physical activity was the reference group. Odds ratios (ORs) and 95% confidence intervals (CI) were calculated.

Model 1 examined the unadjusted relationship between physical activity and sleep. Model 2 adjusted for potential confounders. We decided a priori to adjust for age, current BMI, parity, and randomization group. Additional confounders were identified using the change-in-estimate approach.<sup>30</sup> We considered factors as potential confounders if they resulted in a  $\geq 10\%$  change in the coefficients for each physical activity variable. To examine the independence of domain and intensity-specific PA, we additionally forced activity of other domains or intensities in the model. Model 3 adjusted for perceived stress as psychological stressors have been hypothesized to mediate the relationship between physical activity and sleep.<sup>31</sup> We did not adjust for depressive symptoms due to collinearity with other variables in the model. When alternatively adjusting for trait or state anxiety, our results did not change.

For the analysis of sleep quality as a continuous variable, we used unadjusted and multivariable linear regression models to examine the relationship between physical activity by intensity and type and sleep quality score.

In terms of the analysis between physical activity and sleep duration, too few women reported long sleep duration ( $n = 9$ ) to have sufficient statistical power to evaluate long sleep duration as an independent outcome. Given the association between long sleep duration (defined as  $>8$  hours) and health outcomes including

**Table 1**  
Characteristics of the study sample: Estudio PARTO, 2012–2018

	Study Sample (n = 145)		
	n	%	Mean SD
<b>Demographics</b>			
Age, y			
16–19	10	6.9	
20–24	32	22.1	
25–29	54	37.2	
30+	49	33.8	
Fasting glucose at GDM screen			164.7 31.3
Current body mass index, kg/m <sup>2</sup>			
<25	18	12.4	
25–<30	54	37.2	
$\geq 30$	73	50.3	
Gestational weight gain			
Within IOM guidelines	26	17.9	
Below IOM guidelines	6	4.1	
Above IOM guidelines	89	61.4	
Infant age, weeks			10.7 6.8
Number children in household			
0	28	19.3	
1	60	41.4	
2	31	21.4	
3+	26	17.9	
Number adults in household			
0–1	18	12.4	
2	89	61.4	
3+	37	25.5	
Parity			
0	38	26.2	
1+	106	73.1	
Married, yes	43	29.7	
Living with partner, yes	107	73.8	
Bed partner, yes	113	77.9	
Acculturation			
Low	109	75.2	
High	36	24.8	
Language preference for speaking			
English	106	73.1	
Spanish	39	26.9	
Education			
Less than high school	32	22.1	
High school graduate	45	31	
Post high school	68	46.9	
Household income			
$\leq \$15,000$	37	25.5	
$> \$15,000$ – $\$30,000$	18	12.4	
$> \$30,000$	29	20	
Don't know	61	42.1	
Working/attending school, yes	55	37.9	
<b>Behavioral</b>			
Breast feeding, yes	42	29	
Current smoking status, yes	20	13.8	
Current alcohol intake			
None	105	72.4	
1–5 drinks/month	27	18.6	
$> 5$ drinks/month	11	7.6	
<b>Psychosocial</b>			
Perceived stress			18.5 8.9
Trait anxiety <sup>a</sup>			33 14
State anxiety <sup>a</sup>			24 12.5
Edinburgh Postnatal Depression Scale <sup>a</sup>			2 6
<b>Sleep outcomes</b>			
Sleep Quality (PSQI Score)			6.5 4
Very poor sleep quality (PSQI $> 10$ )	35	24.1	
Sleep duration (hours/night)			5.9 1.7
Sleep duration (categories)			
Short ( $< 6$ hours/night)	67	46.2	
Normal (6–8 hours/night)	69	47.6	
Long ( $> 8$ hours/night)	9	6.2	

a = Median and interquartile range due to non-normal distribution; PSQI = Pittsburgh Sleep Quality Index; Note: Frequency distribution may not add up to 100% due to missing data; Note: Frequency distribution may not add up to 100% due to missing data; Note: We observed no between-group differences in intervention arms.

**Table 2**  
The odds of very poor sleep quality by physical activity domain and intensity: Estudio PARTO, 2012–2018

	Cases		Model 1		Model 2		Model 3	
	n	%	OR	95% CI	OR	95% CI	OR	95% CI
<i>By domain</i>								
<i>Sports/exercise</i>								
None	14	35.00	1.00	Referent	1.00	Referent	1.00	Referent
Some	21	21.21	0.50	0.22–1.12	0.18	0.05–0.58	0.19	0.06–0.66
<i>Occupational</i>								
None	18	21.43	1.00	Referent	1.00	Referent	1.00	Referent
Low	6	22.22	1.05	0.37–2.98	0.97	0.25–3.79	1.31	0.32–5.40
High	9	33.33	1.83	0.71–4.76	2.07	0.51–8.35	1.88	0.43–8.24
<i>P trend</i>			0.25		0.23		0.28	
<i>Household/caregiving</i>								
1st quartile	7	20.59	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	8	23.53	1.19	0.38–3.74	1.74	0.37–8.09	1.65	0.32–8.39
3rd quartile	9	25.00	1.24	0.40–3.80	3.78	0.67–21.21	3.45	0.56–21.33
4th quartile	11	30.56	1.70	0.57–5.06	4.99	0.84–29.45	3.78	0.60–23.99
<i>P trend</i>			0.34		0.11		0.18	
<i>Transportation</i>								
1st quartile	4	12.12	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	11	31.43	3.32	0.94–11.78	3.47	0.70–17.27	3.08	0.59–16.20
3rd quartile	10	30.30	3.15	0.87–11.36	5.60	1.06–29.68	3.05	0.53–17.50
4th quartile	10	26.32	2.59	0.73–9.22	1.57	0.26–9.51	1.30	0.20–8.30
<i>P trend</i>			0.38		0.73		0.97	
<i>By intensity</i>								
<i>Light</i>								
1st quartile	5	15.15	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	10	28.57	2.24	0.67–7.45	2.98	0.61–14.71	2.77	0.49–15.63
3rd quartile	11	29.73	2.37	0.73–7.74	2.40	0.43–13.40	1.07	0.15–7.73
4th quartile	9	25.00	1.87	0.55–6.29	1.88	0.32–10.92	1.19	0.17–8.34
<i>P trend</i>			0.36		0.81		0.70	
<i>Moderate</i>								
1st quartile	6	18.18	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	5	14.71	0.78	0.21–2.84	0.93	0.19–4.48	0.61	0.11–3.52
3rd quartile	11	30.56	1.98	0.64–6.15	1.99	0.41–9.53	1.73	0.32–9.41
4th quartile	12	34.29	2.35	0.76–7.25	2.46	0.53–11.56	2.28	0.43–12.15
<i>P trend</i>			0.06		0.09		0.12	
<i>Vigorous</i>								
None	26	26.53	1.00	Referent	1.00	Referent	1.00	Referent
Some	9	22.50	0.80	0.34–1.91	0.47	0.15–1.45	0.77	0.23–2.64

**Model 1** = unadjusted; **Model 2** = age (16–19, 20–24, 25–29, 30+ years), current BMI (continuous), primiparous (yes, no), income ( $\leq$ \$15,000,  $>$ \$15,000–\$30,000,  $>$ \$30,000, don't know), education (less than high school, high school graduate, post high school), number of children in the household (0, 1, 2, 3+), and physical activity in other domains/intensities; **Model 3** = Model 2 + perceived stress.

diabetes, cardiovascular disease, and obesity,<sup>32</sup> and the fact that the independent relationships between long and short sleep duration, respectively, with health outcomes may be through different mechanistic pathways,<sup>33,34</sup> we felt it was most conservative not to combine the long and short sleep duration groups.

We used a similar analytic approach as described above for assessing the relationship between physical activity and very poor sleep quality. However, in Model 3, we adjusted for depressive symptoms because collinearity with sleep quality was not observed. As a sensitivity analysis, we repeated the analysis with short sleep duration defined as  $<$ 7 hours/night.<sup>21</sup>

All analyses were considered statistically significant at an alpha  $<$ 0.05. SAS version 9.3 (SAS Institute Inc.) was used for all statistical analysis.

**Results**

The final sample included 145 women with data on sleep quality (n = 140) and/or sleep duration (n = 136). The women were primarily of Puerto Rican descent. The majority of participations reported low psychosocial acculturation (75.2%), however the majority preferred speaking in English (73.1%). The women had a mean age of 27.8 (standard deviation (SD) = 5.7) years and were 10.7 weeks (interquartile range = 6.8) postpartum. The majority of participants were overweight or obese (87.2%), multiparous (73.1%), were not married (70.3%), but were living with a partner (73.8%). Nearly 80% of

women shared a bed with a partner. Less than half of the women were currently working or attending school. Approximately 14% and 8% of women currently smoked and consumed 5 or more drinks per month respectively. Less than a third of women breastfed their child. There were no differences in any demographic, behavioral, or psychosocial variable between the intervention groups (Table 1).

The mean PSQI score was 6.5 (SD = 4.0), with 53.6% of the women reporting scores greater than 5 (ie, poor sleep quality). A total of 34 (24.1%) women reported PSQI scores  $>$ 10 (ie, very poor sleep quality). Participants reported approximately 5.9 (SD = 1.7) hours of sleep per night, with 46.3% reporting short sleep duration respectively. There were no statistically significant differences in sleep quality or duration between the intervention groups (Table 1). There was a strong, statistically significant inverse association between sleep quality and sleep duration ( $\rho = -0.81, P < .01$ ). There were moderate, statistically significant positive associations between sleep quality and depressive symptoms ( $\rho = 0.44, P < .01$ ), state anxiety ( $\rho = 0.36, P < .01$ ), trait anxiety ( $\rho = 0.36, P < .01$ ), and perceived stress ( $\rho = 0.38, P < .01$ ). There were weak, but statistically significant inverse associations between sleep duration and depressive symptoms ( $\rho = -0.28, P < .01$ ), state anxiety ( $\rho = -0.21, P = .01$ ), trait anxiety ( $\rho = -0.25, P < .01$ ), and perceived stress ( $\rho = -0.22, P = .01$ ).

The majority of total physical activity was accumulated through household/caregiving activity (median = 75.3%, IQR = 26.1%). Transportation activities comprised the second largest proportion of total physical activity (median = 8.5%, IQR = 8.2%). Sports/exercise made

up approximately 1.7% (IQR = 4.3%) of total physical activity, with 28.2% of women reporting no sports/exercise. Women who reported some sports/exercise typically reported 6.0 (IQR = 13.3) MET-h/wk (~15 min/d). Most women did not engage in any occupational activity (62%).

#### Physical activity and sleep quality

We then evaluated the association between physical activity and very poor sleep quality (Table 2). In unadjusted models, there were no statistically significant associations between physical activity, in any domain or intensity level, and very poor sleep quality. After adjusting for age, BMI, parity, the number of children in the household, education, income, and activity reported in other domains, women that reported engaging in some sports/exercise (vs none) had lower odds (OR = 0.18; 95% CI = 0.05 to 0.58) of reporting very poor sleep quality. Further adjustment for perceived stress had little impact on the observed association. We found no statistically significant associations between any measure of physical activity and sleep quality as a continuous outcome.

#### Physical activity and sleep duration

We then evaluated the association between physical activity and sleep duration (Table 3). In unadjusted analysis, women who

reported participating in some sports/exercise (vs none) had lower odds of short sleep duration (OR = 0.41, 95% CI = 0.18 to 0.91). Adjustment for age, current BMI, and physical activity reported in other domains strengthened the associations (OR = 0.05, 95% CI = 0.01 to 0.26). Further adjusting for depressive symptoms had little impact on the results. Similarly, in adjusted models, women who reported participating in some vigorous-intensity physical activity had 0.13 odds of reporting short sleep duration (95% CI = 0.04 to 0.42). There was no association between physical activity in the other domains or intensity levels and sleep duration. Finally, in terms of our sensitivity analysis, we found no statistically significant associations between physical activity and short sleep duration defined as <7 hours/night.

#### Discussion

In this cross-sectional analysis of postpartum Hispanic women at risk for developing type 2 diabetes, we found that engaging in sports/exercise was associated with lower odds of very poor sleep quality. In addition, engaging in sports/exercise or vigorous intensity physical activity was associated with approximately 75% to 80% lower odds of reporting short sleep duration. There were no statistically significant associations between occupational, household/caregiving, transportation, or light intensity physical activity with sleep quality or duration.

The relationship between moderate and vigorous intensity physical activity trended in opposite directions. Our observation of a

**Table 3**  
The odds of short sleep duration by physical activity domain and intensity: Estudio PARTO, 2012–2018

	Cases		Model 1		Model 2		Model 3	
	N	%	OR	95% CI	OR	95% CI	OR	95% CI
<i>By domain</i>								
<i>Sports/exercise</i>								
None	23	65.7	1.00	Referent	1.00	Referent	1.00	Referent
Some	43	43.9	0.39	0.18–0.87	0.25	0.10–0.66	0.17	0.06–0.53
<i>Occupational</i>								
None	43	52.4	1.00	Referent	1.00	Referent	1.00	Referent
Low	8	32	0.43	0.17–1.10	0.28	0.03–2.33	0.23	0.02–2.45
High	13	52	1.06	0.44–2.56	0.85	0.11–6.78	1.12	0.12–10.40
<i>P trend</i>			0.72		0.41		0.25	
<i>Household/caregiving</i>								
1st quartile	14	40.0	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	18	51.4	1.59	0.62–4.09	1.88	0.56–6.28	1.12	0.28–4.84
3rd quartile	18	52.9	1.69	0.65–4.38	2.92	0.80–10.66	2.80	0.66–11.89
4th quartile	17	53.1	1.70	0.65–4.48	3.01	0.81–11.19	2.15	0.47–9.85
<i>P trend</i>			0.28		0.15		0.34	
<i>Transportation</i>								
1st quartile	16	48.5	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	16	47.1	0.94	0.36–2.46	0.62	0.18–2.15	0.44	0.11–1.84
3rd quartile	18	56.3	1.37	0.51–3.63	1.31	0.37–4.63	1.55	0.37–6.49
4th quartile	15	45.7	0.90	0.35–2.32	0.54	0.14–2.12	0.52	0.11–2.41
<i>P trend</i>			0.89		0.56		0.58	
<i>By intensity</i>								
<i>Light</i>								
1st quartile	14	41.2	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	18	51.4	1.51	0.58–3.92	1.57	0.44–5.63	0.87	0.21–3.55
3rd quartile	20	57.1	1.91	0.73–4.96	1.72	0.45–6.63	0.93	0.22–4.00
4th quartile	15	46.9	1.26	0.48–3.34	0.99	0.24–4.19	0.60	0.13–2.77
<i>P trend</i>			0.55		0.79		0.92	
<i>Moderate</i>								
1st quartile	14	41.2	1.00	Referent	1.00	Referent	1.00	Referent
2nd quartile	17	53.1	1.62	0.61–4.29	2.32	0.67–8.06	3.70	0.92–14.82
3rd quartile	17	50.0	1.43	0.55–3.73	2.27	0.58–8.88	2.94	0.68–12.72
4th quartile	18	54.6	1.71	0.65–4.51	2.01	0.50–8.11	2.45	0.54–11.08
<i>P trend</i>			0.35		0.27		0.31	
<i>Vigorous</i>								
None	53	55.8	1.00	Referent	1.00	Referent	1.00	Referent
Some	14	36.8	0.46	0.21–1.00	0.22	0.08–0.60	0.29	0.10–0.85

**Model 1** = unadjusted; **Model 2** = age (16–19, 20–24, 25–29, 30+ years), current BMI (continuous), primiparous (no, yes), working/attending school (no, yes), and physical activity in other domains/intensities; **Model 3** = Model 2 + depressive symptoms.

divergent impact of moderate vs vigorous intensity activity on sleep may reflect differences in the types of activities that make up moderate and vigorous activity. For example, moderate intensity physical activity was largely composed of household/caregiving activities, including caring for an older adult, whereas vigorous intensity physical activity was largely composed of sports/exercise including as walking. Caring for others, with little social support, may result in shorter sleep opportunities and of less quality. Additional research using movement monitors, which can better differentiate intensities,<sup>35</sup> are needed to elucidate the relationship between the intensity of physical activity and sleep.

Prior studies examining the relationship between physical activity and sleep among postpartum women are sparse and have produced mixed results.<sup>36–39</sup> One recent study examined the association between domain-specific moderate-vigorous intensity PA (MVPA) and sleep quality and sleep duration at 3 and 12 months postpartum among 688 participants (4.6% Hispanic).<sup>36</sup> Sleep quality was assessed with a single question that asked about their sleep on most nights. In contrast to our findings, the authors found no association between MVPA in any domain and sleep quality or duration at 3 months postpartum. However, at 12 months postpartum, every additional hour of recreational activity was associated with 14% increased odds of reporting good (vs poor) quality sleep (95% CI = 1.03–1.27). The contrasting findings at 3 months postpartum may be due to differences in the assessment of sleep and physical activity.

Consistent with our findings, Lillis et al. examined the association between exercise and total sleep duration among 60 nulliparous women (93.3% non-Hispanic White) between 3 to 6 months postpartum. Women reported the type and number of minutes they exercised in an evening diary. Total sleep time, sleep onset latency and wake after sleep onset was measured with wrist actigraphy and subjective sleep quality and nighttime arousals were assessed with a morning sleep diary. Mean exercise duration was positively associated with total sleep time ( $\beta = 0.447$ ,  $SE = 219$ ,  $P < .05$ ). In addition, total sleep duration was longer on days participants exercised more than the mean average ( $\beta = 0.318$ ,  $SE = 149$ ,  $P < .05$ ).<sup>37</sup> However, odds of short sleep duration was not assessed.

Our study has several strengths. Firstly, we used the PPAQ to measure physical activity, which was validated in a similar population of Hispanic women. The PPAQ allows us to capture domain-specific physical activity, which provides contextual information about physical activity. Others have also suggested that domain-specific physical activity varies greatly in its characteristics, energy expenditure, and physiological consequences, and plausibly could have a different mechanistic relationship with sleep.<sup>40</sup>

Secondly, prior studies among postpartum women were conducted in predominantly healthy non-Hispanic White samples. In the current sample, the women were Hispanic at risk for developing type 2 diabetes. While our findings may have limited generalizability to other Hispanic populations, the burden of poor sleep and adverse maternal outcomes are high in this group, making it important to identify modifiable risk factors in this population so that targeted interventions can be developed.

Our study faces several limitations. First, due to the cross-sectional nature of the current analysis, we cannot establish a temporal relationship between physical activity and sleep. For example, we cannot determine whether participation in sports/exercise led to better sleep quality or if women with better sleep were able to be more physically active. Second, our study was also limited by the reliance on self-reported measures of sleep quality and duration. However, the PSQI, one of the most widely used measures of self-reported sleep quality, has shown the ability to distinguish between good and poor sleep.<sup>17</sup> Third, there are no standardized criteria for defining very poor sleep quality in postpartum women. Therefore, we relied upon the top quartile of the distribution of total PSQI scores to

identify very poor sleepers. Thus, our cut-point may be specific to this population and possibly not be generalizable to other studies. However, the findings do provide evidence to support our hypothesis that variability in physical activity is associated with variability in sleep quality.

Fourth, we did not collect information on infant characteristics including feeding habits, nocturnal sleep duration, or sleep location. To the extent to which these characteristics are associated with physical activity and/or maternal sleep, they could potentially confound our results. In addition, we did not collect information on shift work. To the extent to which shift work is associated with both physical activity and maternal sleep, lack of control for this factor could potentially confound our results. Lastly, the PSQI does not collect information on daytime napping, so total sleep duration could not be calculated. However, Lillis et al., found that among women between 3 and 6 months postpartum, those that exercised had longer total sleep time than women that did not exercise.<sup>37</sup> These findings reduce concern that non-exercisers nap during the day to make up for a lack of sleep at night, and therefore support our hypothesis that exercise is associated with longer sleep duration.

Finally, we did not collect information on the participant's specific country of origin. However, based on US census data on Springfield, Massachusetts, the women were primarily of Puerto Rican origin. Therefore, our results are likely generalizable to postpartum women of Puerto Rican origin with a history of impaired fasting glucose during pregnancy.

In conclusion, poor sleep is common among postpartum women, and there is a need to develop targeted interventions to improve sleep in this group. In this cross-sectional analysis of data from postpartum Hispanic women at risk for type 2 diabetes, we were able to generate hypotheses about potential exposures which can be modified to promote better sleep in this population. We found that participation in sports/exercise was associated with a lower odds of very poor sleep quality and short sleep duration. These results support the hypothesis that physical activity has a beneficial relationship with sleep among postpartum women. Additional prospective studies are needed to explore the temporal relationship between physical activity and sleep.

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