

## Journal Pre-proof

The association between light exposure before bedtime in pregnancy and the risk of developing gestational diabetes mellitus



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**Title:** The association between light exposure before bedtime in pregnancy and the risk of developing gestational diabetes mellitus

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**Objective:** Growing evidence suggests that exposure to light at night may be linked to impaired glucose regulation in non-pregnant adults. However, little is known about the effect of evening light exposure during pregnancy on the risk of gestational diabetes mellitus (GDM), a common pregnancy complication with significant health implications for both mother and offspring. Our objective was to investigate the association between objectively measured evening light exposure before sleep during pregnancy and the risk of GDM.

**Study Design:** In this prospective cohort study conducted at 8 clinical U.S. sites between 2011 and 2013, nulliparous women  $\geq 18$  years with a viable singleton pregnancy were recruited between 16<sup>0</sup>-21<sup>6</sup> weeks of gestation to wear a photosensor-integrated wrist actigraphy monitor (Spectrum, Philips Respironics, Murrysville, PA) and complete a sleep diary for 7 consecutive days.<sup>1,2</sup> This study was approved by the institutional review board at each site, and all women gave informed written consent before enrollment. Based on recent recommendations on the maximum evening light exposure,<sup>3</sup> we defined the primary exposure variable as the minutes of light exposure  $\geq 10$ -lux (dim light) during the three hours preceding sleep onset (“Pre-sleep light”), averaged across all valid days of recording (i.e.,  $\geq 20$  hours of wear time in 24 hours; minimum 5, maximum 7 days) and categorized to tercile groups (i.e., “Dim,” “Moderate,” and “Bright”). The primary outcome was the incidence of GDM detected during routine screening between 24-28 weeks of gestation.<sup>2</sup> Associations of pre-sleep light with baseline characteristics and actigraphy-derived sleep variables were examined using Chi-square, Fisher’s exact, and Kruskal-Wallis rank sum tests. We assessed the association of pre-sleep light with GDM with univariate logistic regression and further explored this association with multiple logistic regression after adjustment for potential confounders. Covariates chosen *a priori* included maternal age, early pregnancy body mass index (BMI), maternal race/ethnicity, and timing and duration of sleep, based on established risk factors of GDM, and the season. Additional covariates were chosen based on their association with pre-sleep light or GDM. All tests were performed at a nominal significance level of  $\alpha=0.05$  with two-sided, single-degree-of-freedom tests.

**Results:** Our final analysis included 741 women (ages 18-43; 63% non-Hispanic White; 22% BMI  $\geq$ 30) whose median gestational age was 20<sup>5</sup> weeks (interquartile ratio (IQR) 19<sup>4</sup>-21<sup>6</sup>) on the first day of actigraphy recording. Demographic characteristics are summarized in **Table S1**. Women in the Bright group spent 1.7 (IQR 1.5-1.9) hours in the dim light (<10-lux) during the 3 hours before sleep (vs. Moderate, 2.2 (IQR 2.1-2.3) vs. Dim, 2.6 (IQR 2.5-2.7) hours). Actigraphy-derived light and sleep variables are summarized in **Table S2**. GDM occurred in 31 (4.2%) participants. Greater pre-sleep light exposure was associated with an increased risk of GDM (odds ratio [95% confidence interval]: Bright 5.49 [1.8–23.84]; Moderate 4.05 [1.27–17.94], vs. Dim group). After adjusting separately for age, BMI, race/ethnicity, education, commercial insurance, employment schedule, season, sleep duration, sleep midpoint, sleep regularity index, and daytime light exposure, pre-sleep light exposure remained significantly associated with GDM (**Table 1**). **Figure 1** demonstrates 24-hour profiles of light and activity by GDM status. Women who developed GDM had greater light exposure in the three hours before sleep onset yet did not differ in their light exposure during daytime or sleep or in their activity levels compared to those who did not develop GDM.

**Conclusion:** Our study suggests that greater light exposure before sleep during the second trimester is associated with an increased risk of GDM. This association was not explained by the timing or duration of sleep. These findings are consistent with prior studies in nonpregnant adults, where evening light exposure before sleep acutely impaired energy metabolism and insulin sensitivity.<sup>4</sup> Pre-sleep light exposure may affect glucose metabolism through sympathetic overactivity, altered circadian gene expression, or melatonin suppression. Strengths of this study include week-long, objective measures of light and sleep patterns in a sample diverse in age and socioeconomic measures. However, this study has important limitations, including light measured at the wrist, which may not reflect light exposure at the eye and could have been affected by clothing, and a single light assessment which may not represent habitual light exposure throughout pregnancy. The rate of GDM, while lower than the rate (7.8%) among all women who gave birth in 2020,<sup>5</sup> was on par with the incidence (4.5%) among all nulliparous women aged 18-44 with a singleton live birth in the U.S. between 2011-2013.<sup>6</sup> Reducing evening light exposure,

such as limiting light-emitting devices, is a modifiable behavior. Future work will examine whether reducing light before sleep improves maternal and offspring health outcomes.

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## Tables

Table 1. Association of evening pre-sleep light exposure with gestational diabetes mellitus

Pre-sleep light categories	GDM n/N (%)	Crude OR (95% CI), N = 741	Adjusted OR (95% CI), after adjustment for:				
			Age, linear and quadratic N = 741	BMI, linear and quadratic N = 731	Race/ethnicity, 4 categories, N = 741	Education, N = 741	Commercial Insurance, yes/no N = 740
Q1 (Dim)	3/247 (1.2)	1.00	1.00	1.00	1.00	1.00	1.00
Q2 (Moderate)	12/247 (4.9)	<b>4.05 (1.27, 17.94)</b> p-value = 0.032	<b>3.84 (1.2, 17.04)</b> p-value = 0.0398	<b>4.33 (1.35, 19.28)</b> p-value = 0.0252	<b>4.24 (1.31, 18.94)</b> p-value = 0.0282	<b>5.29 (1.59, 24.16)</b> p-value = 0.0131	<b>4.4 (1.37, 19.55)</b> p-value = 0.0236
Q3 (Bright)	16/247 (6.5)	<b>5.49 (1.8, 23.84)</b> p-value = 0.007	<b>5.02 (1.63, 21.93)</b> p-value = 0.0118	<b>5.97 (1.94, 26.02)</b> p-value = 0.0052	<b>5.92 (1.89, 26.18)</b> p-value = 0.0061	<b>7.2 (2.26, 32.23)</b> p-value = 0.0026	<b>6.38 (2.06, 27.94)</b> p-value = 0.0039

OR given to show association between gestational diabetes and evening light, without consideration of covariates and with separate adjustment for: age; BMI categories; season; race/ethnicity; education; and commercial insurance.

For race/ethnicity, Asian and other are collapsed. Education was dichotomized to high school education or less vs. some college or more.

Pre-sleep light was defined as minutes spent at or above 10 lux (i.e., dim light) during 3 hours prior to the main sleep interval, averaged across all valid days of recording. In the absence of an established cutoff for pre-sleep light with clinical significance, we transformed pre-sleep light into terciles. Women were categorized based on these terciles as being in Dim (Q1), Moderate (Q2), or Bright (Q3) groups. In other words, the Dim group spent the shortest time (median 24 minutes, IQR 33-69) at or above 10 lux in the 3 hours prior to sleep and the bright group spent the most time (median 79 minutes, IQR 69-89) at or above 10 lux in the 3 hours prior to sleep.

Abbreviations: GDM, gestational diabetes mellitus; OR, odds ratio; CI, confidence interval; BMI, body mass index. IQR, interquartile range



**Table 1 (Continued). Association of evening pre-sleep light exposure with gestational diabetes mellitus**

Pre-sleep light categories	GDM n/N (%)	Crude OR (95% CI), N = 741	Adjusted OR (95% CI), after adjustment for:					
			Employment Schedule, 3 categories N = 713	Season, N=741	Sleep midpoint > 5AM, N = 741	Sleep duration < 7h, N = 741	SRI ≤ 25th percentile, N = 739	Daytime light, N=741
<b>Q1 (Dim)</b>	3/247 (1.2)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
<b>Q2 (Moderate)</b>	12/247 (4.9)	<b>4.05 (1.27, 17.94)</b> p-value = 0.032	<b>4.85 (1.21, 32.42)</b> p-value = 0.0476	<b>3.96 (1.23, 17.59)</b> p-value = 0.0356	<b>5.2 (1.59, 23.43)</b> p-value = 0.0129	<b>4.3 (1.34, 19.09)</b> p-value = 0.0257	<b>4.2 (1.31, 18.65)</b> p-value = 0.0284	<b>4.63 (1.39, 21.06)</b> p-value = 0.0223
<b>Q3 (Bright)</b>	16/247 (6.5)	<b>5.49 (1.8, 23.84)</b> p-value = 0.007	<b>9.26 (2.53, 59.92)</b> p-value = 0.0037	<b>5.37 (1.75, 23.41)</b> p-value = 0.0085	<b>7.19 (2.29, 31.82)</b> p-value = 0.0024	<b>5.68 (1.86, 24.71)</b> p-value = 0.0064	<b>6.5 (2.1, 28.48)</b> p-value = 0.0035	<b>6.7 (2, 30.85)</b> p-value = 0.0049

OR given to show association between gestational diabetes and evening light, without consideration of covariates and with separate adjustment for: work schedule; season of recording; sleep midpoint > 5AM; sleep duration < 7h; SRI ≤ 25th percentile; and daytime light.

Work schedule was categorized to: shift work, student or regular day shift, and unemployed. 25th percentile of SRI was 71.3. Daytime light was measured by the average log-transformed light intensity during the 10 brightest hours.

Pre-sleep light was defined as minutes spent at or above 10 lux (i.e., dim light) during 3 hours prior to the main sleep interval, averaged across all valid days of recording. In the absence of an established cutoff for pre-sleep light with clinical significance, we transformed pre-sleep light (in minutes) into terciles. Women were categorized based on these terciles as being in Dim, Moderate, or Bright groups. In other words, the Dim group spent the shortest time (median 24 minutes, IQR 33-69) at or above 10 lux in the 3 hours prior to sleep and the bright group spent the most time (median 79 minutes, IQR 69-89) at or above 10 lux in the 3 hours prior to sleep.

Abbreviations: GDM, gestational diabetes mellitus; OR, odds ratio; CI, confidence interval; SRI, sleep regularity index; IQR, interquartile range

## Figures

### Figure 1.

**Title:** 24-hour light and activity profiles by gestational diabetes mellitus (GDM)

**Caption:** In the Sleep Duration and Quality Substudy of the Nulliparous Pregnancy Outcome Study:

Monitoring Mothers-to-be (nuMoM2b), 741 nulliparous women wore a wrist actigraphy for 7 consecutive days between 16<sup>0</sup>-21<sup>6</sup> weeks of pregnancy, followed by a routine GDM screening between 24<sup>0</sup>-28<sup>6</sup> weeks of pregnancy. We extracted individual light exposure (in lux) and activity levels (in counts) from the actigraphy recording and plotted 24-hour data in 1-hour bins relative to sleep onset, averaged across all valid days of recording. The top panel demonstrates hourly light exposure (A) and activity (B) profiles in women who later developed GDM (red; n=31) and in women who did not develop GDM (blue; n=710). Women who developed GDM were exposed to more light during the 3 hours (A, grey dotted box) before sleep onset, compared to those who did not develop GDM. There was no difference in activity levels across the day by GDM status (B). The bottom panel further details the 3 hours before sleep onset (C, D). We plotted light (C) and activity (D) data during this period in 15-minute bins to demonstrate differential light exposure patterns before bedtime in those who developed GDM (red) compared to those who did not develop GDM (blue). Women who developed GDM were exposed to more light up until 30 minutes before bedtime (C). Again, activity levels were not different between the two groups in any time bin (D). The solid lines represent the group average, and error bars indicate the 95% confidence interval. \*p < 0.05 after adjusting for age, body mass index, the season of recording, sleep duration < 7h, and sleep midpoint >5AM.

