

Shortening day length: a potential risk factor for perinatal depression

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Abstract The aim of this secondary analysis was to determine whether seasonal light exposure, categorized by type of day length, is associated with or predictive of depressive symptoms in late pregnancy and the first 3 months postpartum. Women ($n = 279$) expecting their first child were recruited from prenatal clinics and childbirth education classes. Depressive symptoms were assessed with the Center for Epidemiologic Studies Depression Scale. Day lengths were categorized into short, lengthening, long and shortening. Data analysis included linear mixed models and multiple linear regression. When days were shortening (August to first 4 days of November) in late third trimester, depressive symptom scores were highest (35%) and continued to be higher at each postpartum assessment compared to other day length categories. Implications for clinical practice include increased vigilance for depressive symptoms, particularly if late pregnancy and birth occurs during the 3 months around the Autumn equinox when day length is shortening. Strategies

that increase light exposure in late pregnancy and postpartum should also be considered.

Keywords Day length · Season · Autumn · Winter · Pregnancy · Postpartum · Depressive symptoms · Sleep · Actigraphy · Mood

Introduction

Defined as the onset of an affective mood disorder within the first 12 months after childbirth, postpartum depression (PPD) affects up to 20% of all women (American College of Obstetricians and Gynecologists [ACOG], 2016; Sit et al., 2015). Multiple biological, psychological, and social factors are well documented in the development of PPD. A previous history of depression, depression during pregnancy (Kettunen & Hintikka, 2017), and a history of intimate partner violence (Howard et al., 2013) are among the psychological factors associated with PPD. Biological factors related to PPD include sleep disturbance (Goyal et al., 2009; Stremmer et al., 2017), low vitamin D levels (Fu et al., 2015; Gur et al., 2014; Robinson et al., 2014) and melatonin hormonal changes (Werner et al., 2015). Social factors include low socioeconomic status (Goyal et al., 2010), low level of social support (Kettunen & Hintikka, 2017), and adolescence or advanced maternal age (Muraca & Joseph, 2014; Torres et al., 2017).

Although reduced exposure to natural light has been associated with depression among adults in the general population (Marqueze et al., 2015), conflicting research exists regarding the effect of light exposure or seasonality on depressive symptoms during pregnancy and postpartum. Light exposure influences levels of vitamin D (National Institutes of Health, 2016) as well as melatonin secretion,

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and research suggests that light therapy may be effective for adults who experience seasonal affective disorder, also known as “winter depression” (Golden et al., 2005; Nussbaumer et al., 2015). Using actigraphy monitoring for light exposure, Wang et al. (2003) found no difference in mood or light exposure over 72 h when they compared 15 postpartum women with 22 non-pregnant women during a 2-month period (July–August) in San Diego CA. Moreover, they concluded that infant care responsibilities did not limit postpartum women’s light exposure (Wang et al., 2003). In a sample of 15 women with PPD randomized to 6 weeks of bright light or dim red light, both groups improved (Corral et al., 2007). In their review of five studies on efficacy of light therapy for antenatal depression and PPD, Crowley and Youngstedt (2012) concluded that bright light therapy may be beneficial for pregnant/new mothers by offsetting insufficient low light levels. To promote sleep among mothers with infants in the intensive care unit, researchers tested the effectiveness of bright light on sleep and depressive symptoms among women randomized into a control ($n = 14$) or treatment ($n = 16$) group (Lee et al., 2013). Women in the treatment group self-administered blue–green bright light 30 min per day for 3 weeks using a light visor. No statistically significant difference was noted between the two groups in this small sample, however, there was improvement in depression scores for the treatment group (Cohen’s d effect size = 0.40).

With inconclusive research findings regarding light exposure and light therapy for PPD, the aim of this secondary analysis was to determine if seasonal light exposure is associated with depression symptoms after controlling for known risk factors such as depression history, age and low socioeconomic status. During months with short day lengths, less daylight may influence levels of vitamin D and melatonin, placing women at further risk for depression than pregnancy and other known bio-psycho-social risk factors. Therefore, we aimed to test three hypotheses: (1) seasonal day length will be associated with the trajectory of postpartum depressive symptoms over time, (2) third trimester symptoms of depression will be associated with day length after controlling for bio-psycho-social factors, and (3) day length at third trimester will be predictive of depressive symptoms at 3 months postpartum after controlling for current day length, history of depression, and third trimester depressive symptoms.

Methods

Participants

The data for this secondary analysis were drawn from two longitudinal clinical trials designed to improve maternal

sleep in the postpartum period [removed for blind review]. Parity was controlled by recruiting only first-time mothers, and health status was controlled by recruiting only low risk pregnant women in the third trimester with no indications of pregnancy complications. Both studies were approved by the Committee on Human Research at [removed for blind review] and all participants provided written consent prior to any data collection. Participants in the original studies were recruited during their third trimester between 2001 to 2003 and 2004 to 2008 using convenience sampling from childbirth education classes and antenatal clinics in Northern California. Participants for the 2001–2003 study were recruited from paid childbirth preparation classes with both the pregnant women and her partner enrolled, yielding an older, more affluent, and largely Caucasian sample. In 2004–2008, participants were recruited from clinics primarily serving low-income women, which yielded a younger, less affluent, and racially and ethnically diverse sample. Women were included in the study if they were ≥ 18 years of age, expecting their first child, and able to read and write in English. Detailed eligibility criteria for the two trials have been previously reported [removed for blind review]. The first sample included women with a past history or episode of depression or other mental health problem ($n = 17$) and the second sample excluded women with any history of mental health problems. At enrollment into the study, all women received an information sheet about PPD that included a contact list of available local resources.

Measures

Demographic and personal characteristics

All participants completed demographic questions (age, race/ethnicity, marital status, monthly income, educational level, employment status) and pregnancy history information in the third trimester. During the first 2 weeks postpartum, participants provided information by telephone that included type of birth (vaginal, cesarean), length of hospital stay for mother and infant, and infant’s gender and birth weight.

Seasonal day length

Due to the earth’s changing position with respect to the sun, seasons are characterized by temperature and weather patterns defined by specific calendar start and end dates. In the northern hemisphere, spring is from March equinox to June solstice, summer is from June solstice to September equinox, autumn is from September equinox to December solstice, and winter is from December solstice to March

equinox. While the exact day depends on the year and time zone, twice each year at equinox, day and night lengths are equal (Sept 22 and March 20). Each year, the sun reaches its highest point at noon (summer solstice; longest day) and its lowest point at noon (winter solstice; shortest day) (National Weather Service, 2017).

For this analysis, we used equal distance from the middle of each season, rather than the start of each season, to represent day length in order to maximize the difference between the four types of seasonal day lengths. Thus, the category for “short” day length was from November 5 to February 4, the “lengthening” days category was February 5 to May 4, the “long” days category was May 6 to August 4, and the “shortening” days category was from August 5 to November 4. Given the potential importance for early clinical intervention, seasonal day length category at the time of the late third trimester measures was of primary interest. Because time from the late third trimester measures to the date of birth varied between 1 and 4 weeks, seasonal day length at birth was also examined for its relationship to postpartum depressive symptom scores.

Depressive symptoms

The 20-item, self-report, Center for Epidemiologic Studies-Depression (CES-D) 20-item scale (Radloff, 1977) was used to assess frequency of depressive symptoms in the third trimester and at 1, 2, and 3 months postpartum. The CES-D is well validated and has been used to assess prenatal and postpartum depressive symptoms (Beeghly et al., 2003; Marcus, 2009). Participants were asked to rate their symptoms during the prior week by indicating how often they experienced each symptom on a 4-point Likert scale ranging from 0 (rarely/none or less than 1 day) to 3 (most/all of the time or 5–7 days). Total scores can range from 0 to 60, with higher scores indicating more frequent depression symptoms. A score of ≥ 16 on this depression screening tool indicates high risk for PPD and the need for further assessment of clinical depression (Easterbrooks et al., 2016; Marcus et al., 2003). To estimate internal consistency reliability for the CES-D, Cronbach alpha coefficients were calculated and acceptable at .85 during the third trimester assessment, and above .86 at each postpartum visit.

Perceived stress

The 10-item version of the Perceived Stress Scale (PSS) was used to assess level of stress during the past month (Cohen et al., 1983). Items assess specific stress domains of unpredictability, lack of control, burden overload and stressful life circumstances; responses are based on a

5-point Likert scale (0 “never” to 4 “experienced very often”). Total scores can range from 0 to 40, with higher scores indicative of greater perceived stress. The PSS provides a global assessment of perceived stress, which has been shown to contribute to PPD (Shaw et al., 2000). The Cronbach alpha coefficient in this sample was $\geq .80$ at each time point.

Relationship satisfaction

The 13-item Relationship Satisfaction Scale (RSAT) (Burns et al., 1994) was used to measure the participant’s current satisfaction with her relationship with her spouse or significant other. Items are rated on a 7-point scale from not at all satisfied (0) to very satisfied (6) and higher scores indicate higher relationship satisfaction. The Cronbach alpha coefficient was $> .90$ at the third trimester and at 3 months postpartum.

Sleep duration

To obtain an objective measure of total sleep time, each participant wore a Mini Motionlogger wrist actigraph (Ambulatory Monitoring Inc., Ardsley, NY) for 48–72 consecutive weekday hours at each time point. A minimum of 48 consecutive hours was required for actigraphy data analysis. Wrist actigraphy provides continuous motion data using a wrist-watch size, battery operated microprocessor that senses motion with a piezo-electric linear accelerometer. Each 30-s epoch is scored as sleep or wake using an established algorithm from Action4 software (Ambulatory Monitoring Inc., Ardsley, NY) without researcher bias to obtain total minutes of sleep during the night. Although polysomnography is the gold standard for measuring duration of sleep stages, actigraphy is valid and reliable for estimating sleep and wake times in healthy young adults (Ancoli-Israel et al., 2003). In the present sample, there was no statistically significant difference between night 1 and night 2 data. In addition, both nights were significantly correlated ($r > 0.50$), indicating that 48-h sleep estimates were stable and reliable.

Sleep disturbance

The 21-item self-report General Sleep Disturbance Scale (GSDS) (Lee, 1992) was used to assess subjective sleep disturbance over the past week at each time point. Participants were asked to rate the frequency of specific sleep problems during the past week from 0 (not at all) to 7 (every day). The GSDS addresses problems such as sleep quality, difficulty falling asleep, daytime sleepiness and medication use. Scores can range between 0 and 147. A

higher score is indicative of increased frequency of sleep disturbance. The GSDS had good internal consistency, with a Cronbach alpha coefficient of .88 in samples of employed women and childbearing women (Lee, 1992; Lee & DeJoseph, 1992).

Data analysis

Measures of central tendency [mean \pm standard deviation (SD)], medians, and frequencies were used to describe the third trimester socio-demographic and clinical characteristics of participants in the combined studies. Variables were examined for normal distributions, and square root transformation of CES-D scores was sufficient to meet the assumptions for linear regression models. To address the first hypothesis regarding third trimester depression, Pearson correlations were calculated to determine relationships between depression symptom scores and continuous variables in the third trimester prior to randomization. Chi square (X^2) tests were used to test for associations between categorical variables. Group differences on continuous variables were evaluated using one-way analysis of variance (ANOVA) with Sheffé post hoc tests.

To test the first hypothesis, linear mixed models with post hoc pairwise comparisons were used to evaluate changes in depression symptoms scores from third trimester through the first 3 months postpartum by day length category in late third trimester and by day length category at birth. To test the second hypothesis, the eleven biopsychosocial variables from Table 1 along with the type of day length at the time of the third trimester assessment were entered into a multiple linear regression model to account for the variance in CES-D scores at the third trimester time point. Categorical data were dummy coded when appropriate (i.e., race/ethnicity, age groups, and type of day length). Intervention group assignment was not included in the model predicting third trimester CES-D scores as the assessment was conducted prior to the behavioral intervention. To test the third hypothesis regarding the extent to which day length category at third trimester predicts postpartum CES-D scores, we controlled for intervention group assignment, type of birth (vaginal or cesarean) and infant's sex. We also included third trimester CES-D scores along with other relevant third trimester variables and current 3-month postpartum measures in the multiple regression model.

Data were analyzed using SPSS version 22.0 (IBM, Armonk, NY). Statistical significance was set at $p < .05$, and standardized effect sizes (Cohen's d) were calculated (mean difference/pooled SD) to describe the magnitude of group differences in seasonal day length when relevant.

Results

Of the combined sample of 304 participants with complete data during the third trimester, 11 cases were lost to follow up and had no birth data. They were excluded from this sample due to unknown duration of gestation at their pregnancy assessment. There were 273 (90%) cases with data for all four time points, and there was no attrition for any of the 17 women with a prior mental health problem. There were 16 women with incomplete actigraphy data at the third trimester assessment and 24 women with incomplete actigraphy data at the 3-month postpartum assessment.

Sample characteristics

The 293 women in this analysis were anticipating the birth of their first child and sample characteristics at third trimester are presented in Table 1. Participants were 29.5 ($SD = 6.3$) years of age with 42% unemployed or not working at the time of data collection. There was no significant difference in the number of births by season, most (73%) of the women gave birth vaginally, and 56% of the infants were males.

Depressive symptoms over time and seasonal day length

Mean CES-D scores and risk for PPD decreased significantly ($p < .001$) over time from the third trimester to 3 months postpartum regardless of seasonal day length at third trimester or birth (Fig. 1). A sensitivity analysis of women with complete data for both the third trimester and 3 months postpartum also demonstrated decreasing scores over time, indicating that attrition was not likely to be responsible for the decrease in CES-D scores over time.

The linear mixed models omnibus analysis indicated a main effect of day length at the late third trimester assessment on the trajectory of CES-D scores (square root transformed) over time ($F_{[3,1105]} = 3.155, p = .024$). There were significant post hoc pairwise comparisons for shortening and short day lengths, but no main effect of lengthening or long day light. The post hoc linear mixed model comparing shortening third trimester day length against the other types of day length indicated that the CES-D scores were significantly higher ($p = .005$) over time (95% CI: 12.0, 14.0) compared to the other three types of day lengths (95% CI: 10.9, 11.9). The post hoc linear mixed model comparing short third trimester day length against the other types of day length indicated that the CES-D scores were significantly lower ($p = .042$) over

Table 1 Sample characteristics (n = 293)

Characteristic	Mean \pm SD	No. (%)	Third Trimester Depressive Symptom Score (CES-D)
Total sample			13.2 \pm 8.16
Age (years)	29.5 \pm 6.3		$F_{[2,288]} = 4.1, p = .018$
18–24 years		78 (27%)	14.8 \pm 8.8
25–34 years		152 (52%)	11.9 \pm 7.7*
35 + years		63 (21%)	14.2 \pm 8.0
Marital status			$F_{[1,287]} = 2.2, p = .144$
Single/unmarried		24 (8%)	15.5 \pm 8.1
Partnered or Married		268 (92%)	12.9 \pm 8.2
Annual income			$F_{[2,288]} = 5.8, p = .004$
< \$60,000		143 (49%)	14.8 \pm 9.0
> \$60,000		121 (41%)	11.5 \pm 6.9
Not reported		29 (10%)	12.0 \pm 7.4
Race/ethnicity			$F_{[4,284]} = 2.1, p = .08$
Caucasian		130 (45%)	12.1 \pm 6.8
Asian		70 (24%)	13.3 \pm 9.4
Hispanic		46 (16%)	14.5 \pm 9.6
African American		22 (8%)	17.0 \pm 9.3
Other		21 (7%)	12.2 \pm 5.7
Education			$F_{[1,288]} = 14.5, p < .001$
Completed college		171 (58%)	11.7 \pm 7.1
Did not complete college		122 (42%)	15.3 \pm 9.1
Employment status			$F_{[2,288]} = 1.3, p = .286$
Not employed or working		121 (41.3%)	14.0 \pm 8.9
Employed, not currently working		70 (23.9%)	13.0 \pm 8.2
Employed, currently working		98 (33.4%)	12.2 \pm 7.1
Not reported		4 (1.4%)	
History of mental health problem			$F_{[1,292]} = 0.13, p = .723$
No		277 (95%)	13.2 \pm 8.3
Yes		16 (5%)	13.9 \pm 7.0
Perceived stress (PSS)	15.1 \pm 6.39		$r = .650, p < .001$
Relationship satisfaction (RSAT)	59.1 \pm 13.9		$r = -.469, p < .001$
Sleep disturbance (GSDS)	45.6 \pm 16.4		$r = .474, p < .001$
Sleep duration (actigraphy hrs) (N = 277)	7.0 \pm 1.3		$r = -.107, p = .077$
			$F_{[1,272]} = 10.2, p = .002$
< 7 h		130 (47%)	15.0 \pm 9.1
> 7 h		147 (53%)	11.8 \pm 7.1

GSDS general sleep disturbance scale, PSS perceived stress scale, RSAT relationship satisfaction scale

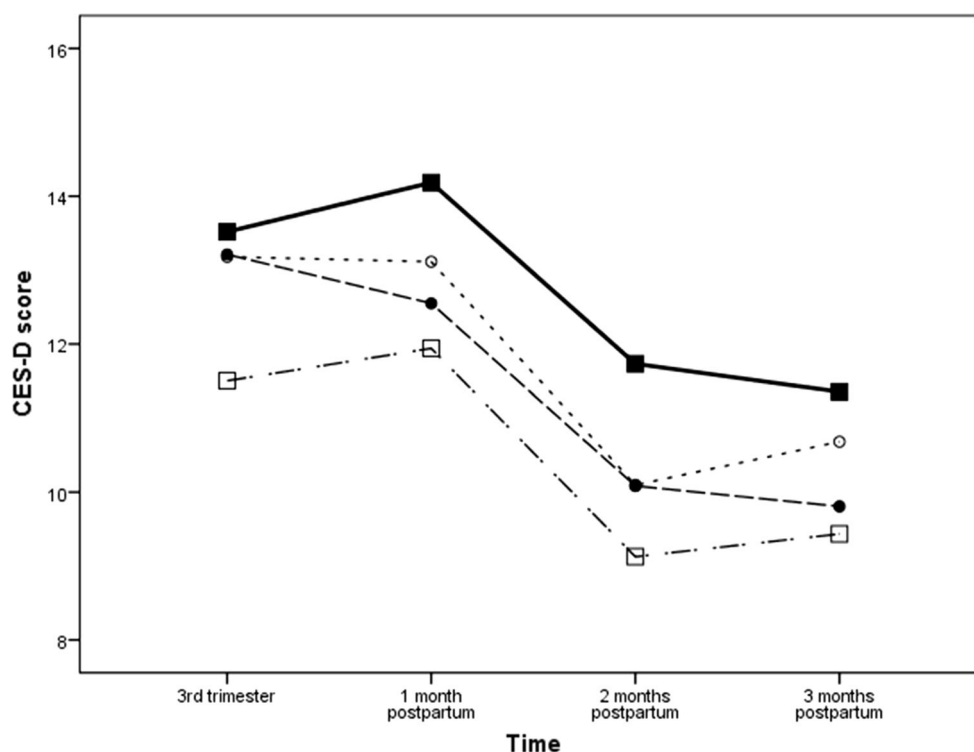
*Post hoc Sheffé: 25–34 years old CES-D scores significantly lower than 18–24 years old ($p = .036$)

time (95% CI: 10.1, 12.3) compared with the other three types of day lengths (95% CI: 11.8, 13.0).

Results from the mixed model and post hoc comparisons were similar when day length at birth was examined ($F_{[3,1105]} = 3.44, p = .016$); women who gave birth during the shortening day length time frame had higher CES-D scores over time (95% CI: 11.8, 14.1) than women who gave birth during the other three types of day length (95% CI: 10.8, 11.9). Table 2 summarizes CES-D scores and risk

for PPD at each assessment by day length at birth. Effect sizes for mean differences in CES-D depressive symptom scores between shortening day length and the other types of day lengths at the time of birth were small to moderate at 1 month ($d = .40$) and 2 months ($d = .27$) postpartum (see Table 3). Effect sizes for mean differences between shortening day length and the other three types of day lengths at the time of birth were small at both the third trimester ($d = .24$) and third month postpartum ($d = .19$).

Fig. 1 Depressive symptom scores by seasonal day length category at third trimester. Legend: There was a significant ($F_{[3,248]} = 20.95$; $p < .001$) decrease in CES-D (square root transformed) scores over time from the third trimester to the 3-month postpartum assessment for the overall sample regardless of day length group. Linear fixed effects omnibus model for third trimester day length with Bonferroni adjustment for multiple comparisons was significant ($F_{[3,1105]} = 3.155$, $p = .024$). Note: black square, shortening day length group ($n = 58$); white circle, lengthening day length group ($n = 68$); black circle, long day length group ($n = 60$); white square, short day length group ($n = 63$)



Women who gave birth during the shortening day length time frame were also at greater risk for depression (CES-D scores ≥ 16) compared to women who gave birth during the other three types of day length periods. Their risks for depression were statistically significant at 1 month ($p = .017$) and 2 months postpartum ($p = .044$) but there was no significant higher risk for depression at the 3-month postpartum time point (Table 2).

Third trimester depressive symptom severity and risk of depression

The third trimester CES-D depressive symptom scores for all participants ($n = 289$) was 13.1 ($SD = 8.2$). As shown in Table 3, the lowest mean score was during the ‘short’ day length period (late fall into early winter) when day length averaged about 10 h. The highest mean score was during the ‘shortening’ day length period (late summer into early fall) when day length averaged about 12 h. However, one-way ANOVA showed no significant difference in mean scores by the four categories of day length. The difference in mean scores between ‘short’ day length and ‘shortening’ day length approached significance ($t = 1.95$, $p = .053$) with a small to medium effect size ($d = 0.325$). See Fig. 2.

The overall rate for risk of depression (CES-D ≥ 16) in the third trimester was 30% ($n = 88$). As shown in Table 3, the lowest risk for depression (26%) occurred during the ‘short’ day length period and the risk for depression was

highest (35%) during the ‘shortening’ day length period. The difference in prevalence rates between these two types of day length periods approached statistical significance ($p = .068$).

Multivariate analysis for third trimester depressive symptom severity

Participant characteristics (maternal age groups, education, marital status, income, race/ethnicity, work status, mental health history), relationship satisfaction score, perceived stress score, general sleep disturbance score, and actigraphy sleep duration were entered into a linear regression model to account for the variance in CES-D scores (square root transformed) during the third trimester. In addition to these salient bio-psychosocial variables, shortening day length at third trimester was also specified in the model based on the omnibus main effects for CES-D scores over time. The model was significant, accounting for 57% of the variance in CES-D scores ($R^2 = .568$; $F_{[13, 235]} = 23.5$, $p < .001$). Controlling for all 13 variables, significant variables included older maternal age, higher income, higher perceived stress, lower relationship satisfaction, higher sleep disturbance scores, and shortening day length (See Table 4). Prior history of mental health issues, marital status, employment, education, and sleep duration were not significant in the model, and being non-Hispanic White race/ethnicity approached significance ($p = .07$).

Table 2 Depression scores by day length category at birth

CES-D scores	Total sample	Short day length at birth	Lengthening day length at birth	Long day length at birth	Shortening day length at birth*
<i>3rd trimester</i>					
Mean ± SD	13.2 ± 8.16	12.7 ± 7.87	12.7 ± 7.06	12.9 ± 8.81	14.7 ± 9.18 ^a
Median	11	11	11	12	12
Risk for depression (scores > 15), n (%)	88/289 (30%)	23/80 (29%)	24/83 (29%)	18/63 (29%)	23/63 (37%) ^b
<i>1 month postpartum</i>					
Mean ± SD	13.2 ± 8.61	11.6 ± 8.00	13.9 ± 8.56	12.6 ± 9.16	14.9 ± 8.79 ^c
Median	12	10.5	12	10	14
Risk for depression (scores > 15), n (%)	88/281 (31%)	17/78 (22%)	28/80 (35%)	18/61 (30%)	25/62 (40%) ^d
<i>2 months postpartum</i>					
Mean ± SD	10.6 ± 7.48	10.0 ± 7.24	10.8 ± 7.33	9.7 ± 6.95	11.8 ± 8.50 ^e
Median	9	9	9	9	9
Risk for depression (scores > 15), n (%)	61/271 (23%)	13/71 (18%)	22/81 (27%)	9/62 (15%)	17/57 (30%) ^f
<i>3 months postpartum</i>					
Mean ± SD	10.5 ± 7.94	10.2 ± 8.27	10.0 ± 7.91	10.4 ± 7.75	11.5 ± 7.88 ^g
Median	8	7.5	8	8	11
Risk for depression (scores > 15), n (%)	59/273 (22%)	15/72 (21%)	13/80 (16%)	16/62 (26%)	15/59 (25%) ^h

*Fixed effects for day length category at birth with Bonferroni adjustment for multiple comparisons was significant ($F_{[3,1105]} = 3.44, p = .016$); post hoc pairwise comparisons: shortening vs short (CES-D square root transformation mean difference = .294, $p = .029$); shortening versus long (CES-D square root transformation mean difference = .294, $p = .041$)

^aCohen's d = 0.237 (shortening vs. short)

^b $\chi^2_{[1]} = 0.97, p = .321$ NS

^cCohen's d = 0.395 (shortening vs. short)

^d $\chi^2_{[1]} = 5.6, p = .017$

^eCohen's d = 0.273 (shortening vs. long)

^f $\chi^2_{[1]} = 4.1, p = .044$

^gCohen's d = 0.190 (shortening vs. lengthening)

^h $\chi^2_{[1]} = 1.8, p = .183$ NS

Table 3 Depressive symptoms by seasonal day length category in late third trimester

Third trimester depressive symptom scores (CES-D)	Total N = 289	Short day length 9.9 ± 0.25 h (autumn into winter) (n = 76)	Lengthening day length 12.3 ± 1.06 h (winter into spring) (n = 77)	Long day length 14.5 ± 0.28 h (spring into summer) (n = 68)	Shortening day length 12.0 ± 1.80 h (summer into autumn) (n = 68)
Mean ± SD	13.1 ± 8.2	11.9 ± 6.7	13.0 ± 7.6	13.5 ± 9.5	14.4 ± 8.8*
Median	11	11	12	11.5	12
Risk for depression (score ≥ 16)	88 (30%)	20 (26%) lowest rate	23 (30%)	21 (31%)	24 (35%) highest rate

*Fixed effects for third trimester day length with Bonferroni adjustment for multiple comparisons was significant ($F_{[3,1105]} = 3.155, p = .024$); post hoc pairwise comparisons: shortening vs short (CES-D square root transformation mean difference = .315, $p = .014$), $d = 0.325$

Multivariate analysis for depressive symptom severity at 3 months postpartum

The same maternal characteristics (age groups, education level, marital status, income, race/ethnicity, work status,

mental health history), along with group assignment and birth and postpartum variables that included baby's sex, vaginal or cesarean birth, and exclusive breastfeeding or bottle feeding were included in the linear regression model to predict depressive symptom severity (CES-D trans-

Fig. 2 Depressive symptom scores by seasonal day length category in late third trimester. Legend: Third trimester CES-D means (black square) with 95% confidence intervals are depicted on the Y axis according to the four seasonal day length categories described on the X axis. There was no significant difference in CES-D scores (square root transformed) by third trimester day length category. The difference in CES-D scores between ‘short’ day length and ‘shortening’ day length approached significance ($t = 1.95, p = .053$), with a small to medium effect size ($d = 0.325$)

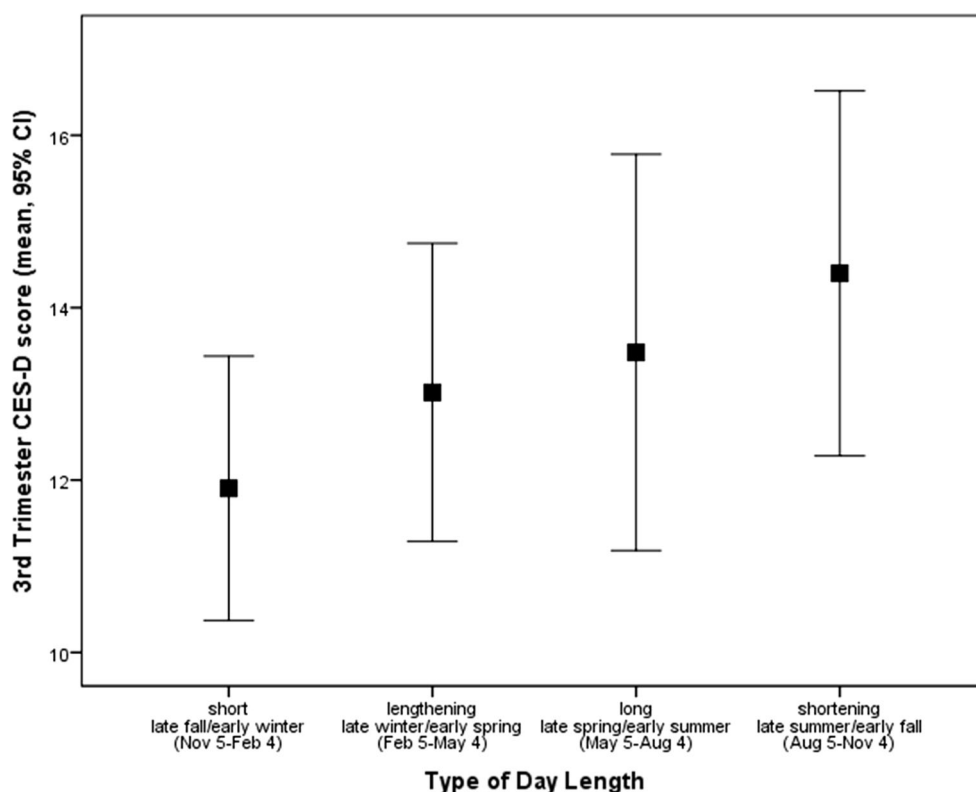


Table 4 Linear regression model accounting for the variance in third trimester depressive symptom scores

Model	Unstandardized coefficients		Standardized coefficients	t	p value
	B	SE			
(Constant)	2.386	.407		5.869	< .001
Age (< 25 years = 1; other = 0)	-.155	.151	-.058	-1.026	.306
Age (> 34 years = 1; other = 0)	.307	.132	.109	2.324	.021
Mental health history (yes = 1; no = 0)	-.021	.246	-.004	-.087	.931
Married (yes = 1; no = 0)	.056	.133	.024	.425	.671
Ethnicity (white = 1; other = 0)	.222	.116	.096	1.918	.056
College graduate (yes = 1; no = 0)	-.160	.137	-.068	-1.169	.244
Currently working (yes = 1; no = 0)	.105	.121	.044	.865	.388
Income (> \$60,000 = 1; other = 0)	.279	.128	.120	2.184	.030
3rd trimester perceived stress (PSS)	.080	.009	.458	9.280	< .001
3rd trimester relationship satisfaction (RSAT)	-.020	.004	-.247	-4.800	< .001
3rd trimester sleep disturbance (GSDS)	.018	.003	.263	5.478	< .001
3rd trimester sleep duration (actigraphy hours)	-.060	.106	-.026	-.569	.570
3rd trimester day length (shortening = 1; other = 0)	.068	.030	.099	2.245	.026

Dependent variable: 3rd trimester CES-D score (square root transformation); $R^2 = .568, F_{[13,245]} = 23.5, p < .001$

formed scores) at 3 months postpartum. Scores for current perceived stress, relationship satisfaction, sleep disturbance, and sleep duration at 3 months postpartum were also included. In addition, third trimester CES-D scores and third trimester day length (shortening vs. other) were entered. Because of varying time intervals between the third trimester day length assessment and the final assess-

ment at 3-months postpartum, types of day length (short vs other shortening, vs other; and long vs other) at 3 months postpartum were also included. This model with 21 variables was significant, accounting for 67% of the variance in CES-D scores at 3 months postpartum ($R^2 = .667; F_{[21, 188]} = 16.7 p < .001$). Results were similar in a linear regression model that also included day length at birth

($R^2 = .66$; $F_{[22, 188]} = 19.2$), but day length at birth was not a significant predictor and day length at third trimester remained significant (data not shown).

In this multivariate analysis with prior history of mental health problems and third trimester CES-D scores in the model, older maternal age group and higher income were no longer significant predictors of postpartum depressive symptom severity. As in the third trimester model, current higher perceived stress, lower relationship satisfaction and higher sleep disturbance scores were significant. Unlike the third trimester model, sleep duration was also significant, with shorter postpartum sleep duration associated with higher CES-D scores (See Table 5). The third trimester shortening day length remained significant ($p = .029$) even after controlling for day lengths at the 3-month postpartum assessment.

Discussion

Study findings support our first hypothesis that the trajectory of postpartum depressive symptoms over time would differ by seasonal day length at third trimester. In fact, after

adjusting for multiple comparisons with linear mixed models, both models with shortening day length in the third trimester and shortening day length *at birth* were significant for higher depressive symptom scores over time. This is also clinically important with implications for earlier intervention during late pregnancy, but if that time point is missed, results suggest that increasing light exposure would also be effective if birth occurs in Autumn when day length is shortening. Future clinical trials research should consider the potential for achieving larger effect sizes for light therapy if it is introduced when day length is shortening at the time of birth for at-risk women.

Our second hypothesis was supported. In this sample of ethnically diverse, first-time mothers, the type of day length in the third trimester, specifically day lengths that are shortening compared to day lengths that are short, long or lengthening, were associated with concurrent depressive symptom severity. Our rate of high risk for depression was 30% (range 26–35%) in the third trimester and 22% (range 16–26%) at 3 months postpartum. The highest rate of clinically elevated depression scores (35%) was noted when the third trimester coincided with shortening day lengths (late summer into early autumn). Our findings

Table 5 Regression model accounting for the variance in depressive symptoms at 3 months postpartum

Model	Unstandardized coefficients		Standardized coefficients Beta	t	p value
	B	SE			
(Constant)	1.775	.594		2.986	.003
Randomized group assignment	– .101	.119	– .040	– .847	.398
Mental health history (yes = 1; no = 0)	.955	.312	.152	3.063	.003
3rd trimester CES-D score (transformed)	.200	.056	.176	3.582	< .001
Age (< 25 years = 1; other = 0)	.334	.183	.112	1.830	.069
Age (> 34 years = 1; other = 0)	.136	.148	.045	.914	.362
Married (yes = 1; no = 0)	.057	.157	.022	.360	.719
Ethnicity (white = 1; other = 0)	.089	.136	.035	.658	.511
College graduate (yes = 1; no = 0)	– .116	.150	– .044	– .777	.438
Currently working (yes = 1; no = 0)	.050	.153	.015	.329	.742
Income (> \$60,000 = 1; other = 0)	– .075	.155	– .030	– .484	.629
Gender of baby (girl = 1; boy = 2)	– .115	.120	– .045	– .960	.338
Type of birth (vaginal = 0; cesarean = 1)	– .208	.138	– .072	– 1.507	.134
Exclusive breastfeeding (yes = 1)	.066	.125	.026	.530	.587
Current perceived stress score (PSS)	.098	.011	.492	8.899	< .001
Current relationship satisfaction (RSAT)	– .012	.004	– .136	– 2.597	.010
Current sleep disturbance (GSDS)	.016	.004	.209	3.974	< .001
Current sleep duration (actigraphy hours)	– .002	.001	– .104	– 2.179	.031
3rd trimester day length (shortening = 1; other = 0)	.109	.049	.139	2.200	.029
Current (3 months postpartum) day length:					
(Short = 1; other = 0)	– .388	.206	– .118	– 1.883	.061
(Shortening = 1; other = 0)	.032	.174	.010	.183	.855
(Long = 1; other = 0)	– .201	.155	– .074	– 1.298	.196

Dependent variable: CES-D total score (square root transformation) at 3 months postpartum; $R^2 = .667$, $F_{[21,188]} = 16.7$, $p < .001$

support other research findings suggesting reduced natural light exposure due to shortening day length is associated with depression (Marqueze et al., 2015), particularly for women regardless of age (Lyll et al., 2018). Moreover, our findings support Crowley and Youngstedt (2012) who concluded that offsetting insufficient low light levels with bright light therapy may be beneficial for women at high risk of perinatal depression. Our findings go further to suggest that initiating light treatment in the late third trimester when seasonal day length is shortening may serve to minimize postpartum depressive symptoms in high-risk mothers during the first 3 months postpartum.

Our final hypothesis was also supported. Type of day length in late third trimester was predictive of postpartum depressive symptoms at 3 months even when controlling for other bio-psycho-social variables that included mental health history and third trimester depressive symptom scores. In the multivariate regression analyses, type of day length at third trimester also remained significant in explaining the variance in postpartum depressive symptoms at 3 months while also considering their current 3-month postpartum day length. Findings for type of day length at birth were similar to findings for day length at late third trimester, likely because of the short time frame between these two time points.

Given the well-documented role of sunlight in suppression of melatonin (Lewy, 2007) and in the synthesis of vitamin D (National Institutes of Health, 2016), our findings support Robinson et al. (2014) who concluded that a low vitamin D level during pregnancy was a risk factor for developing postpartum depressive symptoms. During the first 2 months postpartum, new mothers are more likely to be on maternity leave from employment, protecting their infants in the home without much light exposure. A shortening day length just before or at birth can further reduce their sunlight exposure during postpartum recovery. The lack of sunlight can result in increased melatonin levels and higher melatonin levels in the postpartum period have been associated with depression (Parry et al., 2008). By 3 months postpartum, new mothers are more likely to be returning to usual routines and employment schedules, getting more light exposure regardless of seasonal day length, and more likely to be outdoors with their infant.

Implications for clinical practice

Our study findings have several implications for clinical practice, including encouraging frequent exposure to daylight throughout the pregnancy to enhance vitamin D levels and suppress melatonin. Ensuring daylight exposure is particularly important for women living in higher latitudes where day light exposure is even shorter than in northern California. Additionally, clinicians should encourage

women to get more exercise outdoors when weather and safety permit. Daily walks during daylight hours may be more effective in improving mood than walking inside a shopping mall or using a treadmill in a gym. Likewise, early morning or late evening walks may be relaxing but would be less effective in increasing vitamin D exposure or suppressing melatonin. The use of light therapy strategies (e.g. delivered by light boxes) to assure adequate light exposure may be especially important for women with a previous history of mental health problems, for women already experiencing depressive symptoms in the third trimester, for at-risk women living at high latitudes who are in the third trimester during shortening day lengths, or for women without easily accessible outdoor activity during shortening day lengths.

Although ACOG (2015) recommends that pregnant women consume vitamin D enriched foods to promote growth of fetal teeth and bone, routine prenatal 25-hydroxyvitamin D [25(OH)D] screening is not recommended (ACOG, 2011). This lack of screening is unfortunate when considering altered vitamin D metabolism in African American and Asian women with darker skin pigmentation and increased risk of vitamin D deficiency (Awumey et al., 1998; Harris, 2006; Mitchell et al., 2012). Given the association between PPD and vitamin D deficiency, clinicians should consider 25(OH)D screening and vitamin D supplementation for all women regardless of light exposure. In addition to the shortening day length, the significant contribution from other bio-psycho-social variables in the multiple regression models should not be overlooked for their clinical implications. Thus, along with strategies for enhancing light exposure, clinicians should continue to carefully evaluate new mothers for known risk factors that are present regardless of seasonal day length, such as level of stress, sleep disturbances, satisfaction in their relationships, and lack of resources that accompany low socioeconomic status. What may be challenging for clinicians to address is the new mother's short sleep duration; more research is needed to better understand why short sleep duration had a significant role in the experience of postpartum depressive symptoms in our sample, but was less of a factor in late pregnancy. It may be that women need varying amounts of sleep during pregnancy compared to postpartum in order to feel rested and experience a more positive mood.

Strengths and limitations

Findings of this study should be interpreted with caution given the secondary analysis approach that involved combining two ethnically and socioeconomically diverse samples in longitudinal consecutive studies with similar designs and methods. The secondary analysis approach

also dictated the sample size and variables available for analysis. Prior research and our analyses support the role of day length on depressive symptoms. While it would be logical to consider the body of research on seasonal affect disorder (winter depression) and hypothesize that short day length would be associated with depression, it was surprising to find that symptoms were associated with shortening day length rather than short day length. These findings need to be replicated in larger samples where the seasonal time frame could be narrowed to a more precise month when risk of PPD is at its highest. We were sufficiently powered to detect a medium effect size ($d = 0.5$) with 64 participants per group. However, based on our small effect size estimates ($d = 0.2$ to 0.4), we would likely have needed 100–200 women in each of the four types of day light groups in order to have sufficient power to detect differences in type of day length with statistical significance at $p < .05$ (Cohen, 1988). Our large effect sizes for the multivariate analyses ($R^2 > .55$) were sufficient for statistical power. However, there was collinearity between depressive symptom scores and perceived stress scores that allowed perceived stress to account for a substantial portion of the variance in CES-D scores.

In our relatively large diverse sample of first-time new mothers living in northern California, we had few cases that could be categorized as high risk for PPD, but the range of 16–26% of the sample with scores ≥ 16 on the CES-D at 3 months postpartum reflects the prevalence ranges reported in prior studies, and season or latitude of those studies may partially explain their widely varying prevalence rates. While the rate of PPD is within the expected norms previously reported, it may also be lower than expected due to a potential Hawthorne effect from participants feeling special and contributing to women's health research.

It was interesting that older age was a significant factor in the CES-D scores at third trimester, but younger age was a factor in PPD. These age group differences should be examined in future studies, and the ages of women in our sample should be noted. They averaged 29.5 years of age, while first time mothers in the United States are typically younger (26.3 years) (Mathews & Hamilton, 2016), and this age difference may limit generalizability of our findings to all first-time mothers.

Another potential limitation was the short monitoring period of 48 h to objectively estimate women's sleep duration in addition to their sleep disturbance scores for the past week. Although both objective and self-report sleep measures were significant in the regression models, longer actigraphy monitoring periods would be desirable for estimating sleep patterns. Nevertheless, the short monitoring periods at each of the 4 study assessments captured objective sleep duration during rapidly changing maternal–

infant time points, reduced participant burden, reduced the amount of missing data, and avoided variability between weekdays and weekends.

Our study was one of associations without causality or physiological mechanism inference. It is well known that African Americans and Asians synthesize vitamin D differently than other populations (Awumey et al., 1998; Harris, 2006), and our findings are limited by the lack of vitamin D measures.

While others have hypothesized that the season itself, such as winter or low light exposure, would be associated with depressive symptoms, we hypothesized that PPD would be related to the change in the pattern of day light exposure, specifically shortening day length. In most research that examines seasonality in relation to depressive symptoms, investigators either have very short assessment periods, or include winter months with shortening (early winter), short (winter), and lengthening (late winter) periods of day light. Thus, findings of an association between depressive symptom severity and shortening day length between August and early November need to be replicated at other latitudes and extended to include measures of vitamin D and melatonin in order to uncover potential mechanisms for perinatal depression.

As seen in our multivariate regression analyses, perinatal depression is a complex health problem that is influenced by many bio-psycho-social factors. Our regression models account for over half of the variance in depressive symptom scores, with shortening day length prior to birth, high perceived stress, less satisfying marital relationship, and perception of poor sleep among the most significant factors that need to be replicated and considered in future studies.

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Compliance with ethical standards

Conflict of interest Deepika Goyal, Caryl Gay, Rosamar Torres, Kathryn Lee, declares that they have no conflict of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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