Diurnal Fatigue Patterns, Sleep Timing, and Mental Health Outcomes Among Healthy Postpartum Women

Amanda L. McBean, MS1 and Hawley E. Montgomery-Downs, PhD1

Abstract
Postpartum women have frequently interrupted sleep, report high levels of fatigue, and may experience circadian rhythm disruptions. They are also susceptible to mood impairments, anxiety, and stress. The current study explored associations between maternal postpartum daily fatigue patterns, which should vary according to circadian influences and mental health. Seventy-one primiparous, healthy mothers completed multiple daily self-reports of fatigue during postpartum Weeks 2 and 12 and were categorized at each week as having either a rhythmic or random fatigue pattern during the daytime. Wrist actigraphy data were used to calculate sleep midpoints. Surveys assessed chronotype, mood, anxiety, and stress. At postpartum Week 2, there were no differences in mental health measures between fatigue groups. At postpartum Week 12, higher overall fatigue levels were associated with increased anxiety, stress, and mood disruption. However, overall fatigue levels did not differ between fatigue groups. Women with a rhythmic fatigue pattern reported significantly less stress and more vigor than women with a random fatigue pattern. An earlier sleep midpoint was associated with a rhythmic fatigue pattern during postpartum Week 12. These data suggest that, despite similar average daily fatigue levels, having a rhythmic daily pattern of fatigue may be advantageous for mental health outcomes among postpartum women.

Keywords
anxiety, fatigue, mood, postpartum, sleep midpoint

Sleep disruption, fatigue, and mental health problems are all prominent during the postpartum period (Gay, Lee, & Lee, 2004; Kilic & Eryilmaz, 2011; Lee & Zaffke, 1999; Montgomery-Downs, Insana, Clegg-Kraynok, & Mancini, 2010; Ross, Murray, & Steiner, 2005; Rychnovsky & Hunter, 2009). Although sleep, fatigue, and mental health have been independently studied among postpartum women, the connections among these constructs have not been well elucidated. The goal of the current field-based study was to explore the relationships between variations in fatigue patterns across a day and mental health measures among healthy postpartum women during a time when sleep disturbance is pronounced.

Depression during the postpartum period has been well characterized. A review of studies with multinaional representation suggests that between 10% and 15% of childbearing women are diagnosed with postpartum depression (Ross et al., 2005). Adverse outcomes of postpartum depression include disruption in the marriage, increased neglect in child caregiving, a poorer mother–child relationship, delayed child development, and, at its most severe, increased risk for maternal suicide or infanticide (Field, 2010). Although postpartum depression has been widely researched, fewer studies have focused on other, less obvious, mood constructs, such as anger, tension, vigor, and confusion. In the current study, we assessed a number of mood states in addition to depression in order to provide a more thorough understanding of various mood profiles postpartum.

More recently, research has examined the negative implications of greater anxiety and stress during the postpartum period. Greater maternal anxiety is associated with lower infant development scores, more difficult infant temperament, and child behavior problems (Correia & Linhares, 2007; Glasheen, Richardson, & Fabio, 2010). Maternal postpartum stress is associated with poorer infant health (Fowles & Walker, 2009). However, less is known about subthreshold mental health symptoms, which can also adversely affect aspects of health (including cognition, physical health, and affect; Ayuso-Mateos, Nuevo, Verdes, Naidoo, & Chatterji, 2010) and may indicate an early risk for developing a clinical disorder (Cuijpers & Smit, 2004). For this reason, in the current study, 1 Department of Psychology, West Virginia University, Morgantown, WV, USA

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we used a sample of healthy postpartum women who had no current symptoms or history of depression or sleep disorders.

Fatigue, which can persist until at least 18 months postpartum and is related to worsened perception of maternal mental health and infant development (Parks, Lenz, Milligan, & Han, 1999), is consistently ranked as a top complaint among postpartum women (Troy, 2003). Fatigue is predictive of postpartum depressive symptoms and is correlated with postpartum stress (Groër et al., 2005). Higher levels of fatigue are associated with more disturbed nocturnal sleep during the postpartum period (Rychnovsky & Hunter, 2009). However, fatigue levels also vary over the 24-hr day in a pattern dictated by the endogenous circadian rhythm (Ferguson et al., 2012; Monk et al., 1997). Previous studies have examined overall fatigue levels, but no study has yet evaluated how disruptions to the diurnal rhythm of fatigue may be influencing mental health outcomes during the postpartum period.

Evaluating disruption to the diurnal rhythm of fatigue is important because there is evidence of an altered circadian rhythm among postpartum women (Matsumoto, Shinkoda, Kang, & Seo, 2003; Thomas & Burr, 2006; Wulff & Siegmund, 2000). In non-postpartum populations, circadian rhythm disruptions have been linked to depression, mood disorders, anxiety disorders, and post-traumatic stress disorders (Kennaway, 2010; Ma, Kong, Qi, & Wang, 2008; Mendlewicz, 2009; Sipilä et al., 2010; Yehuda, Golier, & Kaufman, 2005). Although, on average, postpartum women demonstrate a different pattern of melatonin release compared to nulliparous controls, some postpartum women have shown melatonin patterns similar to controls (Thomas & Burr, 2006). This observation suggests that there are postpartum women who may not experience a circadian rhythm disruption and that there are individual differences in how women respond to the physiological and environmental changes associated with the postpartum period. Therefore, it would also be prudent to understand the differences between women who experience disruptions to their diurnal fatigue rhythm and those who do not.

Individuals vary in their preferred timing of behaviors, including sleep. These preferences correspond to variations in the circadian phase, and researchers have established the construct of chronotypes to describe whether a person is more a morning or evening type (Horne & Östberg, 1976; Taillard, 2003). Fatigue is predictive of postpartum depressive symptoms and is correlated with postpartum stress (Groër et al., 2005). Higher levels of fatigue are associated with more disturbed nocturnal sleep during the postpartum period (Rychnovsky & Hunter, 2009). However, fatigue levels also vary over the 24-hr day in a pattern dictated by the endogenous circadian rhythm (Ferguson et al., 2012; Monk et al., 1997). Thus, in the current study, we sought to compare otherwise healthy postpartum women with different fatigue patterns on mental health outcomes and to further explore how chronotype and sleep timing may be related to a unique index of circadian functioning quantified by assessing fatigue patterning across the day.

**Method**

We used data from postpartum Weeks 2 and 12 from a preexisting longitudinal field-based descriptive study of maternal postpartum sleep disturbance (Montgomery-Downs et al., 2010). West Virginia University’s Institutional Review Board approved the study, and we administered informed consent and Health Insurance Portability and Accountability Act authorization to all participants.

**Participants**

Healthy primiparous women were recruited during pregnancy for participation in the study. Inclusion criteria to ensure a healthy sample were a single pregnancy, full-term infant, infant not admitted to the neonatal intensive care unit, and discharge from the hospital within the standard 2 (for vaginal delivery) to 3 (for surgical delivery) days postpartum. Additionally, women were not under the care of a physician for major health conditions, were not receiving current treatment for and did not have a history of major depressive disorder, and did not have a score of <16 on the Center for Epidemiologic Studies Depression Scale (Radloff, 1977). Those who did not meet the above-mentioned criteria were excluded from participation in the study, and when appropriate, referred to mental health resources.

Participants were 71 postpartum women with a mean age of 26.3 years (standard deviation [SD] ± 4.1), an average annual household income of US$61,000 (SD ± $35,000), and an average age of 15.6 years (SD ± 2.9) of education. The majority were married or cohabitating (81.7%), 91.5% self-identified as White, 2.8% as more than one race or ethnicity, 1.4% as Black or African American, 1.4% as American Indian, and 1.4% as Hispanic. Among these women, 70.0% had a vaginal delivery and 69.0% reported exclusively breast-feeding at the time of hospital discharge.

**Measures**

**Sleep midpoint.** Noninvasive, continuous sleep monitoring was performed via actigraphy (Mini Mitter Actiwatch-64, Bend, OR) for 12 continuous weeks beginning at the start of the second postpartum week. Motion was recorded via an accelerometeric sensor that looks like a wristwatch, weighs 17.5 g, measures 28 × 27 × 10 mm, and is worn on the participant’s
nondominant wrist. Activity data were downloaded and calculations were made via a computerized reader and software. We used the default (medium) sensitivity setting to detect sleep and wake periods with the highest epoch resolution (15 s). Actiware Software Version 5.5 (Mini-Mitter Actiwatch-64) was used to analyze and store actigraphy data. The algorithm used by the software scores each 15-s epoch as either sleep or wake by comparison to the chosen setting. The use of the Actiwatch in detection of adult sleep–wake patterns has been validated (Edinger, Means, Stechuchak, & Olsen, 2004).

Participant bedtime and rise time were recorded in real time using a personal digital assistant (PDA)-based sleep diary. The beginning of the sleep period on the actigraphy output was manually identified as the beginning of the first 2-min period of immobility following self-reported bedtime. Rise time was identified as the end of the last 2-min period of immobility before self-reported awakening time. Sleep midpoint was calculated each study night as the halfway point between sleep onset and morning rise time. Actigraphy, in corrobororation with self-recorded sleep diaries, has previously been used to calculate sleep midpoint (Baron, Reid, Kern, & Zee, 2011; Tozawa et al., 2003). To create stable measures, each participant’s nightly sleep midpoints were averaged within each of the two study weeks to produce their average sleep midpoint each week. The average intraclass correlation coefficients (ICCs) at each week indicated strong agreement; thus, sleep midpoint did not show significant within-week variability at either Week 2 (ICC = 0.92, confidence interval [CI] = [0.88, 0.94], *p* < .001) or Week 12 (ICC = 0.93, CI = [0.89, 0.96], *p* < .001), justifying the use of weekly averages. However, at Week 2, midpoints were significantly later on weekends (*M* = 4:50 a.m., *SD* = 77 min) compared to weekdays (*M* = 4:26 a.m., *SD* = 68 min), *t*(61) = 4.33, *p* < .001. At Week 12, there was no statistically significant difference in midpoints between weekends (*M* = 4:02 a.m., *SD* = 77 min) and weekdays (*M* = 3:51 a.m., *SD* = 96 min), *t*(46) = 1.10, *p* = .28. Daytime napping was not included in any of the calculations or analyses because the larger study revealed low rates and durations of daytime napping behavior across each postpartum week (Montgomery-Downs et al., 2010). The advantage of using the sleep midpoint over sleep onset or wake time is that it takes into consideration the entire sleep period and is more closely related to the gold standard biological marker of circadian phase, the dim-light melatonin onset (Martin & Eastman, 2002; Terman, Terman, Lo, & Cooper, 2001).

**Fatigue pattern and fatigue-level assessment.** Participants also used the PDA to self-administer a visual analog of fatigue scale during each diurnal infant feeding (between 6:00 a.m. and midnight). The scale was a unidimensional account of fatigue severity asking, “How tired/fatigued do you feel RIGHT NOW?” (0 = not at all tired/fatigued to 100 = very tired/fatigued), derived from Monk’s Global Vigor and Affect visual analog scale (Monk, 1989), with responses sensitive to circadian rhythm variation across the day (Monk et al., 1997). Our interchangeable use of tired and fatigued was not problematic within this sample because, as we previously reported, this same sample did not differentiate between the traditionally distinct concepts of sleepiness and fatigue when measured using the Stanford and Epworth Sleepiness Scales versus the visual analog of fatigue scale as well as the vigor-activity and fatigue-inertia subscales of the Profile of Mood States (POMS; Insana & Montgomery-Downs, 2010). Because we did not control for the time at which women completed the fatigue scale, we averaged fatigue values across each of the postpartum Weeks 2 and 12 to create a more robust measure for the overall fatigue-level analyses.

To determine whether each participant had a rhythmic or random fatigue pattern, we used the fatigue data from the visual analog scale at postpartum Weeks 2 and 12. By using the same scale to measure both fatigue level and pattern, we ensured that relationships detected in the outcome measures could be attributed to differences in the pattern and not overall levels of fatigue. We chose Weeks 2 and 12 because they were the earliest and latest postpartum periods examined in the larger longitudinal study. Fatigue patterns were assessed by compiling data within each of the study weeks and plotting individuals’ fatigue scores against the time of day when they were completed. Regression models were used to analyze each individual’s fatigue data trends. Women were categorized based on the presence or absence of a statistically significant (*p* < .05) linear, quadratic, or cubic within-individual trend at postpartum Week 2 and again at postpartum Week 12.

We chose the three trends for categorizing fatigue patterns based on the circadian rhythm of sleepiness throughout a day and potential sleep-inertia effects. A linear trend of increasing fatigue across a day would be consistent with expectations based on previous fatigue reports (Ferguson et al., 2012). A quadratic trend would also be possible, given the potential of sleep inertia increasing fatigue upon awakening (Ikeda & Hayashi, 2009). Finally, a cubic trend would also potentially show circadian influences based on a midafternoon dip in the circadian rhythm that may increase fatigue ratings at this time (Monk, Buysse, Reynolds, & Kupfer, 1996). The majority of women (69% of women at Week 2 and 70% at Week 12) were statistically significant on all three trends. Additionally, only 8% of participants at Week 2 and 6% at Week 12 had just one statistically significant trend. Due to the small sample size that would result from splitting the women into separate trend groups, there was insufficient power to analyze the separate contribution of these trends to the outcomes. Women with any significant trend were thus categorized as having a “rhythmic” pattern of fatigue and those without were categorized as having a “random” pattern of fatigue.

The average number of fatigue points contributing to an individual’s scatterplot at postpartum Week 2 was 21.9 (*SD* = 7.4, range = 7–44) and at postpartum Week 12 was 15.9 (*SD* = 7.2, range = 4–33). At postpartum Weeks 2 and 12, 9.9% and 21.1%, respectively, were excluded from analyses for either having fewer than four fatigue reports or not having a sufficient spread of fatigue points throughout the day (i.e.,
at least one fatigue report each in the morning [6 a.m.–12 p.m.], afternoon [12–6 p.m.], and evening [6 p.m.–12 a.m.]. Women who did not awaken until after noon were not excluded based on not having morning reports. These exclusion criteria were set based on the necessity of a sufficient number and spread of fatigue reports in order to detect a significant trend if one were to exist. The women who were excluded from analyses did not differ in any of the dependent variables at postpartum Week 12, but at Week 2, women with missing fatigue data had lower scores on the anxiety measure than women who were included in the analyses, $F(70) = 7.30, p = .009$. Sleep midpoint was compared to the number of fatigue data points at each week to determine whether there were more data points for women who had a phase-advanced rhythm. These correlations were not statistically significant at either Week 2 or Week 12, suggesting that rhythm phase was not related to the number of fatigue reports provided. Examples of “rhythmic” and “random” patterns are illustrated in Figure 1. At Week 2, of 64 women, 39 had a rhythmic fatigue pattern. At Week 12, of 56 women, 40 had a rhythmic fatigue pattern, but only 23 women maintained a rhythmic pattern from postpartum Week 2 to Week 12.

**Chronotype.** Morningness–eveningness trait assessments were collected during the prenatal recruitment visit. The assessment consisted of 7 questions related to daily sleep–wake habits and time-of-day preference for performing specific activities and was adapted from Östberg and Horne’s original 19-question scale (Horne & Östberg, 1976). The shortened scale we used has not been specifically validated; however, we used the shorter scale as one of many attempts to reduce participant burden, as the larger study was already intensive for mothers during the vulnerable time of adapting to the postpartum period.

**Mood, anxiety, and stress.** To reduce participant burden, mood, anxiety, and stress surveys were self-administered at participants’ homes during regular visits by a member of the research team on alternate weeks throughout the longitudinal study. The POMS reflects mood during the previous week and was administered at the end of every other week including postpartum Weeks 3 and 13. These latter weeks were used in analyses for the present study because they were the closest weeks to the fatigue data assessments. Although the POMS only reflects mood during the past week, the lack of statistical significance between within-subject analyses of the POMS’ Weeks 3 and 5 scores, $t(66) = 1.74, p = .09$, and Weeks 11 and 13 scores, $t(63) = .66, p = .51$, suggests that Week 13 data could reasonably represent mood states during postpartum Week 12 as well. The POMS consists of 65 adjectives rated by participants using a 5-point Likert-type scale (0 = Not at all, 4 = Extremely) and is divided into six subscales: tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, confusion-bewilderment, and vigor-activity (McNair, Lorr, & Droppleman, 1992). Total POMS scores range from –32 to 200. Subscale ranges vary, tension-anxiety (0–36); depression (0–60); anger-hostility (0–48); fatigue (0–28); confusion bewilderment (0–28); and the reverse-scored vigor-activity subscale has a range from –32 to 0. Total POMS scores and all but the vigor-activity subscale are negative dimensions so high scores represent worse mood. The scale has been used previously among postpartum women in relation to psychological status (Hayes, Muller, & Bradley, 2001).
The Beck Anxiety Inventory (BAI), administered at the end of every other week, reflects symptoms during the previous week. Data from postpartum Weeks 2 and 12 were used in analyses for the present study because they were the closest weeks to the fatigue data assessments. The BAI is a 21-item survey. Each item has a 0–3 scale (0 = Not at all, 3 = Severely). Total scores range from 0 to 63, and higher scores indicate greater anxiety symptoms (Beck, Epstein, Brown, & Steer, 1988). The BAI has been used in postpartum samples (Stuart, Couser, Schilder, O’Hara, & Gorman, 1998).

The Perceived Stress Scale (PSS), administered at the end of every fourth study week, reflects how often participants felt or thought a certain way during the last month. Data from postpartum Weeks 5 and 13 were used in analyses for the present study because they were the closest weeks to the fatigue data assessments. The PSS is a 10-item survey measuring the degree to which life situations are considered stressful. Each item has a 0–4 scale (0 = Never, 4 = Very often). Total score ranges from 0 to 40, with higher scores indicating more stress symptoms (Cohen, Kamarck, & Mermelstein, 1983). This scale has been used among postpartum women to examine correlations with depression (Boury, Larkin, & Krummel, 2004).

**Statistical Analyses**

SPSS Version 18.0 was used for analyses, a $p < .05$ was considered statistically significant, and Cohen’s $d$ was used to calculate effect sizes (small = 0.2, medium = 0.5, and large = 0.8). Figures include standard error bars. Chi-square analyses were used to assess differences between fatigue group and marriage status. Paired-sample $t$-tests were used to compare within-subject differences in mood, anxiety, and stress scores between postpartum Weeks 2 and 12. Analysis of covariance (ANCOVA) models were used to account for age when assessing differences in mood, anxiety, and stress between fatigue groups. A backward stepwise logistic regression was used to determine which variables best predicted fatigue group.

Participants were excluded from the analyses if they did not meet the above-mentioned requirements for fatigue pattern assessment, and five participants were excluded because of missing fatigue data due to PDA malfunction. We thus categorized 64 of these 71 participants into a fatigue group (rhythmic, $n = 39$; random, $n = 25$) for Week 2. At Week 12, 8 participants were excluded because they did not meet the criteria for fatigue pattern assessment, and 7 participants were excluded because of missing data (6 were lost due to attrition and 1 was lost because of PDA malfunction), resulting in 56 participants categorized into a fatigue group at postpartum Week 12 (rhythmic, $n = 40$; random, $n = 16$).

**Mood**

For all participants, POMS total mood disturbance scores were significantly higher at postpartum Week 2 ($M = 20.78$, $SD = 24.87$) compared to Week 12 ($M = 4.86$, $SD = 20.74$), $t(48) = 4.47, p < .001$. At postpartum Week 2, no significant differences were found on the POMS total or subscale scores between fatigue groups (Figure 2A). At postpartum Week 12, total POMS and all subscale scores but fatigue tended to be lower for women with a rhythmic fatigue pattern, but only the vigor-activity subscale scores were significantly lower after accounting for age, $F(55) = 4.60, p = .04$, $d = 0.66$ (Figure 2B).

**Anxiety**

Anxiety scores on the BAI and the anxiety subscale of the POMS were moderately to strongly positively correlated with each other at both the early ($r = .67$, $p < .001$) and late ($r = .58$, $p < .001$) study weeks. BAI scores were significantly higher at postpartum Week 2 ($M = 6.24$, $SD = 5.64$) compared to postpartum Week 12 ($M = 3.22$, $SD = 3.35$), $t(49) = 3.97$, $p < .001$. BAI score did not differ between fatigue groups at either postpartum Week 2, $F(62) = 1.16, p = .29$ (Figure 3A) or postpartum Week 12, $F(54) = 1.87, p = .18$ (Figure 3B).

**Stress**

PSS scores were significantly higher at postpartum Week 2 ($M = 12.55$, $SD = 5.77$) compared to postpartum Week 12 ($M = 10.14$, $SD = 5.59$), $t(48) = 2.79$, $p = .008$. There was no significant difference in mean PSS scores between fatigue groups at postpartum Week 2, $F(60) = 0.03, p = .87$ (Figure 4A). However, women with a rhythmic fatigue pattern at postpartum Week 12 reported significantly lower stress scores than those with a random fatigue pattern after adjusting for age, $F(53) = 6.35, p = .01, d = 0.75$ (Figure 4B).

**Sleep**

Previously reported data using the current sample indicated no change in total sleep time across the first 12 postpartum weeks but did indicate an improvement in sleep efficiency across this period (Montgomery-Downs et al., 2010). Women with a random fatigue pattern at postpartum Week 2 reported greater total...
There were no statistically significant differences in total sleep time between fatigue groups at Week 12, $F(47) = .05$, $p = .82$. There were also no statistically significant differences in sleep efficiency at either postpartum Week 2, $F(60) = 2.27$, $p = .14$, or Week 12, $F(45) = 2.16$, $p = .15$.

**Fatigue Levels**

To determine whether the differences between fatigue pattern groups could be accounted for by simple differences in their levels of fatigue, rather than fatigue patterns, we also analyzed fatigue levels in relation to mental health outcomes and differences in fatigue levels between fatigue pattern groups. Average fatigue levels were significantly higher at postpartum Week 2 ($M = 48.48$, $SD = 13.11$) compared to postpartum Week 12 ($M = 41.78$, $SD = 16.49$), $t(49) = 2.86$, $p = .001$. At Week 2, average fatigue levels were not significantly correlated with any mood subscale, stress, or anxiety scores. At Week 12, higher fatigue levels were significantly correlated with higher anxiety scores (BAI; $r = .28$, $p = .04$), higher stress scores ($r = .48$, $p < .001$), higher POMS total mood disturbance scores ($r = .42$, $p = .002$), tension-anxiety subscale scores ($r = .31$, $p = .02$), fatigue subscale scores ($r = .40$, $p = .002$), confusion-bewilderment subscale scores ($r = 0.48$, $p < .001$), and lower...
vigor-activity subscale scores ($r = -0.45, p = .001$). However, fatigue levels did not differ between fatigue pattern groups at Week 2, $F(62) = 1.67, p = .20$, or Week 12, $F(55) = 1.0, p = .32$.

**Postpartum Week 12 Predictors of Diurnal Fatigue Pattern Group**

Regression analysis to evaluate the best predictors of a random fatigue pattern was run using only Week 12 data because we had not found differences in scores for anxiety, stress, or subscales of mood between fatigue categories at postpartum Week 2. At postpartum Week 12, women with a random fatigue pattern were more evening type on the Morningness–Eveningness scale and had later sleep midpoints, in addition to being younger. A backward stepwise logistic regression using likelihood ratios was used to test whether a random fatigue pattern at postpartum Week 12 could be best predicted from age, morningness eveningness, and/or sleep midpoint value at postpartum Weeks 2 and 12. Because sleep midpoint at Week 2 was significantly later on weekends compared to weekdays, separate logistic regressions were run using only weekend sleep midpoint and then only weekday sleep midpoint. These did not change the results of the logistic regression, so the average sleep midpoint across the week is reported. Descriptive statistics of all variables included in the regression model are reported in Table 1. The analysis was significant, $\chi^2(4) = 12.7, p = .01$, and the only variable remaining in the

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**Figure 3.** Mean Beck Anxiety Inventory (BAI) scores at postpartum (A) Week 2 and (b) Week 12 for women with rhythmic and random fatigue patterns. Error bars indicate standard error values.

**Figure 4.** Mean Perceived Stress Scale (PSS) scores at postpartum (A) Week 2 and (B) Week 12 for women with rhythmic and random fatigue patterns. Error bars indicate standard error value. *$p < .05$ after adjusting for age.*
Table 1. Demographic Differences Between Fatigue Pattern Groups at Postpartum Week 12.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Rhythmic Fatigue Pattern</th>
<th>Random Fatigue Pattern</th>
<th>p</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incomea ($)</td>
<td>68,000 (36,000)</td>
<td>45,000 (26,000)</td>
<td>.06</td>
<td>0.73</td>
</tr>
<tr>
<td>Ageb (years)</td>
<td>27.5 (3.9)</td>
<td>24.6 (2.6)</td>
<td>.01</td>
<td>0.87</td>
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<tr>
<td>Years of educationc</td>
<td>16.4 (2.4)</td>
<td>15.2 (2.8)</td>
<td>.11</td>
<td>0.46</td>
</tr>
<tr>
<td>Morningness-eveningness</td>
<td>20.8 (4.5)</td>
<td>16.2 (4.7)</td>
<td>.001</td>
<td>1.00</td>
</tr>
<tr>
<td>Avg. sleep midpoint, Week 2</td>
<td>4:09 a.m. (59.2 min)</td>
<td>5:28 a.m. (73.7 min)</td>
<td>&lt;.001</td>
<td>1.18</td>
</tr>
<tr>
<td>Avg. weekend sleep midpoint, Week 2</td>
<td>4:26 a.m. (61.09 min)</td>
<td>5:49 a.m. (77.7 min)</td>
<td>&lt;.001</td>
<td>1.18</td>
</tr>
<tr>
<td>Avg. weekday sleep midpoint, Week 2</td>
<td>4:05 a.m. (59.7 min)</td>
<td>5:19 a.m. (76.5 min)</td>
<td>&lt;.001</td>
<td>1.08</td>
</tr>
<tr>
<td>Avg. sleep midpoint, Week 12</td>
<td>3:34 a.m. (71.0 min)</td>
<td>5:40 a.m. (97.3 min)</td>
<td>&lt;.001</td>
<td>1.48</td>
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<tr>
<th>n (%)</th>
<th>n (%)</th>
<th>χ²</th>
<th>p</th>
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<tbody>
<tr>
<td>Marital status</td>
<td></td>
<td>5.07</td>
<td>.08</td>
</tr>
<tr>
<td>Married/living together</td>
<td>37 (92.5)</td>
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<td></td>
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<tr>
<td>Single</td>
<td>2 (5.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Divorced/separated</td>
<td>1 (2.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>4 (25.0)</td>
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</tr>
<tr>
<td>Divorced/separated</td>
<td>0 (0)</td>
<td></td>
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</tr>
</tbody>
</table>

Note: avg. = average; SD = standard deviation.
* Variable assessed only once at the beginning of the study.

fourth and final step was average sleep midpoint value, which predicted a significant proportion of variation in fatigue group during postpartum Week 12 (p = .003). According to the odds ratio value, for every hour later their sleep midpoint value was, women were 2.32 times more likely to have a random fatigue pattern.

**Discussion**

In the present study, healthy postpartum women with a rhythmic diurnal fatigue pattern at postpartum Week 12 reported fewer stress symptoms as well as more vigor-activity than women with a random fatigue pattern. These findings persisted after accounting for variance in age. Younger age, a more evening chronotype, and a later sleep midpoint were all significantly associated with a random fatigue pattern at postpartum Week 12. A later sleep midpoint at postpartum Week 12 was the most significant predictor of having a random fatigue pattern at postpartum Week 12. The differences between fatigue pattern groups were not accounted for by simple differences in overall fatigue levels, which did not differ between groups. Taken together, these data suggest that sleep patterns and chronobiology play a role in fatigue pattern during the postpartum period and that having a rhythmic pattern of fatigue may be advantageous for mental health outcomes.

Higher levels of fatigue were also related to more anxiety, stress, and depressive symptoms; increased tension, fatigue, and confusion; and less vigor at postpartum Week 12. These findings support previous studies that have found a relation between fatigue and depression as well as fatigue and stress (Groër et al., 2005). Interestingly, the fatigue levels in our study did not differ significantly between the fatigue pattern groups, yet both fatigue level and fatigue pattern were related to mental health outcomes. This finding suggests that fatigue level and fatigue patterns make unique, independent contributions to mental health outcomes during the postpartum period.

Our data did not reveal any mental health differences between the fatigue pattern groups at postpartum Week 2. There were also no significant associations between the mental health measures and overall fatigue levels at postpartum Week 2. However, women with a random fatigue pattern did obtain significantly more total sleep time than women with a rhythmic pattern at postpartum Week 2. We are uncertain of the implications of this finding, considering our findings in a previous study that total sleep time does not change over the postpartum period nor does it differ from that of nulliparous controls (Insana, Williams, & Montgomery-Downs, 2013). We also found in the prior study that total sleep time is of less significance than sleep efficiency in relation to neurobehavioral performance.

Mood, anxiety, stress scores, and overall fatigue levels were all significantly higher in the present study at postpartum Week 2 compared to Week 12. There are several potential reasons to explain why we did not find a relation between fatigue pattern and dependent measures until the later postpartum period. Our early postpartum findings support the findings from earlier studies showing transiently high levels of mood, anxiety, stress, and fatigue in the immediate postpartum period (Seyfried & Marcus, 2003). These high levels are likely a product of a variety of factors that occur in the immediate postpartum period. For instance, normal hormonal changes during the transition to parenthood may temporarily disrupt mood among some women during the immediate postpartum period (O’Keane et al., 2011). Additionally 28% of the current study’s sample gave birth via cesarean section, which has been associated with increased morning fatigue immediately postpartum compared to mothers who delivered vaginally (Lee & Lee, 2007).

Because a random fatigue pattern was associated with increased symptoms of stress and decreased vigor in the later postpartum period, we sought to examine what factors might be contributing to fatigue pattern. Sleep midpoint at Week 12...
was the strongest predictor of a random fatigue pattern at Week 12: Mothers with a later sleep midpoint were more likely to have a random fatigue pattern. Sleep midpoint values were also strongly correlated with chronotype among the women in our study. This strong correlation supports the relation between a prenatally assessed chronotype and postpartum behavior.

These results add to the limited literature regarding the relations between chronotype and fatigue. The existing research on this topic is contradictory. One study, using a large sample of adults, reported evening types to be more likely to vary their bedtime and rise time (suggesting a random fatigue pattern) by over 2 hr than morning types or neither types (Taillard, Philip, & Bioulac, 1999). Another study using a postpartum sample found evening-type women had a greater regularity in their sleep–wake cycles during the postpartum period than morning-type women (Yamazaki, 2007). Our results contradict the latter findings, suggesting that further research is needed regarding chronotype, fatigue patterns, and timing of sleep–wake cycles among a postpartum population.

Although we cannot deduce causation, based on our findings, we speculate that a random diurnal fatigue pattern during the later, but not during the immediate, postpartum period may be a contributing factor to increases in maternal stress and decreases in vigor that previous researchers have reported (Fowles & Walker, 2009; Lee & Zaffke, 1999). Confirmation of a causal pathway and the mechanism remain to be evaluated. Nevertheless, the implications of these findings go beyond the health of the mother. Maternal stress is also associated with decreases in reported infant health at 18 months of age (Fowles & Walker, 2009). However, it is also possible that postpartum mood disruptions contribute to a random pattern of fatigue. Further research is needed in this area to clarify these associations and address causation.

There were several limitations in the current study. First, the use of this particular assessment of fatigue patterns is a novel method that has not been previously validated. Future studies should validate this method against the circadian rhythm biomarker melatonin. Additionally, the current study utilized a preexisting data set that recorded descriptive data about postpartum women’s sleep, so fatigue reports were combined over a week because assessments were not made frequently or regularly enough to utilize individual days. The women were instructed to complete the fatigue assessments during diurnal infant feedings so that data collection would become a routine part of their day. Although this method produced a relatively high adherence to consistent completion of the fatigue assessments, standardized time points throughout the day were not obtained. Standardized time points could have allowed for evenly spread fatigue data throughout the day and more fatigue ratings and reduced the number of participants excluded from the analyses. Furthermore, data on work status or when women returned to work were not collected and so could not be examined in the current study. Finally, the current study did not take into account other factors that may have affected fatigue values independent of postpartum disruption in the sleep–wake cycle. These factors may include maternal hormonal shifts, breastfeeding, and presence of a social support system (Groër et al., 2005; Troy, 2003). Other ecological factors that may contribute to altered fatigue levels and sleep include individual differences in sleep hygiene practices, such as variations in nocturnal light levels and noise pollution, and the infant’s proximity to the mother’s bed (Lee & Gay, 2011; Stremler et al., 2006) as well as the infant’s sleep patterns. It is important that future studies examine changes in rhythmicity from prepregnancy to the postpartum period as well as account for the infant’s nocturnal awakenings.

Our findings in the present study provide new evidence of the importance of analyzing fatigue patterns across the day, in addition to overall fatigue levels, in relation to mental health symptoms postpartum.

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