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Characterization of Late Postpartum Sleep Disturbance, Caffeine-Related Performance, and Daily Functioning

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ABSTRACT

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The early postpartum period is marked by maternal sleep fragmentation and performance deficits. Although sleep gradually improves in postpartum women, reaction times gradually worsen. This performance deficit is seen beyond 6 weeks postpartum, when many women are expected to return to work, and it is unknown when (or if) new mothers' performance deficits fully recover. The current study used existing data to characterize the late postpartum period (6 months-3 years after the child was born) in terms of recovery from sleep disturbance by monitoring the behavior of mothers on both objective and subjective measures. The current study aimed to describe the sleep and overall functioning of late postpartum women in order to better inform women and policymakers about potential performance deficits, especially regarding return-to-work. Objective measures of sleep fragmentation, recorded via actigraphy, revealed recovery of sleep quality to levels found among nulliparous control women, and late postpartum subjective mood scores on the Profile of Mood States were normal. However, objective reaction times, measured via the psychomotor vigilance test, were poor among late postpartum women compared to controls, although postpartum reaction times may be improved by caffeine. Next, objective sleepiness scores, measured using the Multiple Sleep Latency Test, for both early and late postpartum women were at normal levels; however one-third of late postpartum women experienced extreme levels of sleepiness. Early and late postpartum women reported poor subjective sleep quality on the General Sleep Disturbance Scale compared to controls, and late postpartum women reported subjective quality of life scores, measured using the Quality of Life Scale, slightly below the average among healthy populations. In sum, these data support reevaluation of maternity leave policy and further research into potential interventions for late postpartum women.

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Introduction

The purpose of the current study was to characterize sleep disturbance and outcome measures in late postpartum mothers, a population known to experience sleep fragmentation, which is a particular type of sleep disturbance. Sleep fragmentation occurs when sleep is interrupted throughout the night, but total sleep time is preserved. This is distinct from partial sleep deprivation which occurs when the total time spent sleeping is reduced (Bonnet & Arand, 2003), although the two can occur simultaneously. To appreciate the impact of sleep fragmentation, it is necessary to describe the sleep cycle, which begins with three progressive stages of non-Rapid Eye Movement (NREM) sleep, followed by REM sleep. The length of the first NREM-REM cycle is 70-100 minutes, which can increase to 90-120 minutes later in the night (Kryger, Roth, & Dement, 2011). If the sleep cycle is interrupted with an awakening during any one of these stages, it must start from the beginning. Without normal, continuous sleep periods, fragmentation occurs, leading to deficits (Banks & Dinges, 2007; Bonnet & Arand, 2003). The term “fragmentation” refers to this interrupted sleep. “Partial sleep deprivation” refers to a reduction of total sleep time, and “total sleep deprivation” refers to complete lack of sleep. Sleep “disturbance” describes either deprivation (partial or total) or fragmentation; sleep “debt” is the effect of accumulated sleep disturbance.

Sleep Disturbance

In general, sleep disturbance leads to deficits in many areas of performance, such as decision-making, risk-assessment, and executive function (Gottselig et al., 2006; Harrison & Horne, 2000). Sleep fragmentation specifically leads to negative mood scores, indicated by decreased friendliness and increased tension (Bonnet, 1987); Bonnet, Berry, & Arand, 1991), as well as increased irritability and decreased vigor scores (Bonnet & Arand, 2003). Multiple studies have shown that sleep fragmentation significantly impairs performance in areas such as reaction time and mood, even though total sleep time is only minimally reduced. Although deprivation can lead to similar deficits, in these particular circumstances, disruption of sleep continuity—rather than total sleep time—leads to deficits in these circumstances (Bonnet, 1986; Bonnet et al., 1991). One such study fragmented the sleep of participants for two consecutive nights, which resulted in deficits similar to those seen after 40-64 hours of total sleep deprivation, despite only missing a total of 1 hour of sleep each night (Bonnet, 1985). This demonstrates the adverse effects sleep fragmentation can have on functioning.

Although sleep fragmentation is the focus of the current study, it is useful to understand that this sleep pattern has consequences similar to deprivation. Those who have chronic sleep deprivation accumulate sleep debt, which is a total build-up of sleep lost over multiple days or longer (Van Dongen, Maislin, Mullington, & Dinges, 2003). As sleep debt increases, reaction times increase and mood scores decrease (Belenky et al., 2003; Dinges et al., 1997), and partial sleep deprivation over multiple days can lead to impairments similar to total sleep deprivation (Van Dongen et al., 2003). Those who experience chronic sleep fragmentation due to sleep-disordered breathing are likely to have sleep debt, and these individuals' reaction times during driving are slower than drivers who are legally intoxicated (Powell , Schechtman, Blumen, Dinges, & Guilleminault, 1999). Deprivation and fragmentation are measured with comparable

methods and lead to similar performance deficits (Bonnet & Arand, 2003), and chronic sleep fragmentation results in functional impairments similar to those found in sleep debt (Powell et al., 1999).

Even if someone is occasionally able to obtain a night of uninterrupted sleep, complete recovery from chronic sleep fragmentation is unlikely to occur after just one night. Some measures of driving performance do not return to normal levels even after a month of recovery from fragmentation (Hack et al., 2000). Recovery from chronic partial sleep deprivation also takes time, and many Americans get inadequate sleep (less than 7.5-8.5 per night) (Wehr et al., 1993). Fourteen percent of Americans report getting less than six hours of sleep per night (National Sleep Foundation, 2011). Individuals allowed 6 hours of sleep per night during a week may need over 9 hours of total sleep time in order to return to normal performance levels (Banks, Van Dongen, Maislin, & Dinges, 2010). Furthermore, while some may appear to have recovered from sleep restriction earlier in the day, the effects of chronic sleep restriction are more apparent as the day progresses due to the influence of the body's circadian rhythm, which reduces the promotion of wakefulness later in the day (Cohen et al., 2010).

Early Postpartum Sleep

Early postpartum women are more likely to experience sleep fragmentation rather than sleep deprivation, thus these women are appropriate participants for the current study. Montgomery-Downs, Insana, Clegg-Kraynok, & Mancini (2010) found that postpartum women generally slept an average of about 7 hours each night, but this sleep was highly fragmented: the interrupted sleep totaled to 2 hours awake each night. Previous experimental studies suggest that these postpartum women would experience deficits in multiple areas, including reaction time and mood (Bonnet, 1985; Bonnet, 1986; Bonnet et al., 1991). Indeed, early postpartum mothers'

reaction times were significantly slower than controls (Insana, Williams, & Montgomery-Downs, 2013). Although early postpartum sleep gradually returns to normal (Montgomery-Downs et al., 2010), reaction times actually worsen over time, suggesting that cumulative sleep fragmentation may be having an effect (Insana et al., 2013). It is unknown when, or if, new mothers' performance deficits fully recover during the later postpartum period. Therefore, the current study aimed to characterize sleep and performance deficits in the late postpartum period. Without sufficient recovery time, postpartum women may be delaying improvement. If sleep fragmentation persists, it may build up over time. Furthermore, impairment may continue even when women do not feel sleepy. Those recovering from sleep disturbance often report not feeling subjectively sleepy, while objective performance measures still show evidence of deficits. These data are in agreement with previous studies that indicate that people who are experiencing sleep disturbance are not able to properly judge their own levels of sleepiness or impairment (Banks et al., 2010; Lamond et al., 2007; Van Dongen et al., 2003). To allow for the detection of these effects among late postpartum women, this study assessed both objective and subjective measures of sleep.

While there are impairments associated with chronic sleep disturbance, United States federal law permits a maximum 12 weeks of unpaid maternity leave (United States Department of Labor, 1993). However, 77% of those who qualify opt out because of financial reasons, indicating that most new mothers still work (Phillips, 2004). States that do offer paid maternity leave allow 6 weeks away from work. Therefore, a new mother may be given a maximum of 6 weeks of recovery time (or 8 weeks if the delivery was via Cesarean section) before returning to work (Fass, 2009). It is important to understand any sleep or performance deficits existing in the

late postpartum period (after this 6 week period) in order to inform mothers, clinicians, and policymakers about time needed for recovery, especially related to return-to-work.

Caffeine

Because sleep disturbance has strong effects on performance and daily functioning, it is best to recover functioning by making up sleep disturbance. This is not always done, however, and many people often turn to psychostimulants, specifically caffeine, to compensate for insufficient sleep quality. Caffeine is the most commonly used drug throughout the world (Lieberman, 2001), and 87% of Americans use it in some form on a daily basis (Frary, Johnson, & Wang, 2005). Caffeine is a psychostimulant that reduces the effectiveness of adenosine, a neurotransmitter involved in inhibiting many areas throughout the brain. As this inhibitory mechanism is suppressed, the central nervous system is more active, and arousal is produced (Lorist & Tops, 2003).

In non-sleep deprived populations, these properties lead to improved functioning on cognitive and behavioral tasks (Christopher, Sutherland, & Smith, 2005; Lieberman, 1987), including improved scores on cognitive performance measures, such as the Stroop test, as well as tests of verbal ability and executive function (Gottselig et al., 2006; Haskell, Kennedy, Wesnes, & Scholey, 2005; Patat et al., 2000). Caffeine also improves some behavioral deficits found in sleep deprivation, including reaction time (Lieberman, Tharion, Shukitt-Hale, Speckman, & Tulley, 2002; Van Dongen et al., 2001) as a broad measure of behavioral performance (Childs & De Wit, 2008; Patat et al., 2000; Wright, Badia, Myers, & Plenzler, 1997).

Caffeine increases the ability to remain awake when fatigued (Walsh et al., 1990; Wright, Badia, Myers, & Plenzer, 1997), and the general improvements that occur with caffeine use can attenuate the negative effects of sleep deprivation on performance and mood (Beaumont et al.,

2001; Gottselig et al., 2006; Lieberman et al., 2002; Patat et al., 2000). Caffeine alters several mood ratings found in the Profile of Mood States (POMS), including increasing Friendliness and Positive Mood scores, and decreasing Depression scores (Childs & De Wit, 2008). These performance improvements can also be seen during sleep deprivation over several days (Beaumont et al., 2001; Lieberman et al., 2002). It is important to note that while caffeine can help performance deficits, the drug cannot completely restore functioning caused by insufficient sleep. Caffeine aids performance in simple tasks, but does not fully repair higher cognitive processes (Gottselig et al., 2006; Lieberman et al., 2002).

Because postpartum mothers potentially experience long-term sleep fragmentation, it is valuable to examine if caffeine is still beneficial after such an extended time. One study found that regular caffeine use among those with obstructive sleep apnea (OSA)—a disorder characterized by chronic sleep fragmentation—was associated with higher global cognitive performance, although there was no association with reaction times as an individual measure (Norman, Bardwell, Loredo, Ancoli-Israel, Heaton, 2008). However, reaction time before and after caffeine use during chronic sleep fragmentation has not been studied, and it is possible that caffeine does not aid in late postpartum daily functioning by improving performance deficits. Because postpartum mothers experience sleep disturbance from a naturalistic and non-sleep-disordered perspective (Insana & Montgomery-Downs, 2010), examining caffeine use in this population would lead to a better understanding of caffeine use in chronic sleep disturbance.

Statement of Problem

Frequent nocturnal infant awakenings lead to fragmented maternal sleep (Nishihara, Horiuchi, Eto, & Uchida, 2002), which is associated with slower reaction time and decreased mood scores (Bonnet, 1986; Bonnet et al., 1991). In the United States, the standard 6 weeks of

maternity leave may not allow adequate time for recovery after the birth of a child, especially if sleep disruption and its associated performance impairments exist further into the postpartum period (Montgomery-Downs et al., 2010). If both parents work and no other familial caregivers are available, women are often expected to care for a child and continue to work outside the home, although daily functioning may not yet be restored. However, there is little information to characterize when postpartum women recover from this sleep disturbance. The current study aims to determine if late postpartum women still experience sleep fragmentation in order to better understand when recovery may occur.

Three research questions were addressed in this study. The first addressed whether a group of late postpartum women have less fragmented sleep compared to a group of early postpartum women, and whether this sleep is comparable to women who have no children. **Research Question 1: Do late postpartum women (6 months – 3 years) differ from early postpartum women (6 weeks) and nulliparous controls on measures of sleep fragmentation (measured with actigraphy), objective sleepiness (measured with the Multiple Sleep Latency Test), and sleep quality scores (using the Sleep Quality Question)?** It was predicted, based on the first of three hypotheses that late postpartum women would have higher sleep efficiency than early postpartum women, but lower than control women. Sleep efficiency is defined as the percent of time spent asleep between sleep onset and final awakening: those who have higher levels of sleep fragmentation spend less time asleep, meaning sleep efficiency decreases (de Souza et al., 2003). Montgomery-Downs et al. (2010) characterized the improvement of early postpartum sleep fragmentation, and it was expected to improve into the late postpartum period.

Next, it was predicted that late postpartum women's sleep latency scores would be higher than control women. However, the Multiple Sleep Latency Test (MSLT) data from the control group were not available, so MSLT data from a subset of early postpartum women were used instead. It was predicted based on this new hypothesis that late postpartum women's sleep latency scores would be higher than early postpartum women. The sleepier an individual is, the faster they will fall asleep during the MSLT, leading to a lower sleep latency score. Because late postpartum women were expected to experience less sleep fragmentation than early postpartum women, it should be reflected in this objective measure of sleepiness (Arand et al., 2005). Finally, it was hypothesized that late postpartum women's self-reported sleep quality scores would be higher than early postpartum women, but lower than control women. Higher sleep quality scores, which indicate a subjectively better quality of sleep, reflect levels of sleep disturbance seen on actigraphy (Gay, Lee, & Lee, 2004). Postpartum women are expected to recover from sleep fragmentation over time, although they were not predicted to improve to control levels.

The second research question asked whether postpartum women's performance is slower than women who have no children, and whether caffeine use is related to increased reaction time..

Research Question 2: Is caffeine use an effective strategy among late postpartum women?

Based on the first of two hypotheses, it was predicted that late postpartum women would have a higher lapse frequency before caffeine use than control reaction times before caffeine use. A higher lapse frequency during the psychomotor vigilance test (PVT) indicates worse reaction time performance. Although those with chronic sleep disturbance may turn to caffeine in order to aid in daily functioning, the relations between caffeine use and improved performance have not been examined during chronic sleep disturbance, and deficits in the late postpartum period may not be attenuated by caffeine as expected. Based on the second hypothesis, it was predicted that

late postpartum women would have a lower lapse frequency after caffeine use than control reaction times before caffeine use. Sleep disturbance leads to worsening performance on reaction time tests; these reaction time deficits increase as sleep disturbance builds (Lim & Dinges, 2008), and late postpartum women were expected to have greater sleep disturbance than controls. However, caffeine use can improve performance impairments found in sleep disturbance (Beaumont et al., 2001; Gottselig et al., 2006), which may improve late postpartum performance to a level comparable to controls.

The third research question asked how late postpartum sleep is related to a mother's actual and perceived ability to function during the day. **Research Question 3: What is the association between late postpartum objective sleepiness and quality of life (measured with the Quality Of Life Scale), mood (measured with the Profile of Mood States), and reaction time (measured with PVT)?** Based on the first of three hypotheses, it was predicted that lower sleep latency scores among late postpartum women would be associated with lower quality of life scores. This is a valid measure among those with chronic mental and physical health issues (Burckhardt & Anderson, 2003), and a higher Quality of Life Scale (QOLS) score indicates a higher self-reported quality of life. Based on the second hypothesis, it was predicted that lower sleep latency scores among late postpartum women would be associated with higher POMS Total Mood Disturbance (TMD) scores. On the POMS, a higher TMD score indicates worse self-reported mood. Because sleep disruption is associated with negative mood scores, women experiencing more sleepiness should report worse mood scores than women who are not as sleepy (Belenky et al., 2003; Dinges et al., 1997). Based on the final hypothesis, it was predicted that lower sleep latency scores among late postpartum women would be associated with a higher lapse frequency. A measure of actual performance is needed, as perceived and objective

measures often differ (Bei, Milgrom, Ericksen, & Trinder, 2010). Because late postpartum women were expected to have greater sleep disturbance than controls, late postpartum women should have a higher lapse frequency, indicating worse performance (Lim & Dinges, 2008).

Methods

Participants

Data from several groups were used in the current study so that late postpartum sleep could be compared to both early postpartum and control women. Because women have a maximum of 6 weeks paid maternity leave(Fass, 2009), data from 6 weeks postpartum were used in the current study.

Early Postpartum Women. An existing data set from a previous study, designed to characterize the sleep of primiparous mothers from 1 to 12 weeks postpartum, was used. Participants were recruited using local advertisements, such as television and university postings, and word of mouth. Potential participants were screened for sleep disorders based on medical history or symptoms during a survey of common sleep disorders. These early postpartum women were given an actigraph and a personal digital assistant (PDA) to record their sleep/wake patterns for 12 continuous weeks. The PDA was also used to complete reaction time tests and surveys. A member of the laboratory research team met with each participant on a weekly basis and administered additional surveys. Data from postpartum week 6 were used for the current analyses because women typically have about 6 weeks of maternity leave before returning to work.

Within the sample of early postpartum women, there was a subgroup of women who also completed the MSLT. On average, these women participated in the MSLT at 6.45 weeks

postpartum. The sleep latency scores for this subgroup were used as the sleep latency scores for early postpartum women.

Control Women. An existing data set from a study designed to characterize the sleep of nulliparous control women was used. Participants were recruited through university emailing and word of mouth. Potential participants were screened for—and excluded on the basis of—sleep disorders assessed by medical history or symptoms using a survey of common sleep disorders. This was done to ensure that the postpartum populations were compared to those with healthy sleep behaviors. These control women were given an actigraph and a PDA to record their sleep/wake patterns for 12 continuous weeks. The PDA was also used to complete reaction time tests and take surveys. A member of the laboratory research team met with each participant on a weekly basis and administered additional surveys. Data from week 6 were used for the current analyses for comparison to the week used for early postpartum women.

Late Postpartum Women. An existing data set—designed to characterize the sleep of primiparous mothers during the late postpartum period—was used. Participants were mothers in the late postpartum period who had one child between 6 months and 3 years of age, and had not had a second child. Participants were recruited using local advertisements, such as television and university postings, and word of mouth. Potential participants were screened for sleep disorders based on medical history or symptoms using a survey of common sleep disorders. During consent, participants were given an actigraph and a PDA to record sleep/wake patterns, complete reaction time tests, and take surveys for one week. This week of actigraphy and PDA data was compared to the early postpartum and control groups' week 6 data. After one week, participants were brought into the sleep laboratory to complete a day-long MSLT using polysomnography (PSG).

Measures

In order to assess sleep quality and characterize postpartum sleep disturbance, both objective and subjective measures were used. The objective measures, in general, are more valid for determining how long it takes participants to fall asleep and how much time was spent asleep during the night (i.e. sleep latency using MSLT and sleep fragmentation using actigraphy) (Baker, Maloney, & Driver, 1999), the latter being a noted feature of postpartum sleep (Montgomery-Downs et al., 2010). In contrast, subjective measures are valuable for assessing a participant's perceived quality of sleep, which is associated with mood disturbances, and gives an indication of daily functioning (Bei et al., 2010; Insana, Stacom, & Montgomery-Downs, 2011). New mothers may subjectively report that they can function normally, but it is important to discover if—because of a general inability to judge sleepiness correctly— they are actually objectively impaired. Both types of assessment are valuable in order to characterize sleep patterns and effect on functioning, so they were used in the current study to more fully understand late postpartum sleep.

Psychomotor Vigilance. Psychomotor vigilance, or the ability to attend to a current task, is very sensitive to sleep disturbance; for this reason, the PVT, a reaction-time test, is widely used in sleep studies (Lim & Dinges, 2008). Sleep deficits worsen performance on the PVT in a dose-response manner (Belenky et al., 2003; Van Dongen et al., 2003), indicating impaired reaction time (Bonnet, 1986; Bonnet, 1987; Bonnet & Arand, 2003; Bonnet et al., 1991; Stepanski, Lamphere, Roehrs, Zorick, & Roth, 1987). Additionally, the PVT has minimal practice effects (Dinges et al., 1997; Jewett, Dijk, Kronauer, & Dinges, 1999), and it has a high stimulus rate in order to reduce fatigue effects (Dorrian, Rogers, & Dinges, 2005). As the amount of sleep disruption increases, reaction times worsen, and the number of lapses (when a

participant's reaction time is 500ms or more) increases. Among a sleep disrupted population, a lapse can typically be explained by the occurrence of a microsleep, which is when individuals have fallen into Stage I or Stage II sleep (Lim & Dinges, 2008). In the current study, analysis of lapses gave an indication of performance, as it is considered a main outcome measure of this assay (Dorrian et al., 2005; Lim & Dinges, 2008).

The PVT is sensitive to changes in the amount of sleep someone gets as differences in many hours of sleep disruption are reliably reflected by a small change in the number of PVT lapses (Belenky et al 2003; Van Dongen et al, 2003). The ability to detect these differences is particularly important in driving situations, especially because drivers are not always able to recognize extreme levels of sleepiness (Atzram et al., 2001). A higher number of PVT lapses is significantly associated with poorer simulated driving performance following sleep deprivation, specifically in terms of decreased ability to maintain speed and stay in the correct driving lane (Forsman, Vila, Short, Mott, & Van Dongen, 2013; Jackson, Croft, Kennedy, Owens, & Howard, 2013). In one instance, poorer driving performance following sleep deprivation was predicted by poorer PVT performance, where sleep deprived participants had 5 lapses per PVT session and controls had 1.9 (Jackson et al., 2013). Furthermore, the number of PVT lapses is associated with the occurrence of slow eyelid closures, which are risky during driving because drivers are not looking at the road and are potentially experiencing an uncontrolled sleep attack (Price et al., 2003). PVT lapses are related to these sleep attacks because, in the minute leading up to the sudden onset of sleep, PVT performance progressively declines (Konowal, Van Dongen, Powell, Mallis, & Dinges, 1999).

Psychomotor vigilance has also been used to compare performance after sleep disruption with performance while intoxicated because alcohol also impairs the ability to sustain attention

in a manner similar to tests of vigilance (Koelega, 1995), and the effects of intoxication on driving have been well documented (US Department of Transportation, 2012). In Lamond & Dawson (1999), participants with a blood alcohol content (BAC) of .10% performed no differently than participants who had been awake for 24.9 hours. Together, this evidence supports the notion that the differences found in PVT performance for sleep disturbed individuals are associated with decreased performance on driving.

Early postpartum and control women completed the PVT on a handheld PDA within 2 hours after awakening each morning, and before drinking caffeine. Late postpartum women also followed these directions, but those who drank caffeine also completed the PVT a second time, 1 hour after having caffeine. The PVT procedure required participants to press a button on the PDA as fast as possible whenever a visual stimulus (a black target) appeared on the screen. The trial lasted 5 minutes and contained multiple button-presses; reaction times (in milliseconds) and number of lapses were recorded for each day that the PVT was completed. Because participants completed the PVT at least once a day, percent lapses (out of total trials for each administration) were averaged across each week. This was done to reduce day-to-day variability between trials and provided a more representative measure of functioning for the week overall. For late postpartum caffeine-drinkers, before and after caffeine PVT trials were averaged separately.

Multiple Sleep Latency Test. The standard method of objectively assessing daytime sleepiness is the MSLT (Littner et al., 2005). It is based on the assumption that the sleepier an individual is, the faster they will fall asleep. The test uses sleep latency—the average amount of time it takes a person to fall asleep across four daytime naps spaced every 2 hours—to quantify daytime sleepiness. It is the primary assessment of sleepiness used, and as sleep time and efficiency decrease, sleep latency scores also decrease (Arand et al., 2005; Carskadon, Dement, Mitler,

Roth, & Westbrook, 1986). The MSLT is commonly used to assist in diagnosis of certain sleep disorders that use level of sleepiness as a criterion, such as narcolepsy (Littner et al., 2005). It has also been used in relation to certain medical disorders, such as rheumatoid arthritis (Hirsch et al., 1994), chronic obstructive pulmonary disease (Orr, Shamma-Othman, Levin, Othman, & Rundell, 1990), and epilepsy (Drake, Weate, Newell, Padamadan, & Pakalnis, 1994). The MSLT is a valid assessment of the sleepiness associated with sleep fragmentation (Arand et al., 2005), and therefore is an appropriate measure for sleepiness in the postpartum population (Montgomery-Downs et al., 2010). If late postpartum women are also experiencing sleep disturbances, then the MSLT can be used to quantify the impact of that disturbance.

Participants completed a week of actigraphy in order to confirm that they kept a regular sleep pattern during the previous week, including the night before the MSLT (American Academy of Sleep Medicine, 2005). During the lab-based MSLT, participants were given four nap opportunities, spaced 2 hours apart, and polysomnography (PSG) was used to measure sleep latency for each nap. PSG uses several variables in order to recognize stages of sleep. These include EEG to measure brain activity, electro-oculogram (EOG) to measure eye movements, electromyogram (EMG) to measure muscle tension in the chin, and rhythm electrocardiogram (ECG) to measure heart rate. The 10-20 system for EEG electrode placement was used to measure brain activity from specific regions of the brain (C3, C4, O1, O2) (American Academy of Sleep Medicine, 2005). The sleep latency scores across all four naps were averaged in order to get an indication of sleepiness level. An average sleep latency score of less than 8 minutes is considered “sleepy” at a diagnostic level, and narcoleptics have a score of 3.1 minutes on average (American Academy of Sleep Medicine, 2005).

Actigraphy. In order to gain an objective estimate of sleep patterns, and to identify potential sleep deficits, actigraphy was used. Actigraphy is a validated method for objectively assessing sleep/wake patterns among adults (Sadeh, 2011; de Souza et al., 2003), and it has been used to evaluate the effects of sleep deprivation and sleep fragmentation (Gruber, Sadeh & Raviv, 2000; Montgomery-Downs et al., 2010; Natale, Plazzi, & Martoni, 2009). In actigraphy, a small watch-like device which detects movement is worn on the wrist, and sleep/wake patterns are derived from this movement (Sadeh & Acebo, 2002). In a natural setting, the total amount of time spent sleeping can be measured, as well as the length of time disruption persists (Sadeh, 2011; de Souza et al., 2003). This information about typical sleep patterns allows for the assessment of quality of sleep, and has previously been used to characterize sleep fragmentation in early postpartum women (Montgomery-Downs et al., 2010). Actigraphy is therefore appropriate to determine whether sleep fragmentation continues in the late postpartum period.

Participants were instructed to wear Mini Mitter's Actiwatch-64 actigraph (Mini Mitter, Bend, OR) to be worn on the non-dominant wrist, as well as a PDA. The PDA was used to keep a sleep diary (to record sleep and wake times) and a watch diary (to record when the actigraph was taken off). The sleep/watch diaries were used to corroborate actigraph data. After one week of recording, actigraph data were scored by computer algorithm. Researchers defined sleep periods manually using PDA sleep diary information: periods with motion indicate time awake, and periods without motion indicate sleep. Sleep start times were defined as the closest 2-minute period without motion (8 epochs, 15 seconds each) following the reported sleep times. Sleep end time was defined as the closest 2-minute period without motion preceding the reported awakening. This gave an indication of sleep/wake patterns, as well as the following sleep parameters: total sleep time (TST) is defined as the minutes spent asleep; sleep efficiency (SE) is

defined as the percent of time spent asleep between sleep onset and final awakening (de Souza et al., 2003). These parameters are useful in understanding the participants' quality of sleep.

General Sleep Disturbance Scale. It is important to also consider subjective measures of sleep so that a participant's perceived sleep quality can be assessed. One such measure is the General Sleep Disturbance Scale (GSDS). Three questions in this 21-item scale refer to sleep quality. Because these items show internal consistency (K. a Lee, 1992), only one item from the sleep quality subscale was used in order to reduce participant burden. This item was called "the Sleep Quality Question." Scores on the GSDS reflect level of sleep disruption and actigraphy reports (Gay et al., 2004; Insana et al., 2011). If there are differences between this subjective measure and objective measures, this may be accounted for by differences in perceived level of sleepiness: as level of sleep deprivation increases, participants have difficulty reporting how sleepy they truly are (McClelland & Pilcher, 2007). Finally, the GSDS has been used previously in postpartum populations (Gay et al., 2004).

Participants completed the Sleep Quality Question on a PDA within 2 hours after awakening each morning. The question asks, "Where 100 is feeling fully rested, please indicate your quality of sleep," and participants responded on a visual analogue scale. When assessing the postpartum population, it is necessary to consider how mothers perceive their own sleepiness.

Caffeine Consumption. Participants were instructed to create a voice-recorded note about caffeine consumption. Upon drinking caffeine, participants recorded a voice memo on the PDA stating the amount and type of caffeinated beverage consumed, as well as the time of consumption. Voice notes were transcribed manually for each participant. Data from these recordings were used to estimate the amount of caffeine consumed (type and amount of caffeinated product), as this may have been related to PVT score differences.

Profile of Mood States. It has been repeatedly shown that sleep restriction leads to poor mood scores on a number of measures (Bonnet, 1987; Bonnet & Arand, 2003; Bonnet et al., 1991). Because postpartum sleep fragmentation continues at least until week 16 (Montgomery-Downs et al., 2010), the current study aimed to characterize any potential sleep disturbances in the late postpartum period, as well as mood scores. Additionally, negative mood and depressive symptoms in the mother have been associated with cognitive impairments in infants (Galler & Harrison, 2000). Because of the concern for the mental health of the mother and the subsequent risk to the child, the Profile of Mood States (POMS) was used in the current study to monitor mood in the late postpartum period.

The POMS is a validated subjective measure of mood separated into six mood dimensions: tension, depression, anger, vigor, fatigue, and confusion (McNair, Lorr, & Dropplemen, 1971). The total mood disturbance (TMD) score is the overall mood score attained from each mood dimension. Among normative samples, the mean TMD score for adult females is 20.3, and the mean for female psychiatric outpatients (the majority of whom had anxiety, depressive, or personality disorders) is 80.6 (McNair & Heuchert, 2005). The POMS is sensitive to sleep loss (Bonnet et al., 1991; Childs & de Wit, 2008) and has previously been used within the postpartum population (Insana & Montgomery-Downs, 2010). Participants completed the POMS in the sleep laboratory between nap periods.

Quality of Life Scale. If mothers continue to have sleep disturbances into the late postpartum period, this may be related to other measures of perceived daily functioning. One such measure is the QOLS (Flanagan, 1978), which has been used in healthy populations, as well as populations with health problems. This self-report scale asks how satisfied a participant feels in six different aspects of their life: material and physical well-being; relationships with other

people; social, community, and civic activities; personal development and fulfillment; recreation; and independence (Burckhardt & Anderson, 2003). Some women may have a low "quality of life" in some aspects, such as material and physical well-being; other aspects, such as relationships with other people, may have higher ratings linked to becoming a mother. Participants completed the QOLS in the sleep laboratory between nap periods. Normal, healthy populations have a total QOLS score of around 90 (Burckhardt & Anderson, 2003). This measure was used to provide insight into how late postpartum women function at a broad level.

In summary, both objective and subjective measures give valuable information about potential sleep disturbances in late postpartum women. If sleep fragmentation continues into the later postpartum period, then actigraphy should objectively indicate this pattern, and MSLT scores should reflect the expected decreased sleep latency. If performance is compared between late postpartum women and controls, reaction times from the PVT should reveal any differences that exist. Finally, the Sleep Quality Question, POMS, and QOLS should provide a helpful perspective in assessing perceived sleepiness and daytime functioning.

Results

Data Management

Before analysis, all data were analyzed for normality using descriptive tests, tests for skewness and kurtosis, and histograms were visually analyzed for linearity and homogeneity of variance. Data were also checked for missing values. Missing data were not imputed due to small sample sizes and a desire to maintain practical and conceptual meaning; pairwise deletion was used to handle missing data. A $p < .05$ was considered statistically significant; Cohen's d was used to calculate effect sizes when groups had equal sample sizes, and Hedges' g was used when sample sizes were unequal (Rosnow, Rosenthal, & Rubin, 2000).

Early Postpartum Women. There were originally 71 participants in this data set, but missing data were present for different variables due to issues such as equipment malfunctioning or conflicts with participants' personal schedules. For sleep efficiency, data from week 6 postpartum were missing for 3 participants (4.2%). For the remaining women, weekly data were averaged (sleep efficiency for each night within the week) for each participant, and then analyzed. Thus, the additional 2 participants (2.8%) who had fewer than 4 data points in the week were excluded. These data were normally distributed, and no outliers were present.

In regards to data from the Sleep Quality Question, data from week 6 postpartum were missing for 2 participants (2.8%). Again, the data points for each individual per week were averaged, and the 5 additional participants (7%) who had fewer than 4 data points in the week were excluded. These data were normally distributed with no outliers present.

Within the sample of 71 early postpartum women, there was a subgroup of 16 women who completed the MSLT and, thus, have sleep latency scores available for analysis. Because this subgroup was only used for MSLT scores, there were no missing data points in this group. The data collected were normally distributed, and there were no outliers.

Control Women. There were 9 participants in this data set, and data from week 6 of this study were used. For sleep efficiency, only 1 participant (11.1%) had missing data due to equipment malfunctioning, leaving 8 participants available for analyses. Data for the Sleep Quality Question and the PVT lapse frequency had no missing values. For all three variables, all data points for the week were averaged for each participant, and then analyzed. These data were normally distributed with no outliers present.

Late Postpartum Women. There were 12 participants in this data set, and there were no missing values for any variables in this one-week study. For the sleep efficiency and sleep

quality variables, participants' data were averaged within the recording week. Sleep latency, Sleep Quality Question, QOLS, and POMS TMD scores were only collected once and did not need to be averaged. Participant PVT lapse frequencies were categorized depending on when the PVT was administered. The baseline group included the baseline scores from the first PVT administration for each morning (regardless of caffeine use). Then, participants were divided into caffeine-users and non-users. For caffeine users, data were split further: one group included scores before caffeine was used, and the other included scores after caffeine was used. This allowed for direct comparison of scores only related to caffeine consumption in order to test the hypotheses related to lapse differences and caffeine use. In contrast, the baseline group lapse scores allowed for comparison that is uninfluenced by caffeine. All variables were normally distributed with no outliers present.

Finally, correlations were used to test if there were any associations between the age of the child and several maternal measures. However, after using the Bonferonni correction ($p < .008$ considered statistically significant) to reduce error, there were no statistically significant associations between child age and the following variables: sleep latency ($r(10) = -.11$, $p = .739$), sleep efficiency ($r(10) = -.02$, $p = .995$), sleep quality ($r(10) = .65$, $p = .022$), frequency of lapses ($r(10) = -.27$, $p = .394$), TMD score ($r(10) = -.52$, $p = .083$), and QOLS score ($r(10) = .63$, $p = .028$). Results can be seen in Table 1.

Table 1

Correlations between child age and relevant variables, and correlations for research question 3.

Variable	Sleep latency	Sleep efficiency	Sleep quality	Lapse frequency	POMS TMD	QOLS
Child age	-0.11	-0.02	0.65	-0.27	-0.52	0.63
Sleep latency	--			-0.39	-0.15	-0.11

Notes: For variables correlated with the "Child age" row, a $p < .008$ was considered statistically significant after using the Bonferroni correction.
For variables correlated with the "Sleep latency" row, a $p < .05$ was considered statistically significant.

Results for Research Question 1

Research Question 1: Do late postpartum women (6 months – 3 years) differ from early postpartum women (6 weeks) and nulliparous controls on measures of sleep fragmentation (measured with actigraphy), objective sleepiness (measured with MSLT), and sleep quality scores (using the Sleep Quality Question)?

Two independent samples T-tests were conducted to compare sleep fragmentation (using sleep efficiency scores) between groups. One compared late postpartum and early postpartum women's sleep efficiency scores, and the other compared late postpartum and control women's sleep efficiency scores. Late postpartum sleep efficiency levels ($M = 91.1$, $SD = 3.0$) were significantly higher than those of early postpartum women ($M = 82.3$, $SD = 5.3$), $t(76) = 5.5$, $p < .001$; $g = 1.72$. However, late postpartum sleep efficiency levels did not differ significantly from control levels ($M = 89.5$, $SD = 4.4$), $t(18) = .9$, $p = .356$; $g = .41$. Hypothesis 1*: Late postpartum women will have higher sleep efficiency than early postpartum women, but lower than control women* was partly supported. An omnibus ANOVA was not used because only

these two group differences were of interest in this study, and because the difference between early postpartum and control sleep efficiency was found to be significant in previously published analyses (Insana et al., 2013). At week 6 postpartum, sleep efficiency was under 85% compared to controls, who had over 90% sleep efficiency (Insana et al., 2013). Results can be seen in Figure 1.

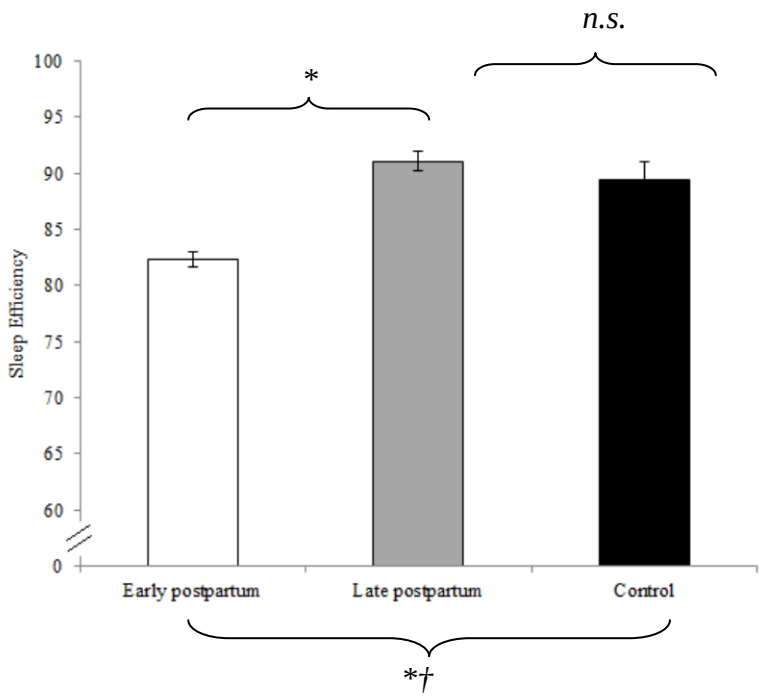

Figure 1. Average sleep efficiency scores for early postpartum, late postpartum, and control women. *Note:* * = $p < .05$; n.s = $p > .05$; † = finding from previously published data (Insana et al., 2013). Error bars show standard error.

An independent samples T-test was used to compare objective sleepiness scores between late postpartum women (M = 11.1, SD = 5.2) and early postpartum women (M = 10.0, SD = 4.1). There was not a significant difference between the two groups, $t(26) = -.6$, $p = .538$; $g = .23$.

Hypothesis 2: *Late postpartum women's sleep latency scores will be higher than early postpartum women* was not supported. It should be noted that sleep latency scores for some late

postpartum women fell into diagnosable sleepiness levels (American Academy of Sleep Medicine, 2005): out of the 12 late postpartum participants, 4 women fell asleep in under 8 minutes, and 1 fell asleep at 8 minutes.

Finally, a one-way ANOVA was used to compare sleep quality scores between control, early postpartum, and late postpartum women. There was a statistically significant difference in Sleep Quality Question scores between groups, $F(2, 82) = 7.3$, $p = .001$. Post-hoc t-tests were used to test for differences between groups. The Bonferroni correction ($p < .017$ considered statistically significant) was used to reduce error for multiple tests. There was a statistically significant difference in Sleep Quality Question scores between control ($M = 84.7$, $SD = 7.5$) and early postpartum women ($M = 68.5$, $SD = 12.9$), $t(71) = 3.6$, $p < .001$, $g = 1.29$. There was not a statistically significant difference in Sleep Quality Question scores between late postpartum women ($M = 74.1$, $SD = 11.6$) and early postpartum women, $t(74) = 1.4$, $p = .171$; $g = .43$. Finally, there was not a statistically significant difference between late postpartum and control women, $t(19) = 2.4$, $p = .027$, $g = 1.01$. Hypothesis 3: *Late postpartum women's self-reported sleep quality scores will be higher than early postpartum women, but lower than control women* was not supported.

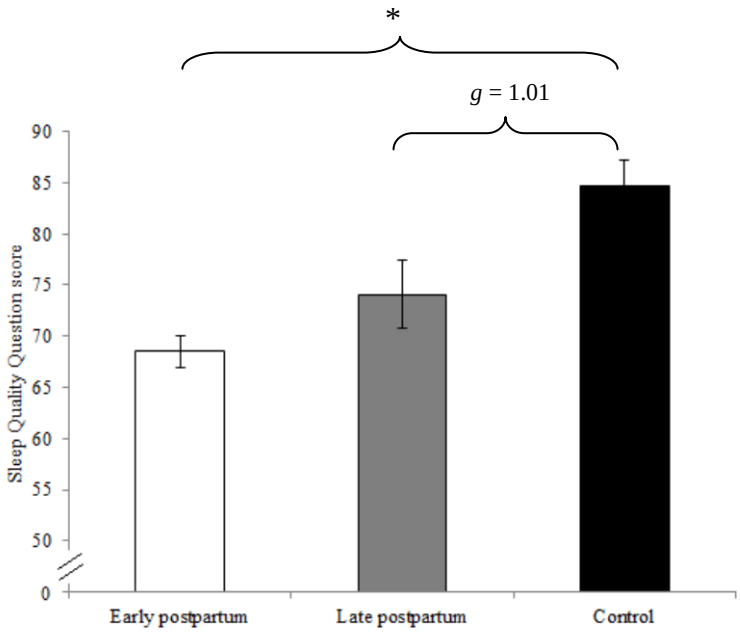

Figure 2. Average sleep quality question scores for early postpartum, late postpartum, and control women. *Note:* * = $p < .05$; large effect size is denoted above brackets. Error bars show standard error.

Results for Research Question 2

Research Question 2: Is caffeine use an effective strategy among late postpartum women?

First, in order to ensure that latency to PVT administration did not influence reaction times, bivariate correlation was used to test whether there were associations between PVT lapses (M = 5.9, SD = 4.5) and how soon the PVT was taken after awakening (M = 45.5, SD = 25.9). This correlation was not statistically significant, $r(74) = -.005$, $p = .964$. Latency to PVT administration was not related to reaction times.

An independent samples T-test was used to compare PVT lapse frequency between late postpartum (M = 7.2, SD = 7.0) and control women (M = 3.0, SD = 1.9), both before using caffeine. There was not a statistically significant difference between the two groups, $t(16) = -1.7$, $p = .118$; $d = .81$. Levene's test for equality of variances was violated, $F(1, 16) = 6.3$, $p = .023$; therefore the values reported did not assume homogeneity of variance. Hypothesis 1: *Late*

postpartum women will have a higher lapse frequency before caffeine use than control reaction times before caffeine use was not supported.

Next, an independent samples T-test was used to compare lapse frequency between late postpartum women after caffeine use (M = 3.0, SD = 1.9) and control women before caffeine use. There was not a statistically significant difference found between the two groups, $t(16) = -.007$, $p = .994$; $d = .00$. Hypothesis 2: *Late postpartum women will have a lower lapse frequency after caffeine use than control reaction times before caffeine use* was not supported. Results can be seen in Figure 3.

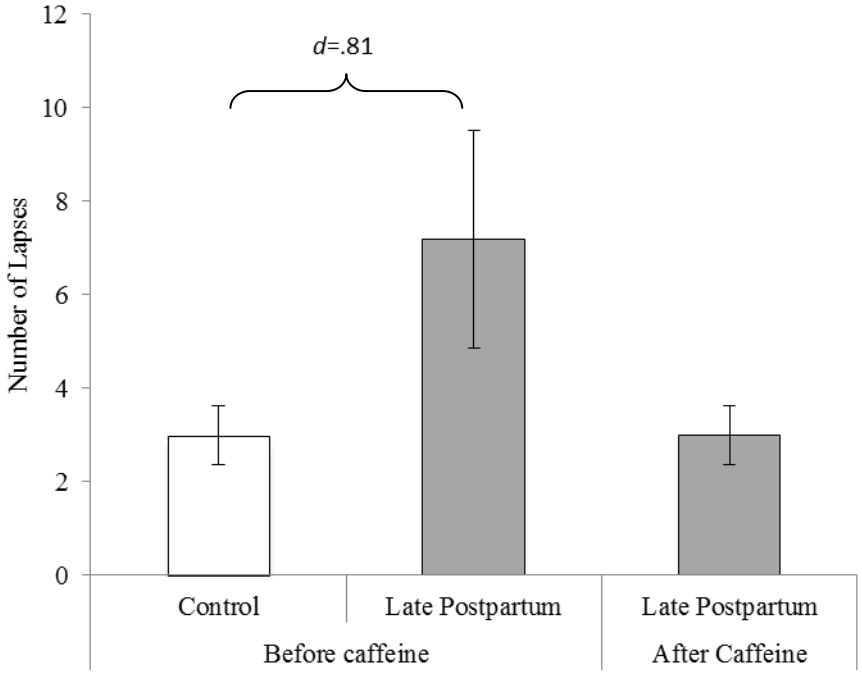

Figure 3. Average frequency of lapses for control and late postpartum women before caffeine use and for late postpartum women after caffeine use. *Note:* Large effect size is denoted above brackets. Error bars show standard error.

Finally, bivariate correlation was used to determine if there was an association between the amount of caffeine used and changes in lapse frequency for late postpartum women (Chin, Merves, Goldberger, Sampson-Cone, & Cone, 2008; McCusker, Fuehrlein, Goldberger, Gold, &

Cone, 2006; McCusker, Goldberger, & Cone, 2003; McCusker, Goldberger, & Cone, 2006). Milligrams of caffeine consumed (M = 140.2, SD = 99.6) was not significantly associated with change in lapse frequency after caffeine use (M =2.0, SD = 3.4), $r(19) = .05$¸ $p = .843$.

Results for Research Question 3

Research Question 3: What is the association between late postpartum objective sleepiness and quality of life (measured with QOLS), mood (measured with POMS), and reaction time (measured with PVT)?

Bivariate correlation was used to assess the association between late postpartum objective sleepiness levels and quality of life scores. Sleep latency scores (M = 11.1, SD = 5.2) were examined for an association with QOLS scores (M = 80.6, SD = 11.0), and there was no significant correlation between the variables $r(10) = -.11$, $p = .733$). *Hypothesis 1: Lower sleep latency scores among late postpartum women will be associated with lower quality of life scores* was not supported.

Next, bivariate correlation was used to assess the association between late postpartum objective sleepiness levels and mood scores. Sleep latency scores were examined for an association with the TMD score obtained from the POMS (M = 16.7, SD = 25.7). There was not a significant correlation between these variables, $r(10) = -.151$, $p = .64$. *Hypothesis 2: Lower sleep latency scores among late postpartum women will be associated with higher POMS Total Mood Disturbance (TMD) scores* was not supported.

Finally, bivariate correlation was used to assess the association between late postpartum objective sleepiness levels and reaction time. Sleep latency scores examined for an association with lapse frequency during the PVT (M = 5.8, SD = 4.9); however, there was not a significant correlation between these variables, $r(10) = -.389$, $p = .212$. Hypothesis 3: *Lower sleep latency*

scores among late postpartum women will be associated with a higher lapse frequency was not supported.

Discussion

The current study found statistically significant differences in sleep efficiency for early versus late postpartum women, but not for control and late postpartum women. Additionally, there was not a statistically significant difference in objective sleepiness scores between early and late postpartum women. There was a statistically significant difference in subjective sleep quality scores between early postpartum and control women, but not between early and late postpartum women. Although there were no statistically significant differences between late postpartum and control subjective sleepiness scores, a large effect size was present.

Before-caffeine lapse frequency differences were not statistically significant between late postpartum and control women, but a large effect size was present. Next, lapse frequencies were compared between late postpartum women after caffeine use and control women before caffeine use, but there was not a statistically significant difference. Finally, among late postpartum women, there were no statistically significant associations between objective sleepiness and quality of life, mood scores, or lapse frequency during the PVT.

Late Postpartum Sleep and Sleepiness

Late postpartum levels of sleep fragmentation are lower than those of early postpartum women at a statistically significant level, suggesting that objective quality of sleep increases over time from week 6 postpartum to the late postpartum period. Because differences between late postpartum and control women's level of sleep fragmentation were not statistically significant, it can be inferred that late postpartum women have recovered sleep quality to levels seen in control women. These results are supported by the findings of Montgomery-Downs et al.

(2010), which show increased sleep quality as far as 16 weeks postpartum. Because recovery from sleep fragmentation is a long process (Hack et al., 2000), late postpartum women were not expected to fully recover control sleep efficiency levels within the current study, indicating that sleep efficiency increased to greater levels than originally predicted. This restoration suggests that women are no longer experiencing the sleep fragmentation found during the early postpartum period, and objective sleep quality has recovered to the levels found among controls. These results are understandable given the development of infant sleep patterns: infant awakenings lead to fragmented maternal sleep (Nishihara et al., 2002), but infants establish a more regular sleep pattern at around 3 months of age (Kleitman & Engelmann, 1953). Therefore, it would be unlikely for mothers to experience interrupted sleep due to infant caregiving during the postpartum age range defined for the current study (6 months-3 years).

The current study also predicted a decrease in objective daytime sleepiness levels from the early to late postpartum period. Although sleep quality objectively increases during the postpartum period, differences in objective daytime sleepiness levels are not statistically significant between early and late postpartum women, suggesting that there was no decrease in daytime sleepiness levels from the early to late postpartum period. On average, both groups of women fell asleep within 10-11.1 minutes. This does not qualify as diagnostically “sleepy” (American Academy of Sleep Medicine, 2005). A meta-analysis of studies using the MSLT shows that the average sleep latency in the normal population ranges from 9.6 – 12.3 minutes (among participants in their 20’s through 40’s) (Arand et al., 2005), and this range of averages is similar to the average sleep latency scores obtained by the current study. This suggests that both early and late postpartum women fall in the average range of sleep latency scores. However, average sleep latency scores vary considerably from study to study. Reported sleep latency

scores for normal, non-sleep-disturbed participants include 13 minutes (Beaumont et al., 2001), 17.4 minutes (Nicole Lamond et al., 2007), and 11 minutes (Roehrs, Randall, Harris, Maan, & Roth, 2011). It is possible that sleep latency scores are influenced by individual differences within the studied population. A study by Van Dongen et al. (2004) found that certain individuals are more vulnerable to deficits after sleep loss, and these individual differences are consistent across multiple instances of sleep disturbance. It is possible that different members of the early and late postpartum groups studied respond differently than others to sleep loss. While the average sleep latency scores among late postpartum women are normal, looking at the individual participants reveals more extreme levels of sleepiness. If a person has a sleep latency score of less than 8 minutes, they are considered diagnostically "sleepy" (American Academy of Sleep Medicine, 2005). Of the late postpartum women in the current study, 41.6% had sleep latency scores of 8 minutes or less. Additionally, women with OSA, a disorder characterized by chronic sleep fragmentation, have an average sleep latency of 5.8 minutes (Ye, Pien, Ratcliffe, & Weaver, 2009); 3 late postpartum women within the current study fell asleep in less than 5.8 minutes. This suggests that many late postpartum women may be struggling with daytime sleepiness while other late postpartum women are not. A trait-like response to sleep disturbance (Van Dongen et al., 2004) may affect objective sleepiness within the current study. It is also possible that other variables (e.g. reaction time, subjective sleep quality) and demographic characteristics (e.g. age, socioeconomic status) relate to why some late postpartum women experience less objective sleepiness than others, and a larger number of participants could be used to address these individual differences.

Early postpartum women report lower subjective sleep quality than controls at a statistically significant level. Additionally, differences in self-reported sleep quality levels

between early and late postpartum women were not statistically significant. These results suggest that the poor subjective sleep quality among early postpartum women has not increased to the levels found in the postpartum period. This conclusion is supported by the possibility that late postpartum women also report lower subjective sleep quality than control women. This particular difference was non-significant (perhaps due to a small late postpartum sample size), but a large effect size was present. It is important to note that, while increased sleep efficiency shows that objective sleep quality has recovered during the late postpartum period, self-reported measures do not reflect this recovery. This is unexpected in that sleep quality scores reflect levels of sleep disturbance measured with actigraphy (Gay et al., 2004). It is speculated that this subjective measure of sleep quality is more related to objective performance (discussed below), as subjective measures and objective performance give an indication of daily functioning (Bei et al., 2010). Nutrition may have an effect on this self-reported measure: one study found that subjective fatigue levels were associated with low ferritin and hemoglobin levels at 3 months postpartum (K. a Lee & Zaffke, 1999). If women in the late postpartum period experience blood abnormalities and associated fatigue, poor sleep quality may be attributed as the cause. However, nutrition was not addressed in the current study. In general, however, late postpartum women do not subjectively report sleeping as well as control women.

Caffeine Use and Reaction Time

As sleep disturbance builds, reaction time deficits increase (Lim & Dinges, 2008); thus, greater lapse frequency was predicted among late postpartum women, compared to controls. Although statistically non-significant (in this case likely due to a large amount of variance between participants), reaction times before caffeine use were slower for late postpartum women than for control women: the average number of lapses among late postpartum women was over

twice the number of lapses as the average for control women. Because there was a large effect size, it is speculated that that significance may be reached with more participants. However, it must be noted that the current study was field-based and PVT administration was not directly monitored by researchers, and it is possible that some of the lapses occurred due to environmental distractions. Even so, the practical significance of the current study's findings is considered: the PVT can predict poor driving performance following sleep deprivation (Jackson et al., 2013). Although the use of a driving simulator in the aforementioned study limits its real-world application, these simulators may be able to predict which individuals are at an increased risk for actual motor vehicle accidents (Lee, Lee, Cameron, & Li-Tsang, 2003). Additionally, adults with OSA, a disorder that is also characterized by chronic sleep debt, had 2.5 times as many lapses as controls without sleep disturbance (this was equivalent to the lapses found in controls with a blood alcohol content of .08) (Powell et al., 1999). Performance in the workplace may also be affected by poor reaction times. In a study of simulated luggage screening (similar to what security personnel would use at airports) following sleep disturbance, fewer reaction time lapses predicted improved ability to detect threats (Basner & Rubinstein, 2012).

Caffeine use was common among late postpartum women in the current study, but less common than in the general American population (Frary et al., 2005): 9 out of 12 women used caffeine at least once during the study week. After using caffeine, differences between late postpartum (after caffeine use) and control reaction time (before caffeine use) performance were not statistically significant. In fact, both control women (before caffeine use) and late postpartum women (after caffeine use) averaged 3 lapses per five-minute PVT session. Reaction time information is only available for controls before caffeine use, so it is not possible to directly compare the effects of caffeine on both groups. However, because 6 out of 9 control women

reported drinking at least one caffeinated beverage a day, and this proportion of caffeine users versus non-users is similar to that found among late postpartum women, it is likely that pre-caffeine reaction times are similar between these groups. Because this was not a randomized, placebo-controlled study, it cannot be concluded that caffeine was able to normalize late postpartum reaction times to a level found in control women who have not had caffeine. However, these preliminary results suggest that further research into this area would be valuable.

These findings regarding reaction time, combined with information about sleep and sleepiness, contribute to the evidence that late postpartum mothers may be experiencing chronic sleep debt. During the earlier postpartum period, sleep fragmentation led to an accumulation of sleep loss over several months. Although sleep recovered from this disturbance by the time mothers entered the late postpartum period, sleep loss had built up over time, leading to a sleep debt. This debt is too great to pay back, despite recovering from the sleep disturbance (Insana et al., 2013), which contributes to the deficits seen in the current study. Although the average late postpartum sleep latency was in the normal range, some women still experience excessive sleepiness which may be the result of sleep debt. Additionally, despite recovery from sleep fragmentation, there is a deficit in subjective levels of sleepiness which have not increased over time, and objective performance may be slower than control performance. Evidence of this sleep debt was also seen during the early postpartum period: over time, objective sleep quality increased (Montgomery-Downs et al., 2010), but reaction times slowed (Insana et al., 2013). The results of the current study suggest that the debt has not been "paid back" with adequate sleep, leading to continued deficits.

Sleepiness and Daytime Functioning

The associations between late postpartum objective sleepiness levels and several measures of daytime functioning were examined. Subjective measures included quality of life and mood; however, these variables were not associated with daytime sleepiness at a statistically significant level. The average reported QOLS score was 80.6, which is only slightly below the average of 90 for the normal population (Burckhardt & Anderson, 2003), and the lowest reported score was 64. Hagg et al. (2003) compared patients with chronic lower back pain to the general population and found similar discrepancies in QOLS (82 and 88, respectively) as those found in the current study. In contrast, those suffering from fibromyalgia reported an average QOLS score of 72 (Offenbächer, Sauer, Kohls, Waltz, & Schoeps, 2012). Interestingly, these studies found that higher self-reported depression was associated with worse QOLS. Since the current study found little mood disturbance (see POMS information below), this may have contributed to QOLS scores only being slightly below average. Quality of Life was assessed in patients with OSA using a different scale, although it was similar to the current study's measure in that it assessed multiple domains of life. Of these patients, 56.4% reported a "Good" quality of life, while 26.5% reported that their quality of life was "Neither poor nor good" (Asghari, Mohammadi, Kamrava, Jalessi, & Farhadi, 2012). Both OSA patients and late postpartum women report being slightly less satisfied with their quality of life than average. When comparing QOLS values to the population in which this scale is widely used (those with chronic illness (Burckhardt & Anderson, 2003), late postpartum quality of life scores are more similar to levels found in populations with chronic illness than in the general population.

The average reported POMS TMD score for late postpartum women was 16.7, which is actually better than the average of 20.3 for normal women. In fact, the worst reported score, 52, was less than one standard deviation away from the average for normal women (Nyenhuis,

Yamamoto, Luchetta, Terrien, & Parmentier, 1999). In a study of OSA, Ye et al. (2009) found that women reported an average TMD score of 21 before starting treatment for their disorder, suggesting that late postpartum women report feeling lower levels of mood disturbance than women with OSA. Postpartum mothers reported feeling positive about having and taking care of their child (Fleming, Ruble, Flett, & Van Wagner, 1990), which may be contributing to the finding that, in general, the late postpartum women in the current study report having normal mood scores. Negative maternal mood is linked with impairments in infants (Galler & Harrison, 2000), but normal mood scores suggest that it is unlikely that these effects would be seen in the current study's sample of late postpartum women.

The relation between objective sleepiness and objective daytime functioning (reflected by PVT lapses before caffeine use) was also examined, but there was not a statistically significant association. Although late postpartum women have an average of 5.8 lapses per PVT session versus only 3 lapses for controls (both before caffeine use), reaction time appears to have quickened since postpartum week 13, when women averaged about 10 lapses per session (Insana et al., 2013). Even though this measure is not associated with objective sleepiness at a statistically significant level, results suggest that reaction times have continued to gradually increase speed from the early to late postpartum period. However, the number of late postpartum lapses is similar to values found in healthy participants experiencing partial sleep deprivation. Reaction time performance was measured during a study that restricted participants' sleep by a specific number of hours for 7 nights in a row. Those who spent 2 nights with only 3 hours in bed, or who spent 5 nights of only 5 hours in bed also had approximately 5 lapses per PVT session (Belenky et al., 2003). Postpartum reaction times before caffeine use have increased

speed from the early to late postpartum period, but late postpartum reaction times are still impaired.

From the average scores on the above measures of daytime functioning, it appears that late postpartum women subjectively report that they are functioning daily on a relatively normal level, even though reaction times may be objectively different from controls. It is speculated that, since the stress response is suppressed in lactating women, low levels of stress may be associated with these subjective measures. Although it is unclear how long this suppression lasts, lactation is associated with lower cortisol levels in response to stress, perhaps due to hormonal changes during the postpartum period (Mastorakos & Ilias, 2006). If late postpartum women still experience this blunted reaction to stress, it may be protective against notably low levels in subjective quality of life and mood.

Objective and Subjective Measures

The results of the current study demonstrate that it is especially important to consider multiple measures when assessing the functioning of late postpartum women because not all sleep-related measures are associated with each other. In a study of 372 adults at risk for OSA, PVT and MSLT results were found to be only weakly correlated. Additionally, when attempting to identify which participants could be considered “impaired,” the PVT was a more reliable predictor than the MSLT (Sunwoo et al., 2012). The results found by Sunwoo et al. (2012) reflect the results of the current study, which show no statistically significant correlations between these two variables. Additionally, there were no statistically significant differences in MSLT scores between early and late postpartum women. In contrast, while not statistically significant, PVT lapses showed large effect size differences, suggesting that there may be group differences on this particular measure. In a study that used principle component analysis to

examine both objective and subjective measures of sleepiness, MSLT, subjective sleepiness, and PVT lapses were found to belong to three separate dimensions of sleepiness (Franzen, Siegle, & Buysse, 2008). It is possible that the variables used in the current study measure different aspects of sleepiness.

Because sleep latency scores were not significantly associated with self-reported quality of life, self-reported mood disturbance, or reaction time scores, it is possible that MSLT scores are unrelated to these constructs measured in the current study. Perceived quality of sleep, in contrast, may give a better indication of daytime functioning, which is similar to the construct being measured in the QOLS and POMS. In a study that used the same early postpartum data as the current study, Insana et al. (2011) found that, out of several measures of sleep, the PVT was more related to actual and perceived sleep efficiency; subjective sleepiness levels were more related to perceived sleep quality, although the measures in Insana et al. (2011) are not identical to those used for the late postpartum within the current study. Van Dongen et al. (2004) found that, among many measures of sleep, fatigue and mood ratings represented one factor, while behavioral alertness (measured with the PVT) and cognitive measures (such as addition tasks) were part of two additional factors. This evidence provides further support for the notion that objective and subjective tests measure different—but important—constructs. Each of the measures used in the current study, while not directly associated with each other, are useful in understanding performance and recovery in the late postpartum period.

Overall Late Postpartum Recovery

Late postpartum women in the current study have fully recovered objective sleep quality and experience very little mood disturbance. Average daytime sleepiness levels are also normal for some women, but other late postpartum women experience extreme levels of sleepiness.

Additionally, late postpartum women subjectively report poor sleep quality and reaction times compared to controls, although reaction times might be quickened by caffeine. Finally, late postpartum women report a quality of life that is slightly below the average for the population.

Despite the apparent recovery from previous sleep disturbance, the accumulation of sleep loss from the early postpartum period can still be seen in the deficits of subjective sleep quality among late postpartum women, and in their potential reaction time deficits. It is speculated that these deficits occur because late postpartum women have not been able to simultaneously maintain normal sleep and pay back their sleep debt. Subjective daily functioning levels (such as quality of life and mood measures) among late postpartum women, however, are at levels that should not lead to concern, indicating that these women report that they are functioning well. However, this pattern of recovery applies to women who have only had one child. If a mother had a second child within the late postpartum period, it is predicted that she would experience the severe sleep disruption that characterizes the early postpartum period, which may build additional sleep loss on top of the sleep debt from her first child. As such, first-time mothers had higher subjective energy levels than women who had multiple children at three months postpartum (K. a Lee & Zaffke, 1999).

These findings, as well as findings from the early postpartum period, suggest that further research is needed to characterize the full scope of deficits and recovery found within the late postpartum period. Previous research shows that women experience performance deficits at 12 weeks postpartum (Montgomery-Downs et al., 2010), and the current study shows that deficits in reported sleep quality and, potentially, reaction time may persist into the late postpartum period. Although some improvements have been made, women who return to work soon after having a child may face continued challenges..

Limitations

This study was limited by small sample sizes in the control and late postpartum groups. Results related to caffeine use and reaction times were not statistically significant, although effect sizes suggested that it may be reached with a greater number of participants and reduced variability. The current study used existing datasets, and it was not possible to compare reaction times pre- and post-caffeine use within the control group. Furthermore, because the current study was not a double-blind, randomized, placebo controlled study with accurate reports of caffeine use, the causal effect of caffeine use cannot be established.

Larger sample sizes would also aid in detecting significant differences between the early and late postpartum MSLT scores, or it would provide further support for a lack of statistically significant differences between these two groups. Although MSLT score averages were similar to control levels, there was no control group available for direct statistical comparison.

Due to the nature of self-report measures, it is impossible to eliminate any subjective influence that might lead to bias among the participants. Participants' behaviors may have changed due to self-monitoring during the study. For example, participants may have attempted to change their responses on the PVT or subjective sleep quality question based on their previous responses (Kirby & Fowler, 1991). Additionally, it is difficult to account for response biases in the current study, particularly for the PVT, because there were no real-world consequences for failure (McGrath, Mitchell, Kim, & Hough, 2010). Although the use of a control group would attempt to account for these particular biases, a bias still may exist in the responses for postpartum women who may expect that their sleep or mood is worse based on the fact that they recently had a child. These factors must be taken into account when interpreting the results of the current study.

Finally, because data were collected during different times of the year, the possibility of seasonal variation should be considered as sleep may be poorer during winter months (Pallesen et al., 2001), which could have acted as a confounding variable. However, the influence of these seasonal differences is still up for debate as recent research has contradicted past findings (Sivertsen, Overland, Krokstad, & Mykletun, 2011).

Future Directions

Further study is needed in order to better understand the impact of caffeine on performance among late postpartum women. Along with increasing sample size, pre- and post-caffeine reaction time measures among control women would allow for direct comparison to the existing pre- and post- caffeine measures among late postpartum women, which would lead to a better understanding of group differences.

Given the notion that women during the late postpartum period (or even during the early postpartum period) may have difficulties returning to work, sleep and performance should be compared between those women who returned to work outside the home and those who became full-time homemakers. This would give a better understanding of how working may affect postpartum recovery. Additionally, examining recovery differences between first-time mothers and women with multiple children (and interbirth interval) would provide information about compounded sleep debt.

Because the current study found differences in recovery for subjective versus objective measures, this area would be open to further exploration. Perceived need for sleep may be useful in understanding what makes some women sleepier than others: perhaps the sleepiest women feel that they need more sleep than they are actually getting. Similarly, those who feel like they need more sleep may be more likely to use caffeine. A measurement of perceived stress (and

physiological stress) would be useful given the notion that the stress response is suppressed during the postpartum period. This subjective stress level may contribute to perceived functioning. Because of the individual differences found in objective sleepiness among late postpartum women, further study is needed to discover what factors predict extreme or normal sleepiness in order to gain a better understanding of what factors influence recovery.

Finally, fathers are likely to experience similar deficits as mothers, and future research should evaluate paternal sleep disturbance and recovery during the postpartum period. In 2011, both the husband and wife were employed in 47.5% of married couples (Bureau of Labor Statistics, 2012). As the trend of two working parents continues, understanding the characteristics of late postpartum sleep may be used to better inform policy.

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