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Actual and perceived sleep: Associations with daytime functioning among postpartum women

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ABSTRACT

Sleep and wake have a homeostatic relation that influences most aspects of physiology and waking behavior. Sleep disturbance has a detrimental effect on sleepiness and psychomotor vigilance. The purpose of this study was to identify which actual or perceived sleep characteristics accounted for the most variance in daytime functioning among postpartum mothers. Seventy first-time postpartum mothers' actual sleep (actigraphically estimated: total sleep time, number of wake bouts, length of nocturnal wake, and sleep efficiency) and perceived sleep (self-reported: number of awakenings, wake time, and sleep quality) were measured along with their daytime functioning (Stanford Sleepiness Scale [SSS], Epworth Sleepiness Scale [ESS], Visual Analogue of Fatigue Scale [VAFS], and morning Psychomotor Vigilance Test [PVT]). Data were repeatedly collected from the same sample during postpartum weeks 2, 7, and 13. Four stepwise linear regressions were calculated for each postpartum week to examine which objective and/or subjective variable(s) accounted for the most variance in daytime functioning. The SSS and VAFS were both most consistently associated with perceived sleep quality. The ESS was most consistently associated with actual total sleep time. PVT performance was most consistently associated with estimates of actual and perceived sleep efficiency. Actual and perceived sleep profiles were differentially associated with specific daytime functions. These results from postpartum mothers may indicate that populations who experience specific forms of sleep disturbance (e.g. fragmentation and/or deprivation) may also experience specific daytime conditions.

1. Introduction

Sleep and wake have a homeostatic relation that influences both physiology and waking performance [1]. Inadequate and disturbed sleep are associated with subsequent deficits in memory [2], decision making [3], and psychomotor performance [4].

Sleep can be estimated both objectively (actual) and subjectively (perceived), and each method may provide different but meaningful information. Previous work indicates that actual sleep and perceived sleep are positively correlated; however, when compared to objective estimates, individuals tend to subjectively overestimate their total sleep time [5,6] and subjectively underestimate their frequency of nocturnal awakenings [7]. A large population-based study indicated that participants with higher levels of disagreement between their actigraphically and subjectively estimated sleep also reported poorer sleep quality [6].

Despite the possible discrepancies in agreement between actual and perceived estimates of sleep, both actual sleep and perceived sleep are associated with sleepiness and consequent neurocognitive deficits. A review by Durmer and Dinges emphasized how various forms of sleep deprivation reach across, and negatively impact, broad neurocognitive domains [8]. Similarly, among a large sample of adults, subjectively reported long and short sleep durations were associated with decreased cognitive functioning [9]. Previous work has not identified whether actual or perceived sleep is more strongly associated with subsequent neurocognitive functioning. However, during the first postpartum week, subjectively estimated sleep was more strongly associated with mood disturbance than objectively estimated sleep [10].

Postpartum mothers are a particularly unique population because they experience high levels of sleep disturbance, especially during the first three postpartum months [11], but do not have comorbidities from sleep fragmenting disorders. Sleep disturbances cause increased objective and subjective sleepiness [12], yet little is currently known about postpartum sleep disturbances despite the evidence that sleep fragmentation is associated with fatigue during pregnancy and through the early postpartum period [13–16]. Therefore, not only are postpartum mothers a unique population, but they may also be a

Abbreviations: SSS, Stanford Sleepiness Scale; ESS, Epworth Sleepiness Scale; PVT, Psychomotor Vigilance Test; VAFS, Visual Analogue of Fatigue Scale; PDA, personal digital assistant; SD, standard deviation; ICC, intraclass correlation coefficient.

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population at particular risk for the deleterious consequences of sleep disturbance.

Reports on the relations between actual and perceived sleep, and their associations with daytime functioning, have been inconsistent. The purpose of the current study was to identify which actual sleep (objectively estimated) and perceived sleep (subjectively estimated) variables accounted for the most variance in relation to daytime functioning. We explored these associations with field-based, ecologically valid measures among a sample of postpartum women who experience sleep disturbance, but who were otherwise healthy. We expected that actual and perceived sleep would differ in their associations with daytime functioning.

2. Methods

These data are from a longitudinal study of postpartum sleep disturbance approved by the West Virginia University Office of Research Compliance (Institutional Review Board). Participants were administered informed consent and Health Insurance Portability and Accountability Act (HIPAA) authorization prior to participation. Participants were first-time postpartum mothers because the purpose of the larger longitudinal study was to explore the relations between sleep deprivation and fragmentation among first-time, non-depressed, postpartum women who had healthy infants.

2.1. Participants

First-time mothers were recruited prenatally via community advertisements from Morgantown, West Virginia. Morgantown is a small city with a population estimate of 26,809; of which, 89.5% were white with an annual median household income of $20,649 [17]. Potential participants were excluded on the basis of premature delivery, pregnancy with multiples, infant admission to the neonatal intensive care unit, history of or current treatment for major depressive disorder, or a score ≥16 on the Center for Epidemiologic Studies Depression Scale [18].

Among the total sample of 70 women, sample sizes across the three time points varied because within the longitudinal study, some participants had missing data during isolated weeks. Actigraphy and Palm Pilots were used for field-based data collection. If one system malfunctioned or was not accurately administered, all data for that week were lost. Weeks of actigraphy data lost to equipment malfunction were 2, 5, and 6 at postpartum weeks 2, 7, and 13, respectively. Weeks of Palm Pilot data lost to equipment malfunction were 5, 4, and 6 at postpartum weeks 2, 7, and 13, respectively. The longitudinal study design led to some participant attrition. One participant dropped from the study before week 7, and 8 participants had dropped by week 13. The remaining missing data points were due to participant non-adherence to the protocol. We did not statistically replace missing values.

The sample sizes at each postpartum week are reported in Table 1. There were no significant demographic differences between those who participated at each of the analysis weeks or between those who dropped from the study and those who continued. Participants were primarily white (94.1%), on average 26.3 (*SD* = 4.1) years old, had an average of 15.6 (*SD* = 3.0) years of education, and had a mean income of U.S. $60,123 (*SD* = $35,105).

2.2. Measures

2.2.1. Daytime functioning: sleepiness, fatigue, and psychomotor vigilance

Daytime functioning measures and the sleep diaries were self-administered using a Palm Zire 72 personal digital assistant (PDA) with a display screen that was 2.25 in. wide, had a 320 × 320 pixel resolution, and was operated with a customized software (Bruner Consulting Co., Longmont, Colorado). Experience sampling method was used to record momentary behaviors as they occurred in daily life [19] because handheld computers are a more effective methodology for research than paper and pencil methods [20]. All PDA entries were time and date stamped as they occurred. The sleep diary entries could also be recorded retrospectively; these recordings were identified as retrospectively entered on the output.

Table 1
Sample size and descriptive statistics for each variable at each postpartum week.

Variable	Postpartum week 2			Postpartum week 7			Postpartum week 13		
	N	*M*	*SE*	*N*	*M*	*SE*	*N*	*M*	*SE*
Daytime function									
VASF	64	50.17	1.62	65	48.19	1.91	56	45.71	2.45
SSS	65	3.03	0.09	65	3.02	0.11	56	2.95	0.13
ESS	65	8.86	0.38	65	7.85	0.46	56	7.53	0.49
Lapses	65	5.90	0.58	64	9.32	0.74	54	10.44	0.96
Objective sleep									
Total sleep time	68	427.91	6.18	64	433.31	7.80	56	426.28	6.85
# Wake bouts	68	49.09	1.37	64	46.17	1.49	56	44.21	1.60
Nocturnal wake time	68	114.14	4.45	64	88.36	4.21	56	64.67	4.44
Sleep efficiency	68	79.45	0.71	64	83.35	0.73	56	87.31	0.80
Subjective sleep									
Number of wakings	65	3.52	0.19	60	2.66	0.23	55	2.29	0.18
Wake time	65	131.69	6.21	59	106.23	6.83	54	61.83	7.08
Sleep quality	65	64.90	1.43	60	69.18	1.37	55	73.48	1.22

Note. VAFS: Visual Analogue of Fatigue Scale; ESS: Epworth Sleepiness Scale; SSS: Stanford Sleepiness Scale.

Reliability and validity for the following measures have not been established specifically among postpartum women.

2.2.1.1. Sleepiness. Sleepiness is a state reflecting an increased drive for sleep when one intends to be awake [21] and was examined with the Stanford Sleepiness Scale (SSS). The scale is 1–7 and higher scores represent greater sleepiness [22]. Sleepiness was also examined with the Epworth Sleepiness Scale (ESS) [23]. This scale uses 8 brief real-life scenarios to measure the susceptibility of falling asleep on a respective scale of 0–3. Total scores range from 0–24 and higher scores represent greater sleepiness. The ESS was validated to reflect behaviors in the past month, but for the current study was used to reflect immediate state. The SSS and ESS have previously been used among samples of healthy postpartum women [24].

2.2.1.2. Fatigue. Fatigue is the subjective report of exhaustion and decreased capacity for both physical and mental activities [25]. Fatigue was examined with a 100-point Visual Analogue of Fatigue Scale (VAFS) [26] that was used to rate, "How tired/fatigued do you feel RIGHT NOW?" (0 = not at all tired/fatigued, 100 = very tired/fatigued). The VAFS display on the PDA had a stylus-movable anchor point that was initially presented in the middle of the scale; the anchor could be moved according to 1-point increments on the display.

2.2.1.3. Psychomotor vigilance. Psychomotor vigilance is a valid index of performance impairment due to sleep loss [27] (for a review see Lim and Dinges [28]). The Psychomotor Vigilance Test (PVT) used in the current study was self-administered using customized software (Bruner Consulting Co., Longmont, Colorado) on the PDA. This PVT is similar to a previously validated version of a Palm based PVT [29] and its use is supported by a study that validates PVT administrations that are < 10 min in duration [30]. This PVT has been reported previously [31] as a simple reaction time task developed to measure sustained attention using a bull's-eye stimulus and has a 10 ms sensitivity resolution. Each 5-minute trial consists of the presentation of approximately 39–56 stimuli at random interstimulus intervals. Lapses (reaction times ≥ 500 ms) can be calculated from reaction time trials and are associated with greater performance impairment [32]. Lapse frequency was calculated for each trial and was used as the index of psychomotor performance.

2.2.2. Perceived (subjective) sleep estimates

Perceived sleep estimates were examined with three questions pertaining to sleep and sleep quality from the previous night: Participants were asked “How many times do you think you woke up last night?”, “Please indicate how long you were awake last night (total).”, and “Where 100 is fully rested, please indicate your quality of sleep:” (0–100 visual analogue scale).

2.2.3. Actual (objective) sleep estimates

Actual sleep estimates were collected via Actigraphy (Mini Mitter Actiwatch-64, Bend, Oregon), a valid system for non-intrusive estimate and analysis of sleep/wake periods among adults [33]. Actigraphy uses general body movements to estimate periods of sleep and wake via algorithmic interpretation of the absence or presence of movement during a specified time interval. The highest resolution was used (15-second epochs), which permits up to 11 days of continuous recording. Concurrent PDA-based participant sleep diaries were corroborated with actigraphy to identify nocturnal rest intervals. The beginning of a nocturnal rest interval was identified as the first of eight consecutive epochs (2 min) of inactivity that followed the sleep diary-reported bedtime; the end of a sleep period was identified as the last of two consecutive minutes of inactivity that preceded the diary-reported wake time. Nocturnal rest intervals were then analyzed with Actiware software. Actiware Software Version 5.5 was used to manage, analyze, and archive actigraphy data. Actiware software utilizes a validated algorithm to score each epoch as sleep or wake. The algorithm uses the recorded activity count to weight a distribution around each epoch then compares each epoch score to a wake threshold value (default setting = 40 was used); epoch scores < 40 = sleep, and scores ≥ 40 = wake.

The larger study revealed low rates and durations of daytime napping behaviors across postpartum weeks 2 through 16 [11]. Therefore, the actigraphically recorded sleep estimates were from nocturnal rest intervals only, and were specifically selected to correspond with the subjective sleep estimates: (1) total sleep time (minutes identified as sleep during a nocturnal rest interval), (2) number of wake bouts (frequency of discontinuous epochs calculated as wake during a nocturnal rest interval), (3) length of nocturnal wake (cumulative minutes scored as wake between first sleep onset and last sleep offset within a rest interval), and (4) sleep efficiency (minutes of sleep during a rest interval divided by the rest interval length [minutes], multiplied by 100). ‘Number of wake bouts’ and ‘length of nocturnal wake’ directly correspond to the respective subjective sleep estimates of ‘Number of times awake’ and ‘Amount of time awake’; however, since the subjective estimate of sleep quality cannot be objectively quantified and is likely a function of both ‘total sleep time’ and ‘sleep efficiency’, both of those actigraphically estimated sleep variables were included in the analyses.

2.3. Procedure

Participants wore an actigraph on their non-dominant wrist continuously (except when it might get wet), and used their PDA to report their sleep and watch-off diary as the events occurred. Participants used the PDA to self-administer the subjective sleep measures and the PVT each morning within 2 h of awakening. Across postpartum weeks the average time of PVT self-administered was 9:37 am (SD ± 2 h 6 min) at week 2, 10:22 am (SD ± 3 h 2 min) at week 7, and 9:58 am (SD ± 2 h 37 min) at week 13. There were no significant associations between latency from sleep-offset to administration of the PVT and PVT lapse frequency ($p = 0.12$, 0.71, and 0.92 at postpartum weeks 2, 7, and 13, respectively); these results indicated that sleep inertia did not affect performance. The SSS, ESS, and VASF were also administered via the PDA every time participants fed their infant during the daytime.

2.4. Statistical analyses

To help protect against the possible effect of environmental distraction on PVT performance we excluded all response time values from the analyses that were greater than two times the group standard deviation plus the mean (≥ 1314 ms) [34]. This method required the removal of 1.93%, 4.08%, and 4.94% of individual response times at postpartum weeks 2, 7, and 13, respectively.

The American Academy of Sleep Medicine's Standards of Practice Committee [35] has determined that one week of actigraphy is sufficient to determine stable sleep–wake patterns; we required at least 4 nights of data and calculated averages for each measure within postpartum weeks 2, 7, and 13. Intraclass correlation coefficients (ICCs) were calculated for each actual and perceived sleep estimate for each study week. All ICCs were significant ($p < 0.001$), and ICC value ranges were 0.59–0.83, 0.55–0.92, and 0.60–0.88 for weeks 2, 7, and 13, respectively (Table 2).

The ESS was not specifically validated to reflect immediate state, but the SSS was. Therefore, Pearson's correlations were calculated between the ESS and the SSS for each study week to demonstrate the ESS integrity for use as a state measure. The ESS and SSS were significantly ($p < 0.001$) correlated during postpartum weeks 2, 7, and 13; $r = 0.76$, $r = 0.77$, and $r = 0.80$, respectively.

Four stepwise linear regressions, with pairwise deletion, were calculated for each postpartum week to examine which actual and/or perceived variable(s) accounted for the most variance in daytime sleepiness and fatigue. Data were analyzed at three time points because postpartum sleep is dynamic, and therefore, subjective and objective sleep variables were expected to be associated with daytime conditions as a function of different sleep patterns during each particular postpartum time point. All actual and perceived sleep variables were cumulatively entered as the independent variables; the VAFS, SSS, ESS, and PVT lapses were entered separately as dependent variables. Stepwise regressions were calculated because these analyses were exploratory. Data were analyzed using SPSS version 16.0; a $p < 0.05$ was considered statistically significant.

3. Results

During week 2, participants completed the VAFS, SSS, and ESS an average of 23.15 (*SD* ± 8.32) times and the PVT 6.56 (*SD* ± 1.33) times; during week 7, 17.57 (*SD* ± 8.43) and 6.27 (*SD* ± 1.40) times, respectively; and during week 13, 18.75 (*SD* ± 7.64) and 6.65 (*SD* ± 0.78) times, respectively. A summary of the regression results are indicated in Table 3.

First, all variables were entered into a regression to examine correlates of the VAFS. During postpartum week 2 actual sleep time was independently associated with the VAFS ($R^2 = 0.14$, $F[1, 60] = 10.05$, $p < 0.01$). During postpartum weeks 7 and 13 perceived sleep quality was independently associated with the VAFS ($R^2 = 0.10$, F [1, 55] = 5.75, $p < 0.05$; $R^2 = 0.11$, F [1, 50] = 5.95, $p < 0.05$, respectively).

Table 2
Intraclass correlation coefficients for each actual and perceived sleep variable for each study week.

Variable	Postpartum week 2 r	Postpartum week 7 r	Postpartum week 13 r
^{O} Total sleep time	0.70^{***}	0.55^{***}	0.66^{***}
^{O} # Wake bouts	0.75^{***}	0.77^{***}	0.80^{***}
^{O} Nocturnal wake time	0.78^{***}	0.76^{***}	0.84^{***}
^{O} Sleep efficiency	0.83^{***}	0.81^{***}	0.88^{***}
^{S} Number of Wakings	0.77^{***}	0.92^{***}	0.83^{***}
^{S} Wake time	0.75^{***}	0.81^{***}	0.80^{***}
^{S} Sleep quality	0.59^{***}	0.68^{***}	0.60^{***}

*** $p < 0.001$; ^{S} subjective sleep measure and ^{O} objective sleep measure.

Table 3
Results summary table for subjective and objective correlates of sleepiness and fatigue variables during postpartum study weeks.

Variable	Week 2 Variable(s)	%Variance	β	Week 7 Variable(s)	%Variance	β	Week 13 Variable(s)	%Variance	β
VAFS	OTotal sleep time	14%**	−0.38	SSleep quality	10%*	−0.31	SSleep quality	11%*	−0.33
SSS	SSleep quality OTotal sleep time	– 26%***	−0.38 −0.28	SSleep quality	10%*	−0.32	SSleep quality OTotal sleep time	– 22%**	−0.34 −0.28
ESS	OTotal sleep time SSleep quality	– 31%***	−0.42 −0.31	OTotal sleep time	17%**	−0.41	OTotal sleep time	11%*	−0.34
Lapses	None	–	–	OSleep efficiency	18%**	−0.43	SWake time OTotal sleep time	— 25%**	0.41 −0.33

% Variance = total cumulative variance explained in multiple regression model. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. ^{S} subjective sleep measure and ^{O} objective sleep measure. VAFS: Visual Analogue of Fatigue Scale; ESS: Epworth Sleepiness Scale; SSS: Stanford Sleepiness Scale.

Second, all variables were entered into a regression to examine correlates of the SSS. During postpartum week 2 perceived sleep quality and actual sleep time, together, were associated with the SSS ($R^2=0.26$, F [2, 60] = 10.57, $p<0.001$). During postpartum week 7 perceived sleep quality was independently associated with the SSS ($R^2=0.10$, F [1, 55] = 6.24, $p<0.05$). During postpartum week 13 perceived sleep quality and objective sleep time, together, were associated with the SSS ($R^2=0.22$, F [2, 49] = 6.71, $p<0.01$).

Third, all variables were entered into a regression to examine correlates of the ESS. During postpartum week 2 actual sleep time and perceived sleep quality, together, were associated with the ESS ($R^2=0.31$, F [2, 60] = 13.65, $p<0.001$). During postpartum weeks 7 and 13 actual sleep time was independently associated with the ESS ($R^2=0.17$, F [1, 55] = 11.38, $p<0.01$; $R^2=0.11$, F [1, 50] = 6.31, $p<0.05$, respectively).

Finally, all variables were entered into a regression to examine correlates of PVT lapses. During postpartum week 2 no actual or perceived variables were associated with lapses. During postpartum week 7, actual sleep efficiency was independently associated with lapses ($R^2=0.18$, F[1, 55] = 12.23, $p<0.01$). During postpartum week 13 perceived wake time and actual sleep time, together, were associated with lapses ($R^2=0.25$, F[2,47] = 7.91, $p<0.01$).

4. Discussion

Among postpartum mothers, actual and perceived sleep profiles were associated with specific daytime functions. Fatigue was most consistently accounted for by with perceived sleep quality. Likewise, sleepiness measured by the SSS was most consistently accounted for by perceived sleep quality. However, sleepiness measured by the ESS was most consistently accounted for by actual total sleep time. Finally, PVT performance was most consistently accounted for by both actual and perceived measures that described consolidated sleep (i.e. sleep without interruptions from awakenings). In sum, variance in subjective sleepiness and fatigue were accounted for by perceived sleep quality, as well as total sleep time. In contrast, objective PVT performance was accounted for by actual and perceived consolidated sleep.

Previous work has identified that specific objective and subjective sleep-related outcome variables are differentially affected by sleep deprivation. For example, following experimentally induced sleep deprivation, objectively measured affect was associated with objective sleepiness, whereas, subjective mood was associated with subjective sleepiness [36]. Additionally, work by Van Dongen et al. [37] indicates that following experimentally induced sleep loss schedules, participants were impaired on various aspects of subjective and objective neurobehavioral functioning that appeared to cluster according to three orthogonal domains: "self-evaluation of sleepiness, fatigue, and mood"; "cognitive processing capability"; and "behavioral alertness as measured by sustained attention" (p. 431). These authors explain that different neurocognitive systems may be affected differently by sleep deprivation, and that individuals are likely not accurate judges of their actual sleep-associated performance impairment. The current study is complementary in that it emphasizes the bidirectional nature of sleep and functioning in which different profiles of actual and perceived sleep are associated with specific daytime functions.

The current study coincides with recent work showing that among healthy, non-depressed postpartum women, perception of poor sleep was more strongly associated with postpartum mood disturbance than actigraphically estimated sleep [10]. Cumulatively, these results suggest that health care providers could consider targeting specific postpartum sleepiness, fatigue, or mood among at-risk women by customizing interventions to target a specific sleep profile.

Normative longitudinal sleep data from our larger study indicates that across the first 4 postpartum months, maternal total sleep time remains stable, but sleep efficiency markedly improves [11]. The current analyses are correlational and do not imply directionality, though they may provide novel insight into the dynamics among sleep, perception, and functioning among other sleep-disturbed populations. For example, abnormal sleep and wake timing (e.g. shift-workers or delayed sleep phase syndrome) and sleep fragmenting disorders (e.g. sleep apnea or periodic limb movement disorder) may contribute to different, yet specific daytime functional impairments.

The subjective sleepiness measures, the SSS and ESS, were most consistently accounted for by different sleep estimates; that is, perceived and actual sleep, respectively. We expected the SSS and ESS to demonstrate similar associations with actual and perceived sleep variables; the results may be explained by previous research that indicated that the SSS is more strongly associated with fatigue measures than with sleepiness measures [38]. This pattern was upheld among the current data since both the VASF and the SSS were most consistently associated with perceived sleep quality. Because different women participated at different time points, we cannot make conclusive statements about the changes in scales or performance over time.

There are several design and psychometric limitations to this study. The ESS has been used as a state measure [24], yet it has only been psychometrically validated as a measure of trait. Correlation analyses did however indicate that the ESS and the SSS were correlated, and the value was relatively stable during the three study weeks. Therefore, although the ESS was not validated to measure state sleepiness, it appeared to be an acceptable measure for this purpose. Both reaction time assessments <10 min have been validated [30], and a palm-base PVT have been validated [29], and the version we use has been reported previously [31], although the specific PVT version that we use has not been validated. The ESS and the PVT were not validated as they were particularly used in the current study, results indicated that these measures were associated with sleep variables and thus demonstrate their value in interpreting their respective daytime conditions as indicated. To avoid participant burden, the PVT was self-administered once daily. The timing was precisely controlled because the PVT shows circadian variability [39], but this meant that we could not evaluate circadian changes. Finally, the current analyses were correlational and do not permit the inference of causality among sleep and daytime functioning measures. However, the naturalistic field-based nature of the study and our use of both objective and subjective measures bolster the ecological validity of the results. Specifically, mothers were examined with measures that have practical significance to daytime functioning while in their naturalistic environment and while behaving according to their typical daily routines. It is unknown whether these results are specific only to postpartum women or may generalize to other populations with particular sleep profiles, such as those with fragmenting sleep disorders (e.g. sleep apnea and periodic limb movement disorder), insomnia, or shift work disorder.

5. Conclusion

The current work indicates that both actual and perceived sleeps are uniquely associated with sleepiness, fatigue, and psychomotor performance. These associations express dynamic changes over time during periods of chronic sleep disturbance—in this case as experienced by first-time mothers during the early postpartum period. Therefore, both actual sleep and perceived sleep are important to understand various forms of daytime functioning. Researchers and clinicians should consider including assessment of both objectively (actual) and subjectively (perceived) sleep estimates when examining associations with daytime functioning among sleep disturbed populations.

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