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A Novel Home Sleep Monitoring Device and Brief Sleep Intervention for Bipolar Disorder: Feasibility, Tolerability, and Preliminary Effectiveness

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Abstract

Sleep disturbance is common in bipolar disorder and negatively impacts its course of illness. The purpose of this study is to assess the feasibility and tolerability of a novel EKG-based home sleep monitoring device (M1) as well as a brief (two session) psychosocial sleep intervention for individuals with bipolar disorder. The sleep intervention is individually tailored for patients with insomnia or hypersomnia and is designed to extend skills designed for non-psychiatric populations as well as include specific considerations for sleep disturbance in bipolar disorder. We found that both the M1 monitor and the sleep intervention were feasible and well tolerated. Participants' sleep duration improved after the brief sleep intervention, but the sleep was more unstable as measured by the M1. Self-reported sleepiness, sleep quality, and mood symptoms improved; however, only some measures reached statistical significance (i.e., duration of sleep, dysfunction due to sleepiness). These data suggest that the M1 device is a feasible means to obtain objective sleep quality and quantity data in individuals with bipolar disorder. A brief sleep intervention may be helpful in improving sleep in a bipolar population at risk for substantial sleep disturbance, but larger, longitudinal studies are warranted.

Keywords

brief sleep intervention; home sleep monitoring; bipolar disorder; insomnia; hypersomnia

Introduction

Sleep disturbance (hypersomnia and insomnia) in bipolar disorder occurs frequently with 62% experiencing dysregulated sleep and that dysregulation is associated with a worse course of illness, and more severe anhedonia, greater weight loss, as well as increased psychomotor retardation, and fatigue (Roberts, Shema, Kaplan, & Strawbridge, 2000). Sleep disturbances occur during mood episodes and persist even during periods of euthymia, most likely as a result of biological and psychosocial factors. For example, bipolar disorder is associated with clock gene abnormalities, which may be related circadian rhythm system disruptions (McCarthy, Nievergelt, Kelsoe, & Welsh, 2012). Uncontrollable life stressors may also cause shifts in circadian rhythms and routine changes such as meals and work hours, which likely affect individuals' ability to regulate their sleep-wake cycle (Harvey, Schmidt, Scarna, Semler, & Goodwin, 2005). Bipolar individuals may also experience

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anxiety and fear about their sleeping patterns, and dysfunctional thoughts prior to bed are associated with less restorative sleep (Johnson & Roberts, 1995).

Given that psychosocial factors affect sleep and the negative side effects of insomnia medications, individuals with bipolar disorder may be amenable to psychosocial interventions to improve their sleep. CBT for insomnia (CBT-I) has shown to be effective in improving sleep is an attractive intervention but has not been tested in individuals with bipolar disorder. CBT-I includes modules such as the importance of sleep hygiene, functional analysis of poor sleep, goal setting in regards to sleep and wake times, and cognitive restructuring of negative thoughts about sleep (Perlis, Jungquist, Smith, & Posner, 2005). A meta-analysis of 59 studies found that psychological interventions led to durable and reliable changes in sleep latency and time awake after sleep onset (Morin, Culbert, & Schwartz, 1994). The average therapy duration for these studies was about 5 hours (*SD* = 3.5), suggesting that short interventions may be helpful.

Adapting a psychosocial intervention specifically for bipolar disorder is important because these patients face specific problems that traditional CBT interventions may not address. Therapists must balance cognitive restructuring of patients' dysfunctional thoughts about sleep with concerns that patients may have about sleep deprivation. Therefore, we developed a psychosocial sleep intervention that uses components found to be effective in treating insomnia, but also making specific adaptations to target a bipolar population.

A key aspect of developing a targeted sleep intervention is to pilot-test its effectiveness by assessing sleep quality; however, limited studies have characterized sleep architecture, an indicator of sleep quality, in bipolar disorder. Previous studies have only used actigraphy, which simplifies sleep-wake based on rest-activity from wrist movements and thus does not provide detailed data regarding sleep depth or stages (Ancoli-Israel et al., 2003). Current assessments of sleep physiology rely primarily on standard polysomnography, which categorizes sleep stages from electroencephalographic (EEG) signals. Conducting laboratory polysomnography, which often involves having a patient spend the night in a sleep laboratory, is not only expensive and burdensome, but the unusual environment negatively impacts sleep physiology, and the typical single-night paradigm does not measure variability across multiple nights. Therefore, the second aim of this study is to explore the feasibility and effectiveness of measuring sleep quality in patients with bipolar disorder using a newly available home sleep monitoring device, the SleepImage M1 device.

The M1 is used to ascertain stability, or quality, of sleep. Several features of the M1 device represent important advantages over traditional laboratory polysomnography. It is less expensive, less intrusive, allows multiple nights of recording, and the scoring is fully automated. The M1 device adheres to the chest and captures single-lead electrocardiogram (ECG) data during sleep. It utilizes a special algorithm to analyze ECG data according to a metric called cardiopulmonary coupling (CPC; Thomas, Mietus, Peng, & Goldberger, 2005). The M1 detects High Frequency Coupling (HFC), which indicates deep or "stable" NREM sleep, Low Frequency Coupling (LFC), which is light or "unstable" NREM sleep, and a composite "state" called Wake/REM (it cannot distinguish wake from REM). The percentage of high frequency coupling (HFC%) is taken to indicate better sleep quality. Most people who wake up repeatedly are making transitions between wakefulness and light NREM sleep and thus, should be detectable as an excess of "unstable" sleep by this device. The M1 device also collects actigraphy data from trunk movements, which can be used as an adjunct metric of fragmentation to infer sleep duration.

In the present study, we tested the feasibility and preliminary effectiveness of a brief sleep intervention and M1 device for individuals with bipolar disorder. We hypothesized that the

brief sleep intervention and M1 device would be feasible and well tolerated, and that the sleep intervention would show promise in improving overall sleep quality and mood symptoms.

Methods

Brief Sleep Intervention

Insomnia tends to be more prevalent than hypersomnia during manic episodes (Cassidy, Murry, Forest, & Carroll, 1998), whereas both can occur during depressive episodes (Ford & Cooper-Patrick, 2001; Harvey, 2008) suggesting that there are unique triggers and therapeutic strategies for insomnia versus hypersomnia. Thus, the proposed intervention for bipolar disorder was a flexible, modular approach such that participants were assigned to either module 1 (insomnia) or module 2 (hypersomnia) depending on their needs. Each module consisted of a 60-minute session that occurred approximately 10 to 14 days after Session 1 to allow participants to practice the homework and skills discussed.

Prior to beginning either the insomnia or hypersomnia module, subjects completed a structured interview to assess their comorbid diagnoses and current mood state. Similar to other brief sleep interventions for healthy populations (Edinger & Sampson, 2003), the first session began with psychoeducation; however, we specifically focused on reviewing sleep disturbance in bipolar disorder, the importance of sleep duration and regularity, and the factors that may impact their sleep. The goal of this review was to increase treatment adherence by providing the rationale for actively participating in a sleep intervention. A functional analysis of a poor night of sleep was conducted in the second half of this session to identify factors that contributed to patients' vulnerability, triggers, and subsequent thoughts, feelings, and behaviors. This analysis identified the current sleep problem as well as the specific target areas for treatment. Patients were then assigned to either Module 1 (insomnia) or Module 2 (hypersomnia). For homework, participants were asked to continue to monitor their sleep and identify possible triggers.

Module 1: Insomnia Intervention—To begin this module, participants discussed their sleep patterns and specific sleep needs with the clinician, an important component adopted from CBT interventions for insomnia in non-psychiatric populations (Edinger & Sampson, 2003). Specifically, we discussed the influence that participants' lifestyle habits (e.g., exercise, diet, alcohol use) as well environmental factors (e.g., light, noise, temperature) can have on their sleep. We also included specific factors for bipolar disorder, such as the timing of psychotropic medication doses and management of comorbid diagnoses (e.g., anxiety, substance abuse, and/or PTSD). Building off the functional assessment from session 1, we discussed potential solutions to specific poor sleep triggers. For homework, participants practiced healthy lifestyle changes that can improve their sleep (e.g., reduce substance use, maintain a regular bed time, reduce light/noise in bedroom).

The second session of this module was focused on stimulus control, or reversing the dysfunctional associations that can develop when one's sleep environment is paired with wakefulness. Participants were taught to avoid in-bedroom activities incompatible with sleep and to stay in the bedroom only when asleep or sleepy. This intervention typically had four goals: 1) to utilize the bed and bedroom only for sleeping; 2) to go to bed only when feeling tired; 3) to get out of bed and leaving the bedroom when unable to fall asleep within 15–20 minutes and return to bed when feeling tired; and 4) wake up and get out of bed at the same time every day. We made one modification to this intervention based on Harvey's (2008) work in pediatric bipolar patients, which showed that bipolar individuals should *not* wait until they feel tired to go to bed as they may need more time to "wind down," or prepare for bed. Thus, we taught progressive relaxation techniques and provided an activity to do in the

middle of the night to assist in falling back to sleep. Problem-solving strategies and psychoeducation were utilized to assist with impulse control and adherence.

We also focused on cognitive re-structuring and relapse prevention because individuals with bipolar disorder often have dysfunctional thoughts about sleep (Harvey et al., 2005). We identified and challenged beliefs and fears regarding sleep in order to replace these cognitive distortions with realistic expectations about sleep and daytime function. We concluded with a brief review of the material learned to reinforce new skills and enhance relapse prevention.

Module 2: Hypersomnia Intervention—The hypersomnia module began with education about the social zeitgeber theory (Ehlers, Frank, & Kupfer, 1988). This theory states that maintaining a regular wake up time and bedtime may improve circadian rhythm regularity, which may have positive effects on one's mood. Thus, the goal of this module was to increase treatment adherence by enhancing motivation to go to bed as well as to get out of bed at regular times (e.g., within 45 minutes) despite still feeling sleepy or having a lack of desire to get up. Similar to the insomnia module, problem-solving strategies were used to overcome obstacles to adhering to the typical wake up and bed times. Homework was assigned between the two sessions to allow participants to practice the problem-solving strategies discussed.

Individuals with bipolar disorder have difficulty getting out of bed in the morning and staying out of bed during the day. Thus, increasing behavioral activation by scheduling more regular daily events can be utilized to overcome this inhibition. We completed a positive activity checklist and a daily schedule that focused on setting realistic target times for these activities. Similar to the insomnia module, we concluded the hypersomnia module with cognitive restructuring and relapse prevention strategies; however, the cognitive distortions addressed in this module are different than those for insomnia because participants tend to have negative attributions about themselves due to their hypersomnia (e.g., "I am lazy" or "I stay in bed all day, so my life is worthless or has no meaning"). This session ended with a review of the skills taught in the module to minimize relapse.

Participants

Participants were recruited from the Massachusetts General Hospital Bipolar Clinic and Research Program and thus, all participants had a psychiatrist for medication management. Ethical approval was obtained from the hospital's institutional review board. Eight participants (7 Caucasian, 1 Hispanic/Latino; 5 female) provided written informed consent and completed the study. The age of articipants ranged from 24 to 65 years (M = 42.3, SD = 14.4). Six participants had Bipolar I disorder, two had bipolar II disorder and 88% had a current comorbid anxiety disorder. None of the participants had any known or active sleep disorder, history of significant cardiac, pulmonary, neurological, hepatic, or renal disease, taking beta-blockers, or in a current acute major depressive or manic episode. Based on their functional analysis, all participants were placed in Module 1 as they reported having the most difficulty with insomnia.

Measures

Montgomery-Asberg Depression Rating Scale (MADRS)—The MADRS (Montgomery & Asberg, 1979) is a 10-item scale to measure overall depressive symptom severity. Higher scores indicate more severe pathology. The MADRS is one of the most studied depression rating scales, is sensitive to change, and has high reliability (r = 0.65–0.97), internal consistency (α = 0.86), and validity (r = 0.70–0.89; (Stein, Kupfer, & Schatzberg, 2005).

The Young Mania Rating Scale (YMRS)—The YMRS (Young, Biggs, Ziegler, & Meyer, 1978) assesses manic symptom severity, with higher scores indicating more severe pathology. The YMRS is the most widely studied instrument for mania, and it has high reliability (r = 0.84–0.93), internal consistency (α = 0.80), and validity (r = 0.65–0.80; (Stein et al., 2005).

Pittsburgh Sleep Quality Index (PSQI)—The PSQI (Buysse, Reynolds, Monk, & Berman, 1989) is a 19-item self-report questionnaire that measures sleep quality and sleep disturbance over the past month on seven component scores (ranging from 0 to 3). These scores are summed to obtain a PSQI total score (ranging from 0 to 21), and higher scores indicate greater sleep difficulties, with a threshold value of 5. The PSQI has high validity and reliability among different populations, including in individuals suffering from insomnia (Backhaus, Junghanns, Broocks, Riemann, & Hohagen, 2002; Carpenter & Andrykowski, 1998).

Epworth Sleepiness Scale (ESS)—The ESS (Johns, 1992) is an 8-item self-report questionnaire that assesses general daytime sleepiness. Subjects rated how likely they are to doze off in each of the eight situations (0 – *would never doze;* 3 – *high chance of dozing*). The scores are summed for an overall score, with higher scores suggesting increased daytime sleepiness. The ESS has high internal consistency (α = 0.88) and high test-retest reliability (r = 0.82; (Johns, 1992).

Sleep Intervention Acceptability (SIA) Scale—The SIA consists of 10 self-report ratings for their expectations at baseline and actual experience with the brief sleep intervention (e.g., “I expect that this intervention will help me to sleep better” vs. “This intervention helped me to sleep better”). Participants rated the items on a 5-point scale (1 – *strongly agree;* 3 – *neutral;* 5 – *strongly disagree*). Internal consistency for both the baseline and post-intervention measures were high (α = 0.85 and 0.89, respectively).

M1 Acceptability Questionnaire—This 7-item measure assessed participants’ overall experience using the device, in terms of comfort, ease, and understandability. Internal consistency (Cronbach’s alpha) was 0.61 at visit 2 and 0.74 at visit 4.

Clinical Monitoring Form (CMF) Medication Module—The CMF (Sachs, Guille, & McMurrich, 2002) is used to record subjects’ psychiatric medications and dosages from the past week.

Sleep Diary—Participants completed a sleep diary every morning for one week to document their sleep from the previous night. Participants recorded the number of minutes it took them to fall asleep (sleep latency), the number of hours they slept, and their Stanford Sleepiness Scale (SSS) rating.

Stanford Sleepiness Scale (SSS)—The SSS (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) is a self-report measure of daytime sleepiness. Scores range from 0 to 7 (0 – *feeling active, vital, alert, or wide awake*; 7 – *no longer fighting sleep, sleep onset soon; having dreamlike thoughts*) with higher scores indicating greater sleepiness. The SSS has a validity correlation of 0.68 (using Wilkinson addition and vigilance tests) and a test-retest reliability of 0.88 (Hoddes et al., 1973).

Procedure

At Visit 1, a trained evaluator assessed participants’ mood (i.e., YMRS, MADRS). Participants completed the questionnaires regarding sleep quality (i.e., PSQI, ESS) and

expectations of the sleep intervention (i.e., SIA). Participants were oriented to the M1 device and then took it home to wear it for as many nights possible between visits 1 and 2. The morning after wearing the M1, participants completed a sleep diary entry to document their sleep from the previous night.

One week later, participants returned for Visit 2 and began the brief sleep intervention with the study clinician. They also completed the M1 acceptability questionnaire. Participants returned 10–14 days later for the second session of the brief sleep intervention at Visit 3. After this visit, participants wore the M1 device nightly and completed the sleep diary. One week later (Visit 4), participants completed the assessments conducted at Visit 1 and the M1 acceptability questionnaire.

Statistical Analyses

Data were entered and analyzed using IBM SPSS. Descriptive statistics (mean, standard deviation) were calculated and examined for each outcome variable before and after the intervention. For each sleep diary, we calculated the mean self-reported sleep latency, sleep duration, and paired samples t-tests were conducted to examine differences with a two-tailed level of significance ($p < .05$). For the objective sleep data obtained by the M1, we conducted paired-samples t-tests to compare participants' median HFC%, LFC%, and sleep duration before and after they completed the sleep intervention. Median values were used to avoid undue influence of outliers. We did not adjust for multiple comparisons given these analyses are meant to be hypothesis-generating.

Results

Feasibility/Acceptability of Treatment and M1 Device

All eight participants completed the sleep intervention and attended 100% of the sessions. Seventy five percent of patients were taking a mood stabilizer (e.g., lithium, valproic acid), 13% on anxiolytics/hypnotics (e.g., zolpidem, lorazepam), 50% on antidepressants (e.g., fluoxetine, buproprion), and 13% on antipsychotics (e.g., clozapine, quetiapine). Participants had high expectations for the sleep intervention as they strongly agreed that the intervention would be user friendly ($M = 1.75$, $SD = 0.46$), they would learn skills that would help them change ($M = 1.88$, $SD = 0.35$), and that they would like using those skills ($M = 1.88$, $SD = 0.64$). Most of their expectation scores/ratings did not change after receiving the sleep intervention (p's >.05), suggesting that the intervention met their initially high expectations. In addition, participants were more likely to report learning skills that they could use on their own ($t[7] = 2.65$, $p < .05$), as well as recommend the intervention after receiving it ($t[7] = 3.42$, $p < .05$).

In regards to the M1, all participants wore it for at least two nights. The average number of nights the M1 was worn was 6.12 days after Visit 1 ($SD = 1.36$; Range = 4 to 8 days) and 5.5 days after Visit 3 ($SD = 2.33$; Range = 2 to 8 days). At Visit 2, participants agreed that the M1 was very easy to use ($M = 4.50$, $SD = 0.54$), easy to apply ($M = 4.50$, $SD = 0.76$), and did not interfere with their sleep ($M = 4.88$, $SD = 0.35$); at the end of the study, there were no statistically significant changes in these items; however, participants were less likely to report that they would wear the device again ($t[7] = 3.42$, $p < .05$). Nevertheless, the mean rating was still very high at visit 4 ($M = 4.25$), indicating that participants reported still being likely to wear the M1 again.

Preliminary Effectiveness of Treatment

Given the small sample size, we conducted exploratory analyses on the sleep intervention's effectiveness. Table I shows the objective sleep indices obtained from the CPC analysis and

sleep diaries. There was no significant change in the median stable (HFC%) sleep after receiving the sleep intervention; however, participants slept significantly longer after the sleep intervention, but also had more unstable (LFC%) sleep. We also found no statistically significant change in self-reported sleepiness ($t[7]= 0.20$, $p = .85$) or in total PSQI scores ($t[5] = 2.13$, $p > .05$). However, participants reported having less dysfunction during the day due to sleepiness after the intervention ($t[7] = 2.38$, $p < .05$).

The brief sleep intervention also yielded a trend toward improvement in depressive symptoms ($M = 19.13$, $SD = 11.28$ at Visit 1 vs. $M =13.50$, $SD = 9.78$ at Visit 4, respectively), but the variance was large and this difference did not reach statistical significance ($t[7] = 1.18$, $p = .28$). Likewise, mania symptom scores showed a trend toward improvement ($M = 5.00$, $SD = 5.24$ at Visit 1 and $M = 1.88$, $SD = 2.64$ at Visit 4, respectively), but did not reach statistical significance ($t[7] = 1.33$, $p = .22$).

Discussion

We developed a brief psychosocial sleep intervention for bipolar disorder, as well as explored the feasibility and acceptability of a novel home sleep monitoring device (M1 device). Our data suggest that the brief psychosocial sleep intervention and the M1 device are both tolerable and feasible for participants given (1) their high adherence rates and (2) participants' initially high expectations remained stable. Although participants reported being less likely to wear the M1 after the intervention, their acceptability rating for this device was still high. We also found that the brief sleep intervention improved sleep duration, but was also associated with more unstable sleep as measured by the M1.

One possibility for the increase in unstable sleep is that the brief sleep intervention may have been overly focused on ways to improve sleep duration as opposed to sleep quality. This may suggest that future sleep interventions for bipolar disorder should focus more on factors that contribute to the degree of restful sleep (e.g., intrusive thoughts, aspects of the sleep environment, ability to self-soothe). Nonetheless, participants slept longer as well as reported less day dysfunction due to sleepiness after receiving the brief sleep intervention. There was also a trend for improvements in other indices (e.g. manic and depressive symptoms, sleep quality) after the sleep intervention, but they did not reach statistical significance in this small sample.

Our small sample size and the length of the intervention may explain why we did not observe more improvement in sleep, symptoms and functioning. For example, participants may not have had enough time to practice the skills taught in the treatment, because almost all of the participants requested more time between sessions to practice the skills taught at Visit 2 (i.e., sleep session 1) before learning new skills at Visit 3 (i.e., sleep session 2). Thus, we may modify the intervention to allow for four weeks between the two sleep sessions and add a phone interview at week 2 to "check in" with participants, or problem-solve any obstacles they may have faced in practicing the skills taught at the first session. Similarly, we may also add two weeks between the final sleep session and the final outcome assessment to give participants more time to practice the skills they learned. We believe that these changes can enhance the effectiveness of the sleep intervention.

Other limitations of this study include lack of blinded evaluators and no control group. In addition, we did not include a longitudinal follow-up, so we were unable to evaluate whether participating in the intervention led to any long-term change. The brief sleep intervention was conducted by the same clinician (author LS) who developed the manual, which ensured treatment integrity (i.e., that the manual was followed closely), but dissemination is limited

because we have not yet developed clinician training materials and integrity measures (for the new clinicians). Thus, future studies will involve creating these materials.

We also did not examine the validity of the M1 device because prior studies found that CPC analyses can reveal sleep instabilities in individuals with conditions such as major depression and fibromyalgia (Thomas et al., 2010; Yang et al., 2010). Given our small sample size, we were also unable to compare sleep duration derived from the M1 with the self-reported measure from participants' sleep diaries because we did not have sufficient data points to examine these correlations. However, it is important to note that individuals can often misperceive their sleep duration (Fernandez-Mendoza et al., 2011). Therefore, future studies evaluating the M1's ability to measure sleep in individuals with bipolar disorder by comparing CPC with existing objective measures, such as polysomnography, is warranted.

In summary, sleep disturbance in bipolar disorder continues to be understudied, despite its influence on course of illness and quality of life. In the present study, we designed a brief sleep intervention for this population and subjects found it feasible and tolerable. We also successfully implemented the M1 device for objective measurements of sleep. Future research is warranted to further investigate its efficacy, but the current study shows that a brief sleep intervention has the potential to ameliorate sleep disturbance in bipolar disorder.

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Table I

M1 Cardiopulmonary Coupling Data and Sleep Diary Items

Variable	Pre-Intervention *M (SD) Median*		Post-Intervention *M (SD) Median*		t^1
Cardiopulmonary Coupling Data					
Stable Sleep (High-frequency coupling), %	49.6 (18.1)	50.9	48.5 (19.0)	48.3	1.57
Unstable Sleep (Low-frequency coupling), %	33.4 (15.1)	32.4	37.4 (17.9)	37.5	−2.39*
Sleep Duration, min	381.2 (55.9)	381.2	423.3 (51.9)	424.6	−2.47*
Sleep Diary Items					
Sleep Latency (minutes)	23.45 (8.75)		21.07 (7.70)		0.79
Sleep Duration (hours)	6.95 (0.93)		7.48 (0.47)		−1.37
Stanford Sleepiness Scale score	3.47 (1.35)		3.41 (1.28)		0.29

[1] Due to a small sample obtained from each participant, T-tests were conducted using median values for the M1 sleep data to make it less sensitive to outliers

* $p < .05$