Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix

Efficacy of Brief Behavioral Treatment for Chronic Insomnia in Older Adults

Differences Between Included and Excluded Subjects. Excluded subjects had a higher percentage of men (52% vs. 38%), but did not differ in age, sex, race, medical comorbidities, or PSQI score from included subjects (Appendix Table 1).

Additional Polysomnographic Methods. Polysomnography (PSG) was conducted in participants' homes at their usual sleep times, using Compumedics Siesta monitors. One screening PSG was obtained to quantify apnea and periodic limb movements. Two additional consecutive nights of PSG were conducted at both pre-treatment baseline and post-treatment. Technologists applied sensors and instructed participants on how to remove devices the following morning. The PSG montage included bilateral central and occipital electro-encephalograms, bilateral electro-oculograms, bipolar submentalis electromyograms, and one channel of electrocardiogram. Additional channels for sleep-disordered breathing were recorded on the first night, including nasal pressure, oral-nasal thermistors, inductance plethysmography, and fingertip oximetry. Periodic limb movements were assessed using bilateral anterior tibialis electromyogram. PSG technologists scored sleep records in 20-second epochs using standard sleep stage scoring criteria[1] and American Academy of Sleep Medicine[2] definitions for apnea and hypopnea events. PSG outcomes included SOL, WASO, TST, and SE averaged over two nights at pre-treatment and two nights at post-treatment. Apnea-hypopnea index, desaturation index, and periodic limb movement arousal index were used to characterize the sample. In order to be considered usable, each PSG study had to include at least four hours of concurrent data for sleep staging and sleep-disordered breathing (screening night only). If a study did not meet these criteria, a repeat night was scheduled. Based on these criteria, usable screening PSG data were obtained in 97.4% of participants, pre-treatment baseline data in 98.7%, and post-treatment data in 97.4%.

It is often difficult to identify bedtime in home sleep studies, which is critical for identifying sleep onset latency (defined as the interval between bedtime and sleep onset). For these unattended home studies, we identified bedtime using a convergence of information from different sources: First, participants' self-reported bedtime from the concurrent sleep diary; second, by the appearance of characteristic "settling" of the PSG signals near the self-reported bedtime; and third, by identifying unambiguous Stage 2 NREM sleep and going backwards in the record to a period of persistent and unambiguous wakefulness without a large amount of artifact.

Additional Description of BBTI and IC Interventions. Eligible participants were randomly assigned to BBTI or IC conditions by permuted block design, stratified by age (>75) and sex. BBTI is a behavioral intervention for insomnia developed for this study. It consists of one 45-60 minute individual intervention session, followed by a 30-minute follow-up session two weeks later. Brief (less than 20 minute) telephone calls were also conducted after one and three weeks. BBTI includes education about general behaviors that promote or interfere with sleep (i.e., sleep hygiene education) and homeostatic and circadian mechanisms of human sleep regulation.[3] This education provides the rationale for the four main interventions of BBTI: 1. Reduce time in bed; 2. Get up at the same time every day, regardless of sleep duration; 3. Do not go to bed unless sleepy; and 4. Do not stay in bed unless asleep. These interventions are derived from sleep restriction and stimulus control techniques, whose efficacy has been well-documented in insomnia treatment.[4,5] Sleep restriction limits the number of hours in bed to improve sleep consolidation.[6] In this study, time in bed was limited to the number of hours typically spent asleep plus 30 minutes, but never less than 6 hours. Stimulus control involves limiting the bed and the sleep environment to sleep and sexual activity, based on the rationale that sleep is a learned behavior contingent upon the environment.[7] When the participant awakens during the night and cannot return to sleep, s/he is instructed to leave the bed and engage in pre-determined, low-stimulation activities to foster sleepiness. During the session, an individually-tailored "prescription" was developed for a restricted sleep schedule, regular timing of sleep, and activities to be performed out of bed when

awake, based on information derived from the participant's sleep diary and from with participant's input on preferences. The in-person booster session and telephone calls were used to review educational material, assess treatment adherence, and modify sleep schedules if necessary. The participant's prescription for time in bed was increased by 15 minutes if sleep latency and wakefulness during the night were both less than 30 minutes (averaged from the sleep diary); time in bed was deceased if sleep latency and wakefulness during the night were both greater less than 30 minutes; and time in bed was maintained otherwise. This algorithm was repeated for each of the four weeks during the acute treatment phase.

The IC condition was intended to emulate the type of behavioral instruction most primary care patients might receive. Participants randomized to IC received three brochures published by the American Academy of Sleep Medicine on insomnia, sleep and aging, and sleep hygiene. They were instructed to read and review the brochures over the following weeks. Two weeks later, they received a follow-up telephone call to answer questions that may have arisen. After the randomly-assigned intervention, IC participants were then offered BBTI.

Both interventions were delivered by a single master's level mental health nurse practitioner (LKB) who had no prior experience in sleep medicine or behavioral interventions for insomnia. Training consisted of observing clinical assessments of patients with insomnia, observing BBTI being delivered by the investigators (DJB, AG), and performing the intervention under direct supervision. Weekly supervision was conducted during the first 5 cases, followed by as-needed individual supervision and case discussions during weekly research meetings.

Treatment Expectations. Participant expectations for the assigned treatment were rated using five 100 mm visual analog scales[8] administered after randomization but before the first treatment session. Participants assigned to BBTI had significantly more positive treatment expectations than IC participants for 4/5 scales: How sensible the intervention appeared, how successful they expected it to be, whether they would recommend it to someone else, and how

much improvement they expected (p<.01 for each). The groups did not differ on how much effort they thought the treatment would required.

Treatment Acceptance and Integrity. Treatment acceptance was evaluated by calculating the number of participants who attended their scheduled sessions. For participants assigned to BBTI, 3/39 attended only one of the two in-person sessions; one of those three completed session 2 by telephone and had one of the two scheduled telephone calls. All of the IC participants completed their one in-person session and telephone follow-up session.

Treatment integrity was evaluated by audiotaping all intervention sessions and randomly rating 33% of all sessions using a checklist of treatment elements. Ratings were conducted by a single research assistant supervised by a study investigator (AG). Treatment integrity was high for both BBTI and IC conditions. BBTI sessions contained 97% (SD 3.2) of intended BBTI elements and IC sessions contained 97% (SD 2.7) of intended IC elements.

Definition of Response and Remission. For the primary outcome analyses, four categorical outcomes were compared using chi-squares: Response (change in PSQI score of ≥3 points *or* change in sleep diary SE of ≥+10%); remission (response criterion *plus* final PSQI score <5 *and* sleep diary SE >85%, corresponding to "good sleep" values,[9,10]); partial response (improvement in PSQI *or* SE as defined above, but worsening on the other measure); and non-response (change in PSQI score of <3 points *and* increase in sleep diary SE <+10%. There are no generally-accepted criteria for response or remission in insomnia treatment studies.[11] We chose the criteria for response on the basis of three types of data. First, these change scores correspond to approximately one standard deviation of the pre-treatment values and therefore, a treatment change effect size (Cohen's *d*) of approximately 1.0, which is traditionally considered to be a large effect.

Second, these change scores are consistent with mean change values observed in published clinical trials of behavioral and pharmacologic treatments for insomnia. For the PSQI,

the average change score in nine behavioral and pharmacologic treatment studies of insomnia, including both active and control conditions, was 2.5.[12-20] For sleep diary SE change scores, we reviewed published data from seven classic and recent behavioral treatment trials[10,12,19,21-25] and two published articles with review data.[5,24] Among all randomized participants, including active and control conditions, the mean change in diary-based SE was 8.8%, and among those receiving active treatments, the mean change was 13.7%. Published data reviewed in[24] indicated a mean SE change of 7.4% in all participants, and 13.2% in active those assigned to active treatment. Data reviewed in[5] indicate a mean SE change of approximately 9% in medication treatment studies and 12% in behavioral treatment studies. Thus, a SE change score of 10% is consistent with the mean change observed in behavioral and pharmacologic treatment trials including both active and control conditions.

Third, we examined unpublished data from our own research group to determine how our criteria would compare with another self-report metric, the Insomnia Severity Index (ISI). A change score of -6 has been identified as the minimally important difference for the ISI.[26] We identified 81 individuals who had both PSQI and ISI scores before and after active or control behavioral treatment for insomnia used in various research studies. The sample included 17 participants from the current study; we added the ISI only toward the end of this trial. The mean change in ISI was -5.9 (5.3) and the mean change in PSQI was 3.2 (4.0). The correlation between ISI and PSQI change scores was $r = 0.55$, $p < .0001$. Thus, a change score of -3 in the PSQI is approximately equivalent to a change score of -6 in the ISI. The mean change in diary SE was 5.6 (10.6), and the correlation with ISI change was $r = -.35$, $p < .006$. Thus, a change score of +10% in diary SE would correspond to a an ISI change score of >6 points.

Imputed Data. Missing data were imputed for statistical models. Data were missing due to collection errors, participant refusal, equipment malfunction (in the case of actigraphy), and drop-outs after randomization. Rates of missing data were calculated as the maximum number of imputed values for any one measure at any one time point: General clinical measures (<4%), sleep

diary (5%), actigraphy (<14%), and polysomnography (5%). Note that these figures represent the maximum amount of missing data for any one measure within that domain; other measures within the domain may have included larger numbers of subjects.

We conducted sensitivity analyses on the MANOVAs for each of the four outcome domains. The pattern of significant and non-significant results was identical to that reported in the main paper when we imputed data with the best or worst observed score, with one exception: The Time effect for actigraphy was no longer significant when imputing with the best observed score.

Subgroup analyses. Subgroup analyses were conducted to determine whether categorical outcomes for BBTI varied as a function of key participant characteristics (Appendix Table 2). Although these comparisons had small sample sizes, we did not find differential treatment responses based on the use of hypnotics or antidepressants, presence of sleep apnea, recruitment source (primary care vs. community), or early[27] vs. later study cohort.

Statistical power. Prior to the start of this study, we conducted power analyses based on data from previous published studies and a small pilot study conducted prior to the reported study. Those analyses indicated that a sample size of 45 would provide power of .80 or greater for outcomes in sleep diary and polysomnographic measures, and power of .72 for categorical outcomes. Reductions in funding from the study sponsor necessitated a reduction in sample size. Because significant differences were identified in all domains except polysomnography, we believe that our study was adequately powered to detect differences. The actual results from our study showed larger effect sizes for categorical and self-report measures, but smaller effect sizes for polysomnography, than we predicted prior to the study.

Additional Outcome Data For Participants Assigned To the IC Condition. After completion of the randomly-assigned intervention, participants initially randomized to IC who did not respond to that intervention were offered BBTI; those who agreed were assessed after 4 weeks

with questionnaires and sleep diaries to assess the same outcomes used in the main study. Of the 30 IC participants who initially showed partial or nonresponse, 21 initially elected to receive BBTI, but 2 of these subsequently decided to receive other treatment. Of the 19 who actually received BBTI, 53% (n=10) met criteria for response, and 26% (n=5) met criteria for remission after four weeks.

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eTable 1: Included vs. excluded subjects

	Screened out N=68	Included N=79	Statistics
Age	72.0 (7.2)	71.7 (7.26)	t=0.26, df=145, p=0.80
% Male	52.9 (n=36)	31.6 (n=25)	Fisher exact p=0.02
% Caucasian	92.7 (n=63)	93.7 (n=74)	Fisher exact p=0.99
Comorbid Health Conditions	5.95 (3.56) (n=61)	5.61 (2.73)	t=0.64, df =138, p=0.52
PSQI	11.2 (3.6) (n=61)	10.4 (3.0)	t=1.35, df=138, p=0.18

eTable 2: Subgroup Analyses

No sleep medications vs. sleep medications

	No Sleep Medication	Sleep Medication	Fisher Exact P-value
%Response/Remit	70.4 (n=19/27)	58.3 (n=7/12)	.49
%without Insomnia Diagnosis Post-Treatment	55.6 (n=15/27)	54.6 (n=6/11)	.99

No antidepressant vs. antidepressant

	No Antidepressant	Antidepressant	Fisher Exact P-value
%Response/Remit	80.8 (n=21/32)	71.4 (n=5/7)	.99
%without Insomnia Diagnosis Post-Treatment	50.0 (n=16/32)	83.3 (n=5/6)	.20

Apnea hypopnea index

	≤ 5	> 5	Fisher Exact P-value
%Response/Remit	54.6 (n=6/11)	70.4 (n=19/27)	.46
%without Insomnia Diagnosis Post-Treatment	36.4 (n=4/11)	61.5 (n=16/26)	.28

Primary care vs. community

	Community	Primary Care	Fisher Exact P-value
%Response/Remit	62.1 (n=18/29)	80.0 (n=8/10)	.45
%without Insomnia Diagnosis Post-Treatment	53.6 (n=15/28)	60.0 (n=6/10)	.99

Early vs. late cohort[1]

	Early	Late	Fisher Exact P-value
%Response/Remit	70.6 (n=12/17)	63.6 (n=14/22)	.74
%without Insomnia Diagnosis Post-Treatment	64.7 (n=11/17)	47.6 (n=10/21)	.34

[1] Early cohort reported in Germain A, Moul DE, Franzen PL, et al. Effects of a brief behavioral treatment for late-life insomnia: Preliminary findings. *Journal of Clinical Sleep Medicine* 2006;2(4):403-6.