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Original Research Article

An Open Trial of Morning Bright Light Treatment Among US Military Veterans with Chronic Low Back Pain: A Pilot Study

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Abstract

Objective. To examine the feasibility, acceptability, and effects of a home-based morning bright light treatment on pain, mood, sleep, and circadian timing in US veterans with chronic low back pain. **Design**. An open treatment trial with a seven-day baseline, followed by 13 days of a one-hour morning bright light treatment self-administered at home. Pain, pain sensitivity, mood, sleep, and circadian timing were assessed before, during, and after treatment. **Setting**. Participants slept at home, with weekly study visits and home saliva collections. **Participants**. Thirty-seven US veterans with medically verified chronic low back pain. **Methods**. Pain, mood, and sleep quality were assessed with questionnaires. Pain sensitivity was assessed using two laboratory tasks: a heat stimulus and an ischemia stimulus that gave measures of threshold and tolerance. Sleep was objectively assessed with wrist actigraphy. Circadian timing was assessed with the dim light melatonin onset. **Results**. Morning bright light treatment led to reduced pain intensity, pain behavior, thermal pain threshold sensitivity, post-traumatic stress disorder symptoms, and improved sleep quality ($P < 0.05$). Phase advances in circadian timing were associated with reductions in pain interference ($r = 0.55$, $P < 0.05$). **Conclusions**. Morning bright light treatment is a feasible and acceptable treatment for US veterans with chronic low back pain. Those who undergo morning bright light treatment may show improvements in pain, pain sensitivity, and sleep. Advances in circadian timing may be one mechanism by which morning bright light reduces pain. Morning bright light treatment should be further explored as an innovative treatment for chronic pain conditions.

Key Words: Circadian; Bright Light; Chronic Low Back Pain

Introduction

Approximately 50% of US military veterans report that they experience pain on a regular basis [1,2], most commonly in the back and head [1]. One common approach to treating chronic pain is with opioid analgesic medications, which are not always effective, have negative side effects, and are widely misused [3,4]. Cognitive behavioral therapy (CBT) and exercise are available nonpharmacological treatments, but CBT requires access to specialized personnel and exercise requires high participant motivation. Thus, there is an urgent need to develop readily available, affordable, safe, and practical nonpharmacological approaches to managing chronic pain.

Results of meta-analyses indicate that exposure to bright light in the morning can improve sleep [5] and

mood [6]. Therapies designed around bright light consist of having participants receive high-intensity ultraviolet-free light, most typically from a light box, during morning hours. In contrast to pharmacological treatments, morning bright light treatment is associated with few side effects, which often spontaneously remit [7,8], and patients rarely discontinue treatment due to side effects [8]. Bright light devices are considered safe, with participants showing no changes in ophthalmologic exams after six years of daily use in the fall and winter months [9]. The sleep and mood benefits of morning bright light treatment may in part be attributable to circadian phase advances (shifts earlier in the timing of the body clock) which often occur following morning bright light exposure [10].

Chronic pain is a multidimensional phenomenon, interrelated with many factors, including negative mood and poor sleep. Moreover, PTSD, depressive, and anxiety symptoms are all associated with elevated pain intensity [11,12]. Noting that people experiencing sleep disturbance are at greater risk of developing chronic pain [11,13–15] and that improving sleep reduces pain and pain sensitivity [16,17], we proposed that a treatment that improves sleep and mood—morning bright light treatment—may reduce pain intensity among people with chronic low back pain.

We recently reported results from a small sample of women with fibromyalgia who underwent bright light treatment. They received a daily one-hour morning bright light treatment, generated from light boxes, for six consecutive days. The women reported clinically meaningful improvements in pain and function [18]. The purpose of the current study was to examine the feasibility, acceptability, and effects of a similar home-based self-administered morning bright light treatment on pain, mood, sleep, and circadian timing in a new patient population, US veterans with chronic low back pain. To our knowledge, bright light treatment has never been tested as a potential treatment for chronic low back pain. Based on the literature and our previous findings, we hypothesized that the morning bright light treatment would reduce pain and pain sensitivity, improve function, mood, and sleep, and advance circadian timing (shift the timing of the body clock earlier). Further, if morning bright light treatment works partly via changes in circadian timing, then circadian timing changes should correlate with outcome changes. Alternatively, patient expectations of achieving benefits may also represent a mechanism, albeit not specific to bright light. To address this issue, we examine correlations among participant expectations and pre- to post-treatment changes in circadian timing and outcomes.

Methods

Participants

Thirty-seven US military veterans (10 females, 27 males) who reported chronic low back pain were enrolled in the study (Table 1). The veterans were required to provide proof of veteran status (e.g., DD Form 214, a certificate of release or discharge from active military duty). The presence of significant chronic low back pain was determined from a self-report of chronic low back pain for at least the previous six months, with an average intensity of at least 4/10 (1 = no pain to 10 = worst pain possible). Veterans also signed an authorization form to obtain their medical records regarding their back pain, which was used to verify a preexisting complaint of chronic low back pain to a medical provider.

Exclusion criteria were a) other significant chronic disease (apart from medication-controlled diabetes and hypertension); b) other condition associated with chronic pain (including chronic headaches, fibromyalgia, complex regional pain syndrome, rheumatoid arthritis); c) past or present psychosis or bipolar disorder; d) present alcohol or substance abuse problems; e) suicidal ideation; f) high risk for obstructive sleep apnea, restless leg syndrome, or seasonal affective disorder [19–21]; g) taking daily nonsteriodal anti-inflammatory medications (NSAIDs) and/or beta-blockers (these medications suppress melatonin) [22,23]. Accepted subjects reported no retinal pathology or eye surgery, and none were taking photosensitizing medications. No subjects were color blind as determined from the Ishihara test, and none had any prior experience with bright light treatment. Prescribed or over-the-counter sleep aids (apart from exogenous melatonin) and antidepressants were permitted, provided that medication use remained stable 30 days before and during the study. No subjects had worked any night shifts or traveled outside the Central Time Zone in the month preceding the study. The study was approved by the Rush University Medical Center Institutional Review Board, and all participants gave written informed consent before participation. This clinical trial was registered as NCT02373189 on clinicaltrials.gov.

Five veterans failed drug and alcohol screening on the first day of the study and did not participate further. An additional seven veterans dropped out before the start of the light treatment due to a variety of reasons, including jail time, job offers, and family crises. Therefore, a total of 25 veterans received the bright light treatment.

Protocol

This was a single-arm trial, in which all subjects received morning bright light treatment. The study consisted of a seven-day baseline during which subjects slept at home on their usual sleep schedule (ad lib). This baseline was followed by a daily one-hour morning bright light treatment for 13 consecutive days. Subjects underwent a baseline pretreatment assessment, a midtreatment assessment after six days of morning bright light treatment, and a final treatment assessment after a further seven days of morning bright light treatment. These assessments involved subjects visiting the Department of Behavioral

Table 1. Demographic characteristics of the sample of US veterans with chronic low back pain

Characteristic	Total Sample (N = 37)
Sex, No. (%)	
Female	10 (27)
Male	27 (73)
Age, mean (SD), y	48.4 (14.1)
Race, No. (%)	
African American	22 (59)
White	8 (22)
Hispanic	5 (14)
More than 1 race	2 (5)
Partner status, No. (%)	
Single	18 (49)
Domestic partner	19 (51)
Educational status, No. (%)	
Postgraduate degree	1 (3)
College graduate	17 (46)
Some college	15 (41)
High school or less	1 (3)
No answer	3 (8)
Body mass index, mean (SD), kg/m^2	30.0 (5.8)

Sciences at Rush University Medical Center at a set time in the morning. Upon arrival, they were breathalyzed for alcohol, underwent pain sensitivity testing, completed questionnaires, and then returned home for saliva sampling, used for later determination of circadian timing (details below). Research staff also visited the veterans in their homes to set up the light boxes for the one hour per day morning bright light treatment after baseline, mid-treatment to confirm the light box setup was unchanged, and finally post-treatment to collect the light boxes.

Wrist Actigraphy

All subjects wore a wrist actigraphy monitor (30-second epochs, Actiwatch Spectrum, Respironics, Bend, OR, USA) on their nondominant wrist throughout the baseline and 13 days of bright light treatment and were instructed to complete sleep diaries and press the event marker on the actigraphy monitor before and after sleep during each of these days. The subjects were also instructed to ensure that the photosensor on the wrist monitor was not covered during the bright light treatment. The wrist actigraphy data were analyzed with the Actiware 6.0.9 program (Respironics, Bend, OR, USA). The setting of nightly rest intervals for analysis was guided by the event markers, sleep diaries, light data, and activity levels [24]. Objective actigraphic estimates of sleep onset time (clock time of the first epoch scored as sleep in each rest interval), wake time (clock time of the last epoch scored as sleep in each rest interval), total sleep time (number of minutes scored as sleep in each rest interval), and sleep efficiency (proportion of time from sleep onset to waking in each rest interval, scored as sleep, expressed as a percentage) were extracted for each study day. During the 13 days of bright light treatment, the subjects were advised to maintain their habitual sleep duration, and naps were discouraged to improve nighttime sleep efficiency. The sleep variables from the three nights of sleep immediately before the assessments were each averaged to estimate sleep just before the assessments.

Questionnaires

During the assessment visits, subjects completed questionnaires to assess pain, function, mood, and sleep. Pain and function were assessed with the PROMIS Pain Intensity, Pain Behavior, Pain Interference, and Physical Function domains. Depressive symptoms were assessed with the Center for Epidemiologic Studies Short Depression Scale (CES-D 10) [25], anxiety symptoms with the State Trait Anxiety Inventory (STAI) [26], and post-traumatic stress symptoms with the PTSD Checklist for DSM-5 (PCL-5) [27]. Subjective reports of sleep quality were collected with the Pittsburgh Sleep Quality Index (PSQI) [28] and the Insomnia Severity Index (ISI) [29].

Test of Pain Sensitivity

There were two pain sensitivity tests. First, participants underwent an ischemic pain task based on procedures described by Maurset et al. [30]. Participants first engaged in two minutes of dominant forearm muscle exercise using a hand dynamometer at 50% of his or her maximal grip strength, as determined before beginning the laboratory procedures. Then they were asked to raise their dominant forearm over their head for 15 seconds. A manual blood pressure cuff was then inflated on the participant's dominant biceps to 200 mmHg SBP, the arm was lowered, and the cuff remained inflated until tolerance was reached, up to a maximum of eight minutes. Participants were instructed to indicate when they first experienced pain after the cuff was inflated, with this ischemic pain threshold defined as the time elapsed from task onset to when the sensation was first described as "painful." Ischemic pain tolerance was defined as the time elapsed between onset of the pain task and participants' expressed desire to terminate the task (set at a maximum of eight minutes).

The second laboratory pain task was a heat pain task using a Medoc TSAII NeuroSensory Analyzer (Medoc US, Minneapolis, MN, USA). This equipment was used to assess thermal pain threshold and tolerance using an ascending method of limits protocol, as in several previous studies [31–33]. Four trials each were conducted for thermal pain threshold and tolerance, with each trial conducted sequentially at one of four different nonoverlapping sites on the nondominant ventral forearm. An interval of 30 seconds between successive stimuli was employed. For pain threshold trials, the probe started at an adaptation temperature of 32°C, with the temperature increasing at a ramp rate of 0.5°C/sec until the participant indicated that the stimulus had begun to feel

"painful" by depressing a button on a computer mouse. For each tolerance trial, the probe started at an adaptation temperature of 40°C, with the temperature increasing at a ramp rate of 0.5°C/sec until the participant indicated that maximum tolerance had been reached. Means of the four thermal pain threshold and tolerance trials were separately derived for use in analyses. Maximum possible tolerance temperature was 51°C due to an automatic hardware cutoff built into the TSAII device to ensure participant safety. Before beginning the first laboratory session, all participants underwent standardized training to familiarize themselves with the thermal stimulus device and the concepts of pain threshold and tolerance.

Circadian Phase Assessments

At the end of the assessment visits, subjects were trained in the use of a validated home saliva collection kit [34,35] to assess the dim light melatonin onset (DLMO). The DLMO is the most reliable circadian phase marker in humans [36,37]. Key features of the home saliva collection kit included 1) a track cap bottle (MEMS, Aardex, Switzerland), which provides objective markers of the sample times; 2) a photosensor (Actiwatch Spectrum, Philips, Bend, OR, USA) worn around the neck on top of clothing to objectively verify light <50 lux (to avoid melatonin suppression); and 3) a label dispenser to avoid incorrect sample labeling. A checklist and timer with alarms guided the subject to dim their home lighting and conduct the saliva collection. Neither toothpaste nor mouthwash was permitted. Small snacks and fluids were permitted, except in the 10 minutes before each sample, and subjects were required to rinse and brush their teeth with water while remaining seated 10 minutes before each sample if they had consumed food or drink. At the baseline assessment, subjects sampled their saliva with salivettes (Sarstedt, Newton, NC, USA) every 30 minutes starting six hours before and until their average bedtime. At the midtreatment and post-treatment assessments, subjects began to sample their saliva two hours earlier to optimally capture a phase advance (shift earlier) in the DLMO. The subjects were prompted by phone calls to refrain from consuming NSAIDs 72 hours before (replacement acetaminophen was provided) and alcohol/caffeine 24 hours before the saliva collections to avoid confounding the measurement of melatonin. The frozen saliva samples were collected by research staff during the home visits. Upon return to Rush University Medical Center, the samples were thawed, centrifuged, refrozen, and shipped in dry ice to Solidphase, Inc. (Portland, ME, USA). Technicians there performed the direct radioimmunoassay using standard Buhlmann kits with assay sensitivity of 0.5 pg/mL and intra- and interassay coefficient of variation <7.5% at 3 pg/mL. A DLMO was calculated for each phase assessment as the clock time (with linear interpolation) when the melatonin concentration exceeded the mean of three low consecutive daytime values plus twice the standard deviation of these points [38,39].

Bright Light Treatment at Home

The morning after the baseline assessment, research staff visited subjects in their homes to set up the light boxes. The research staff discussed with the subject their preferred activity during the light treatment (e.g., watching TV, working at a computer, reading, etc.). Two broad-spectrum white light boxes (33 × 18 × 55 cm, EnergyLight HF3318/60, Philips, Inc.) were set up to the left and right at a distance that allowed the subject to view a TV or computer in front of them (Figure 1). Each subject's comfort was first maximized using comfortable chairs and/or cushions, as appropriate, and then the light boxes were positioned to maximize light intensity (Extech EA33 light meter, Nashua, NH, >3,000 lux). A 60-cm string was taped to the base of each light box to remind the subjects how close they needed to sit near the light boxes, and painter's tape was placed around the base of each light box to show where the boxes should remain. The morning light treatment was for one hour per day for a total of 13 days and started each morning at the subject's average wake time (derived from the baseline week of wrist actigraphy) or up to one hour earlier to accommodate morning social responsibilities (e.g., work, child care) [40]. A photosensor (Actiwatch Spectrum, Philips, Inc., Bend, OR, USA) was taped facing inwards to the outside of each light box to confirm adherence. An alarm clock was set to the start of the bright light treatment and was placed near the light boxes (subjects also set their home alarm clock). Subjects were given a list of written reminders: a) do not permit anyone to touch the light boxes; b) only turn on light boxes during the scheduled time; and c) turn on all ambient lighting during light treatment time. At the end of the light box set up, subjects completed a treatment expectation item of 1 = "expect to be completely pain free" to 7 = "expect no change."

Research staff phoned each subject daily, shortly after the start of the light treatment, to confirm correct use of the light boxes, ensure that the photosenor on their wrist monitor was uncovered, and assess potential side effects. Research staff also visited the subjects at home at midtreatment (after six days of light treatment) to confirm that the light box set up was unchanged and at post-treatment (after 13 days of light treatment) to collect the light boxes. During this post-treatment home visit, subjects completed a treatment satisfaction item of 1 = "not satisfied at all" to 10 = "extremely satisfied."

Statistical Analysis

To examine the change in the measures between baseline, after six days, and after 13 days of light treatment, we used a semiparametric generalized estimating equation regression model with an identity link function and an

Figure 1. A research staff member sitting at a participant's desk after the light boxes were set up. Two light boxes were used: one light box was positioned slightly to the left, and one light box was positioned slightly to the right so that the participant could work on a computer or watch TV between them.

exchangeable working correlation matrix to account for correlations of the outcome measures over time. This nonparametric approach remains robust with smaller sample sizes and is less likely to lead to false-positive findings. Baseline served as the reference time frame, and two indicator variables for after six days and after 13 days of light treatment were created to examine the change in outcome measures at six days and 13 days relative to baseline measures. As only one veteran dropped out of the study after the start of light treatment, no additional missing data methods were performed. As this proof of concept study was focused primarily on acceptability and feasibility of treatment, and secondarily on treatment efficacy, all two-tailed statistical tests were based on a type I error rate of 5%. In addition, simple baseline to post-treatment change scores were computed for all measures. Correlations were generated among the participant treatment expectation measure and the baseline to post-treatment change scores.

Results

Acceptability and Feasibility

One veteran dropped out at the midtreatment assessment point in order to go on a vacation, and thereby only received six days of light treatment. The remaining 24 veterans completed the full 13 days of light treatment. The average expectation rating was 4.0 ± 1.9, suggesting that the veterans endorsed the possibility that the morning bright light treatment could reduce their pain. Light readings from the photosensors on the light boxes were checked against the light readings on each subject's wrist monitor during the light treatment to gauge when subjects received the light treatment. Results indicated that on average subjects received bright light during 87.8% of the scheduled light treatment times (range = 18.5–99.4%). Likely due to ≥80% adherence in all participants but two, no significant associations were found between adherence and outcome measures. No participant reported any side effects or adverse events associated with the light treatment. The average treatment satisfaction rating was 8.0 ± 2.2, suggesting that, on average, the veterans were well satisfied with the treatment.

Pain Sensitivity from Laboratory Pain Tasks

No pain sensitivity data were lost. The light treatment did not lead to any significant changes in ischemia pain threshold or tolerance (Table 2). Thermal pain threshold significantly increased from baseline to after 13 days of light treatment, reflecting a decrease in pain sensitivity after the light treatment. Thermal tolerance, however, did not change significantly during light treatment.

Self-Reported Pain, Function, Mood, and Sleep

The online PROMIS assessment failed on two occasions, resulting in only a partial baseline assessment for one subject and a missing final assessment for another subject. Pain Intensity and Pain Behavior significantly decreased from baseline to post-treatment (Table 2). Pain Interference did not significantly decrease from baseline to post-treatment. Physical Function showed a trend toward improvement at post-treatment ($P = 0.07$). All subjects completed depressive and anxiety symptom questionnaires, but some subjects were unwilling to complete all the PTSD symptom questionnaires (two subjects at baseline, three subjects at midtreatment, and four subjects at post-treatment). There were no significant effects of light treatment on depressive or anxiety symptoms (Table 2). PTSD symptoms were significantly reduced from baseline to post-treatment. All subjects completed the self-report sleep questionnaires. Scores on both the Pittsburgh Sleep Quality Inventory and Insomnia Severity Index were reduced significantly during bright light treatment (Table 2).

Wrist Actigraphy

A wrist actiwatch failed for one subject during the last week of light treatment. There was evidence that the light treatment led to earlier sleep start and sleep end timing. However, total sleep time and sleep efficiency did not significantly change from baseline to post-treatment (Table 2).

Circadian Timing

The DLMOs for seven veterans were not valid due to low levels of melatonin (<5 pg/mL) or to at least one erratic melatonin profile. Two veterans did not dim their home lighting, which likely suppressed their melatonin levels, invalidating calculation of their DLMOs. In the final sample, there were 17 DLMOs at baseline, and 16 DLMOs at both midtreatment and post-treatment.

Table 2. Means and SDs of variables at baseline, after six days, and after 13 days of morning bright light treatment

Variable	Baseline	6 d	13 d
Ischemic threshold, sec	81.48 (119.80)	67.56 (100.69)	84.67 (129.23)
Ischemic tolerance, sec	187.88 (160.13)	217.04 (176.01)	200.46 (162.40)
Thermal threshold, °C	42.95 (3.68)	43.27 (4.09)	43.72 (3.11)*
Thermal tolerance, °C	47.09 (1.64)	47.16 (1.74)	47.11 (1.97)
PROMIS Pain Intensity	48.84 (6.30)	49.59 (7.65)	47.02 (7.77)*
PROMIS Pain Behavior	56.67 (6.49)	55.94 (6.92)	54.63 (8.09)*
PROMIS Pain Interference	56.39 (8.33)	56.05 (8.33)	55.37 (8.72)
PROMIS Physical Function	44.21 (8.66)	45.09 (8.58)*	44.99 (8.68)
CES-D 10	6.60 (4.84)	7.04 (5.40)	6.13 (5.08)
STAI	35.00 (11.58)	36.20 (11.68)	36.92 (11.42)
PCL-5	15.91 (20.11)	14.95 (21.38)	12.10 (18.04)*
PSQI	7.72 (5.10)	7.04 (3.17)	5.96 (2.91)*
ISI	8.56 (5.28)	6.24 (5.43)*	6.71 (4.81)*
Actigraphy sleep start, h:mm	23:25 (1.80)	23:09 (1.81)	22:55 (1.75)*
Actigraphy sleep end, h:mm	7:10 (1.63)	6:20 (1.47)*	6:27 (1.51)*
Actigraphy total sleep time, h	402.47 (75.66)	372.83 (82.45)*	383.40 (67.46)
Actigraphy sleep efficiency, %	87.02 (5.23)	86.87 (5.72)	85.46 (7.36)
DLMO, h:mm	19:58 (1.57)	19:29 (1.28)*	19:11 (1.46)*

*Indicates mean significantly different from baseline at $P < 0.05$.

CES-D 10 = Center for Epidemiologic Studies Short Depression Scale; DLMO = dim light melatonin onset; ISI = Insomnia Severity Index; PCL-5 = PTSD Checklist for DSM-5; PSQI = Pittsburgh Sleep Quality Index; STAI = State Trait Anxiety Inventory.

The DLMO significantly phase-advanced (shifted earlier in clock time) from baseline (Table 2).

Correlations Among Change Scores

We generated correlation coefficients among participant treatment expectation ratings and baseline to post-treatment change scores for all outcome variables (Table 3). Given that the sample size was 25 participants for most measures and only 16 participants for the DLMO values, we did not expect many statistically significant correlations. Instead, we examined patterns of correlation coefficients to evaluate to what degree outcome changes were related to DLMO changes—a potential mechanism specific to bright light treatment—and to participant expectations of benefit from treatment—a potential mechanism not specific to bright light treatment. There were two correlation coefficients ≥ 0.30 for participant ratings of expected benefit and six correlation coefficients ≥ 0.30 for DLMO changes. Results suggest some evidence for the notion that baseline to post-treatment circadian timing changes may have accounted for outcome improvements, at least to a larger extent than participant expectations of benefitting from the morning bright light treatment.

Discussion

US military veterans report a high prevalence of chronic pain [1,2]. Pharmacological approaches for the management of chronic pain are fraught with unwanted side effects, and, in the case of opioid-based analgesic medications, risk of serious misuse [3,4]. We proposed that morning bright light treatment could represent a low-cost, low–side effect, and practical alternative to analgesic medications. The purpose of this open trial was to examine the feasibility, acceptability, and effects of a home-based, self-administered morning bright light treatment on pain, mood, sleep, and circadian timing in a small sample of US military veterans with chronic low back pain. Our results suggest that morning bright light treatment was feasible and acceptable to veterans with chronic low back pain. Although there was significant subject dropout during the baseline phase, only one subject dropped out after initiating the light treatment. Importantly, the subject's stated reason for dropout was not due to treatment side effects. Treatment expectation and satisfaction scores also suggest good acceptability of this form of treatment in this population. These findings are consistent with the published literature indicating that there are minimal side effects associated with bright light treatment [7,8] and low patient discontinuation rates [8].

We found that self-reports of pain intensity and pain behavior significantly reduced, whereas self-reported physical function significantly improved during the morning bright light treatment. Although the baseline to post-treatment effect sizes for all three factors were no greater than medium (Cohen's $d = 0.26$), results suggest that subjects did indeed improve on pain and function in response to this treatment. Both sleep quality and insomnia symptoms showed significant improvement, with larger effect sizes (Cohen's $d = 0.37$–0.44). Sleep quality improved, but the average score still reflected some sleep quality problems post-treatment (PSQI ≥ 6). Subjects did move from an average "subthreshold insomnia" score at baseline to "no clinical significant insomnia" at post-treatment on the ISI. However, although the objective sleep variables derived from the wrist actigraphy showed

Table 3. Correlations among participant treatment expectations, DLMO changes, and outcome changes

Baseline to Post-treatment Change Scores	Participant Expectations	DLMO Changes
Ischemic threshold, sec	0.21	–0.09
Ischemic tolerance, sec	–0.17	0.21
Thermal threshold, °C	–0.01	–0.23
Thermal tolerance, °C	0.13	0.03
PROMIS Pain Intensity	–0.24	0.33
PROMIS Pain Behavior	–0.14	0.38
PROMIS Pain Interference	0.05	0.55*
PROMIS Physical Function	–0.31	–0.20
CES-D 10	0.23	0.28
STAI	0.17	0.35
PCL-5	–0.06	–0.27
PSQI	0.27	0.06
ISI	0.27	0.46
Actigraphy sleep start, h:mm	–0.06	0.11
Actigraphy sleep end, h:mm	–0.35	0.42
Actigraphy total sleep time, h	–0.24	0.24
Actigraphy sleep efficiency, %	–0.15	–0.02

*Indicates correlation coefficient significant at $P < 0.05$.

CES-D 10 = Center for Epidemiologic Studies Short Depression Scale; DLMO = dim light melatonin onset; ISI = Insomnia Severity Index; PCL-5 = PTSD Checklist for DSM-5; PSQI = Pittsburgh Sleep Quality Index; STAI = State Trait Anxiety Inventory.

an advance in sleep timing (~30–45 minutes), there was no significant post-treatment change in total sleep duration or sleep efficiency. Thus the subjective improvement in sleep quality was not observed in the objective sleep variables. These findings are consistent with the results of a meta-analysis reporting a larger effect size for subjective sleep reports but smaller effect sizes for objective sleep variables in response to morning bright light treatment [5].

Results for pain sensitivity changes were not consistent. On the one hand, we found that the morning bright light treatment significantly increased thermal pain threshold. On the other hand, ischemic pain threshold and ischemic pain tolerance did not significantly change. Of note, there is little consensus on the degree to which findings from laboratory-induced pain are relevant to the clinical experience of pain [41]. Results reveal a weak relationship between clinical and laboratory-induced pain, suggesting that these pain experiences represent distinct processes [42–45]. Still, reducing pain sensitivity as indexed by laboratory tasks would appear clinically important insofar as changes in pain sensitivity may reveal changes in central pain modulation.

Despite meta-analyses indicating that morning bright light treatment can significantly reduce depressive symptoms [6] and reports suggesting that light treatment may have some antianxiolytic effects [46,47], we did not observe any significant changes in depressive and anxiety symptoms. The lack of significant change may have been due to subjects in this sample reporting relatively low levels of depressive and anxiety symptoms on average (baseline CES-D 10 < 10 and baseline STAI = 35) (Table 2). However, PTSD symptoms significantly decreased during the light treatment, which is consistent with a recently completed study (clinical trial NCT00701064).

As expected from other studies of the effects of morning bright light [48], the dim light melatonin onset advanced, or shifted earlier, by approximately 50 minutes. This result suggests that the treatment altered circadian timing in a meaningful way. This result also offered the possibility that other treatment effects may have been at least partly wrought via changes in this physiological mechanism. The pattern of correlations among the baseline to post-treatment changes in outcomes and DLMO support this notion. That is, shifts to earlier circadian timing (phase advances) were related to improvements in pain intensity, pain behavior, pain interference, anxiety symptoms, and insomnia symptoms, with correlation coefficients of at least $r = 0.30$. Far from definitive given the small sample and study design, these findings at least support the notion that circadian timing changes may represent a treatment mechanism through which bright light treatment affects improvement in pain, mood, and function [18].

There were several limitations of the study. The sample size was small, due in part to limited funding and also due to difficulties in recruiting veterans from the community for an intensive 53-day protocol. The study also lacked a placebo control condition, as in this open trial all available resources were aimed at examining the acceptability, feasibility, and initial efficacy of the morning bright light treatment. Thus, some of the positive effects of morning bright light treatment observed here could be placebo effects in response to participating in a study holding the possibility of benefits. We evaluated this possibility by examining correlations between participant expectations of treatment benefit (recorded before treatment) and baseline to post-treatment outcome changes. Only two of 17 correlations were at least $r = 0.30$. These findings do not support the notion that placebo (via expectancy) effects were largely responsible for treatment gains. Further, we found significant effects on two separate assessment methods, subjective pain reports and one pain sensitivity metric, which is especially noteworthy considering our small sample size. We also observed that when present, the benefits of light treatment generally continued to increase from six days to 13 days of light treatment, which is consistent with the antidepressant time course of morning bright light treatment [6] and suggests that continuing the morning bright light treatment for more than two weeks could yield larger treatment effects.

Conclusions

Results from this open trial suggest that a home-based morning bright light treatment, one hour per day,

starting at habitual wake time, is a feasible and acceptable treatment protocol for US military veterans with chronic low back pain. As a proof of concept study, our results also support the efficacy of morning bright light treatment for improving pain, function, mood, and subjective sleep. Finally, preliminary findings suggest that circadian timing changes could represent an active mechanism of morning bright light treatment for pain and function. Thus, in conclusion, more research studies, with larger sample sizes and a placebo control condition, should further explore morning bright light as a potentially effective innovative treatment for chronic pain populations.

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