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Predictors of Cognitive Behavioral Therapy for Insomnia (CBTi) Outcomes in Active-Duty U.S. Army Personnel

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Cognitive behavioral therapy for insomnia (CBTi) is well established as the first-line treatment for the management of chronic insomnia. Identifying predictors of response to CBTi should enable the field to efficiently utilize resources to treat those who are likely to respond and to personalize treatment approaches to optimize outcomes for those who are less likely to respond to traditional CBTi. Although a range of studies have been conducted, no clear pattern of predictors of response to CBTi has emerged. The purpose of this study was to examine the impact and relative importance of a comprehensive group of pretreatment predictors of insomnia outcomes in 99 active-duty service members who received in-person CBTi in a randomized clinical trial. Results indicated that higher levels of baseline insomnia severity and total sleep time predicted greater improvements on the Insomnia Severity Index (ISI) following treatment. Higher depression symptoms and a history of head injury predicted a worse response to treatment (i.e., smaller improvements on the ISI). Clinically meaningful improvements, as measured by the reliable change index (RCI), were found in 59% of the sample. Over and above baseline insomnia severity, only depressive symptoms predicted this outcome. Future studies should examine if modifications to CBTi based on these predictors of response can improve outcomes.

Keywords: insomnia; cognitive behavioral therapy; military; randomized clinical trial; predictors of outcomes

CHRONIC INSOMNIA IS DEFINED by the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (*DSM-5*; American Psychiatric Association, 2013) as difficulties falling and/or staying asleep that occur at least three times per week, resulting in daytime consequences and significant distress. Insomnia is one of the most significant risk factors for depression, substance abuse, anxiety, and suicide in the general population (e.g., Taylor, Lichstein, & Durrence, 2003) and for posttraumatic stress disorder (PTSD), depression, and anxiety in active-duty service members (Gehrman et al., 2013). Cognitive behavioral therapy for insomnia (CBTi) is well established as the first-line treatment for the management of chronic insomnia as indicated by practice guidelines published by the National Institutes of Health (National Institutes of Health, 2005), American College of Physicians (Qaseem, Kansagara, Forciea, Cooke, & Denberg, 2016), American Academy of Sleep Medicine (Morgenthaler et al., 2006), European Sleep Research Society (Riemann et al., 2017), British Association for Psychopharmacology (Wilson et al., 2010), and the U.S. Department of Veterans Affairs and Department of Defense (VA/DoD) Clinical Practice Guidelines (Management of Chronic Insomnia Disorder and Obstructive Sleep Apnea Work Group, 2019).

Active-duty service members face a myriad of unique circumstances that negatively impact sleep and put them at increased risk for developing insomnia. Those circumstances include, but are not limited to, overnight and rotating shifts, frequent transitions between units and station assignments, and early-morning start times (e.g., Bramoweth & Germain, 2013; Pruiksma et al., 2018). Approximately 20% of service members report clinically

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significant insomnia (Taylor et al., 2016) compared to 10% of the general population (Morin, LeBlanc, Daley, Gregoire, & Merette, 2006). Insomnia is typically comorbid with physical and mental health problems (e.g., Kelly, Robbins, & Martin, 2019; Taylor et al., 2016). Despite these unique circumstances that can impact sleep, studies have found CBTi to be effective in active-duty military populations. One retrospective cohort study of 98 service members (94% in the U.S. Army) treated in a military sleep disorder clinic found improvements on sleep-diary-assessed sleep variables and self-reported insomnia severity, particularly among service members who received four or more sessions of CBTi (Lee et al., 2019). A randomized clinical trial compared in-person CBTi (n = 34) to Internet CBTi (n = 33) and to a waitlist control (n = 33) in a U.S. Army population (Taylor, et al., 2017). Internet and in-person CBTi performed significantly better than the minimal contact control on sleep-diary-assessed sleep variables, self-reported insomnia severity, and dysfunctional beliefs and attitudes about sleep. In-person CBTi was more effective than Internet CBTi on self-reported sleep quality and dysfunctional beliefs and attitudes about sleep. A follow-on study that continued to recruit active-duty service members into in-person CBTi (n = 75) and the waitlist control (n = 76) also found that CBTi significantly reduced mental fatigue, nicotine use, and caffeine use and improved activity, motivation, and general mental health (Taylor, Peterson, et al., 2018). Contrary to hypotheses, there were not reductions in symptoms of depression, anxiety, PTSD, or hypnotic medication use.

Although evidence strongly supports CBTi, not all participants who complete the therapy obtain optimal improvements. Identifying predictors of response to CBTi should enable the field to efficiently utilize resources to treat those who are likely to respond and to personalize treatment approaches to optimize outcomes for those who are less likely to respond to traditional CBTi. Supplementary Table 1 includes a summary of previous studies that have examined predictors of response to CBTi. These studies used a variety of treatment approaches (e.g., individual, group), study designs (e.g., clinical samples, secondary analyses of randomized clinical trials), and definitions of good treatment outcome to test for various predictors of response (e.g., demographics, initial insomnia severity, treatment process). Indeed, of the nine studies included in Supplemental Table 1, over 12 different methods for operationalizing good outcomes were utilized. Although no clear pattern of predictors of response to CBTi has emerged, some studies have found that higher baseline insomnia severity (Currie, Wilson, & Curran, 2002; Espie, Inglis, & Harvey, 2001; Van Houdenhove, Buyse, Gabriëls, & Van den Bergh, 2011) and higher baseline total sleep time (especially sleep duration of $\geq$ 6 hours; Bathgate, Edinger, & Krystal, 2017) predict better insomnia treatment outcomes. Several studies have found the following variables to not be significant predictors of outcomes: gender, anxiety, depression, and post-traumatic stress symptoms (see Supplemental Table 1).

Many previous studies examining predictors of CBTi outcomes were typically (a) underpowered (i.e., small sample size relative to number of predictors tested), (b) did not include the comprehensive assessment matrix recommended by experts in the field (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006), (c) excluded patients with comorbidities, and (d) did not recruit active-duty military. The purpose of this paper was to examine the impact and relative importance of a comprehensive group of predictors of insomnia outcomes in 99 active-duty service members who received in-person CBTi as part of a larger randomized clinical trial (Taylor, Peterson, et al., 2018; Taylor et al., 2017). The larger trial used recommended assessment procedures and had minimal exclusion criteria for comorbid conditons. We hypothesized that greater baseline severity of insomnia and total sleep time would predict greater improvements in insomnia as assessed by the total score and reliable and clinically meaningful change on the Insomnia Severity Index (ISI; Morin, 1993). Based on a previous study of correlates and predictors of insomnia in the U.S. Army conducted at the same location (Taylor et al., 2016), we also examined whether a variety of demographic factors (age, gender, race, ethnicity, education, marital status, number of children), military service factors (months of service, grade, duty, number of deployments), medical factors (history of head injuries and medication use for psychiatric diagnoses, PTSD, and sleep), sleep (insomnia severity, total sleep time, sleep efficiency, dysfunctional beliefs about sleep), mental health symptoms and health-related quality of life (alcohol use, anxiety, depression, PTSD), social support, and stressful life events predicted either changes in insomnia or attainment of reliable and clinically meaningful change in insomnia.

Method

PARTICIPANTS

Participants were 99 service members stationed at Fort Hood, Texas, who were recruited between April 2012 and December 2014, assigned to in-person CBTi, and completed the posttreatment

Table 1
Sample Characteristics at Baseline ($N = 99$)

Demographic-descriptive	
Age	32.8 ± 7.6 (range = 20 - 52)
Number of children	1.6 ± 1.7 (range = 0 - 6)
Male	80 (81%)
Married	65 (66%)
Times married	
0	16 (16%)
1	58 (59%)
2	20 (20%)
3	5 (5%)
Ethnicity-Race	
Asian	3 (3%)
African-American	32 (32%)
Hispanic	14 (14%)
Caucasian	48 (48%)
Education	
High school or less	22 (22%)
Some college/associate degree	65 (66%)
College graduate	12 (12%)
Military	
Months of service	127.0 ± 85.9 (range = 20 - 367)
Military grade	
Junior Enlisted (E-1 to E-3)	13 (13%)
Non-Commissioned Officers (E-4 to E-6)	60 (61%)
Senior Non-Commissioned Officers (E-7 to E-9)	16 (16%)
Warrant Officer/Officer	10 (10%)
Military duty	
Combat arms	32 (32%)
Combat support	32 (32%)
Service support	35 (35%)
Times deployed	
0	1 (1%)
1	34 (34%)
2	34 (34%)
3	20 (20%)
4+	10 (10%)
Medical	
History of head injury	26 (26%)
Taking psychiatric and/or PTSD medications	32 (32%)
Taking sleep medications	27 (27%)
Sleep	
Insomnia Severity Index (ISI; dependent variable)	17.5 ± 4.6 (range = 4 – 28)
Sleep diary	
Sleep efficiency	71.3 ± 11.9 (range = 35.6 – 87.4)
Total sleep time	5.2 ± 1.2 (range = 1.7 - 7.2)
Short sleep duration (≤ 6 hours per night on average)	75% (74)
Dysfunctional Beliefs and Attitudes About Sleep (DBAS)	89.4 ± 27.4 (range = 19 - 145)
Symptoms and Health-Related Quality of Life	
Alcohol Use Disorders Identification Test (AUDIT)	3.4 ± 3.8 (range = 0 - 23)
Beck Anxiety Index (BAI)	13.2 ± 11.5 (range = 0 - 45)
Beck Depression Inventory-II (BDI)	13.7 ± 10.3 (range = 0 - 51)
PTSD Checklist- Military Version (PCL-M)	37.2 ± 14.1 (range = 17 - 76)
Veterans RAND 12-Item Health Survey (VR-12)	
Mental Health Subscale	42.3 ± 12.9 (range = 9.9 - 64.4)
Physical Health Subscale	42.5 ± 10.4 (range = 11.4 - 63.2)
Social Support and Stress	
Interpersonal Support Evaluation List-Short Form (ISEL)	

(continued on next page)

Table 1 (*continued*)

Demographic-descriptive	
Appraisal	12.6 ± 3.0 (range = 4 - 16)
Belonging	12.9 ± 2.9 (range = 5 - 16)
Tangible	12.8 ± 2.9 (range = 4 - 16)
PERI-Life Events Scale	10.7 ± 9.0 (range = 0 - 41)

Abbreviations: PTSD = posttraumatic stress disorder.

assessment. The sample characteristics at baseline are presented in Table 1. Participants were randomized either to immediate in-person CBTi (n = 65) or to a waitlist control period followed by in-person CBTi (n = 34). This study is a secondary analysis of data collected before and after CBTi. The methods and CONSORT chart for the larger clinical trial are described in detail elsewhere (Taylor, Peterson, et al., 2018; Taylor et al., 2017). Briefly, the inclusion criteria for the study included (a) being on active duty; (b) having at least one military deployment in or around Iraq or Afghanistan (per the fiscal year 2009 Psychological Health/Traumatic Brain Injury Research Program Request for Applications identifying a priority for research addressing "post-deployment evidence-based preventive and early intervention"); (c) diagnosis of persistent insomnia disorder (American Psychiatric Association, 2013) assessed with the Structured Clinical Interview for *DSM-5* Sleep Disorders (Taylor, Wilkerson, et al., 2018); (d) < 85% sleep efficiency on a 1-week sleep diary; (e) stable on psychotropic and hypnotic medications for at least 1 month; (f) if on continuous positive airway pressure therapy for sleep apnea (CPAP), stable for at least 1 month; and (g) correct utilization of actigraphy as documented on corresponding sleep diaries. Exclusion criteria were (a) < 3 months since returning from deployment (to ensure the duration criteria for "persistent" insomnia and not "situational/acute" insomnia); (b) hypersomnia, chronic sleep deprivation, or circadian rhythm disorders; (c) pregnancy; (d) working rotating shifts or shifts requiring that the service member report to work earlier than 6 A.M. or later than 9 P.M.; (e) suicidal risk meriting crisis intervention; and (f) serious mental health diagnosis such as bipolar disorder or psychosis.

The study was approved by the Institutional Review Boards at Brooke Army Medical Center (reviewing for the hospital at Fort Hood where the study was conducted), the University of Texas Health Science Center at San Antonio, and the University of North Texas. The study was also approved by the U.S. Army Medical Research and Materiel Command (now the U.S. Army Medical Research and Development Command) Human Research Protection Office.

MEASURES

Below are brief descriptions of measures that are described in more detail in the original and secondary outcome publications (Taylor, Peterson, et al., 2018; Taylor et al., 2017) and in a publication of the Common Data Elements used in the Consortium to Alleviate PTSD (Barnes et al., 2019). Most have well-established reliability and validity and those without are noted.

Predictor Variables

Demographics, military service characteristics, and health interview forms. Demographics, military service characteristics, and health information were collected as part of a standard battery (Barnes et al., 2019) assessing standard demographics (age, gender, race, ethnicity, education, marital status, number of children), military service information (military grade, service length, number of deployments, typical duty, number of times deployed) and health-related information (history of head injury, hypnotic and other medication usage).

Sleep diaries. Daily sleep diaries were used to derive average sleep parameters to assess inclusion criteria. Baseline average total sleep time and sleep efficiency (total sleep time/time in bed x 100) were examined as predictor variables. Sleep diaries are significantly correlated with polysomnography (Means, Edinger, Glenn, & Fins, 2003) and are better than single-point retrospective estimates of sleep.

Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS; Morin, Vallières, & Ivers, 2007). The DBAS is a 16-item measure that assesses beliefs and attitudes about sleep. Items are rated on a 10-point Likert scale ranging from "strongly disagree" to "strongly agree," with higher scores indicating more maladaptive beliefs. The DBAS exhibited good internal consistency (α = .80) in the current sample.

Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, De la Fuente, & Grant, 1993). The AUDIT is a 10-item measure of alcohol consumption that has become harmful to health, with total scores ranging from 0–40, where higher

scores indicate a greater likelihood of an alcohol use disorder. The AUDIT has a complicated scoring algorithm in which participants answer varying numbers of items depending on how they answer earlier ones, precluding the ability to meaningfully calculate reliability.

Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988). The BAI is a 21-item measure of anxiety, with the degree of symptom severity within the past week rated on a 4-point Likert scale ranging from "not at all" to "severe." Total scores range from 0–63, where higher scores indicate greater anxiety symptoms. The Cronbach's alpha was .93 at baseline.

Beck Depression Inventory-II (BDI; Beck, Steer, & Brown, 1996). The BDI is a 21-item measure of symptoms of depression, with the degree of disturbance attributable to symptom severity within the past week rated on a 4-point Likert scale ranging from "no disturbance" to "maximal disturbance" Total scores range from 0–63, where higher scores indicate greater depressive symptoms. The Cronbach's alpha for the BDI was .93 at baseline.

PTSD Checklist-Military Version (PCL-M; Weathers, Litz, Herman, Huska, & Keane, 1993). The PCL-M is a 17-item measure of symptoms of *DSM-IV*-defined PTSD indexed to military experiences, with total scores ranging from 17 to 85, where higher scores indicate greater PTSD symptoms. Internal consistency was high (α = .94) at baseline.

Veterans RAND 12-Item Health Survey (VR-12; Kazis, Miller, et al., 2006). The VR-12 was designed to assess health-related quality of life and was derived from the Veterans RAND 36 Item Health Survey. The VR-12 has been widely used in the Veterans Health Administration. The changes to the survey have increased the overall precision of the instrument and the discriminant validity of the physical and mental component summary scales (Kazis, Nethercot, et al., 2006). The VR-12 utilizes a scoring algorithm that produces a physical component summary score and mental component summary score that are scaled from 0 to 100, with higher scores reflecting greater physical and mental health.

Interpersonal Support Evaluation List–Short Form (ISEL; Cohen & Hoberman, 1983). The ISEL measures multiple dimensions of perceived social support. The short form is a 12-item measure that asks participants about their relationships with other people in their lives in three specific areas: Appraisal (perceived availability of advice and/or guidance), Belonging (perceived availability of empathy, concern, and acceptance from others), and Tangible (perceived availability of material or financial assistance from others). Responses are given on a 4-point scale with anchors, ranging from 1 (*definitely false*) to 4 (*definitely true*). Higher scores indicate more perceived social support within each respective domain. Coefficient alphas were acceptable for the Appraisal (α = .70), Belonging (α = .80), and Tangible (α = .71) subscales.

PERI Life Events Scale (Dohrenwend, Askenasy, Krasnoff, & Dohrenwend, 1978). The PERI Life Events Scale is a 102-item measure, designed to assess the number and severity of low and moderate-magnitude stressful life events that a person has experienced in the previous 6 months. Military subject-matter experts selected the 10 most relevant items for the purposes of this study in a military population. Items are scored on a 7-point Likert scale ranging from "not stressful at all" to "extremely stressful" and summed for a total score, with higher scores reflecting greater distress due to life stressors. Cronbach's alpha was .71 at baseline.

Outcome Variable

Insomnia Severity Index (ISI; Morin, 1993). The ISI is a 7-item measure that assesses perceived severity of insomnia. Each item uses a 4-point Likert scale from 0 (*not at all satisfied*) to 4 (*very much satisfied*). The items sum to produce a total score ranging from 0–28, with higher scores indicating greater severity. Clinically significant insomnia was indicated by a score of $\geq$15 (Morin, Belleville, Bélanger, & Ivers, 2011). The Cronbach's alpha was .76 at baseline.

INTERVENTION

Cognitive Behavioral Therapy for Insomnia (CBTi)

The CBTi intervention is detailed elsewhere (Taylor et al., 2017) and the treatment manual is available on-line (Taylor et al., 2019). Briefly, CBTi consisted of six weekly 60-minute sessions and included stimulus control, sleep restriction, sleep hygiene, relaxation training, problem solving, and cognitive restructuring.

Data Analytic Approach

The primary outcome variable was change from baseline to posttreatment on the ISI. It is well known that the naïve correlation between baseline and change has a spurious negative component because measurement error in the baseline is also part of the change score. McNemar (1958) and Blomqvist (1977) independently developed methodologies to

essentially correct this correlation for attenuation (unreliability) and estimate the association of initial level with true change. In these data, the negative correlation between baseline ISI and ISI change was larger than any other variable. We therefore began by examining this correlation with correction for unreliability. We then included baseline ISI as a covariate in all subsequent analyses.

To determine which baseline variables best predicted change on the ISI, we ran stepwise regression models with all of the variables described above as predictor variables (see Table 1). The p value to enter was set at a generous .50, but the p value to stay was .05. Given the large number of predictors, statistical significance in the final selected models was evaluated with adjusted p values using the Benjamini and Hochberg (1995) procedure to control for the False Discovery Rate at an alpha of .05. The regression analyses were done using software in the SAS 9.4 library (PROCs GLMSELECT, GLM, REG). For clarity, we refer to the overall results for these models as "incremental R^2" to remind readers that baseline ISI was included as a covariate in all models, and the analyses examined predictor effects over and above the baseline value.

Next, to examine clinical significance, we examined the same variables above as predictors of the reliable change index (RCI; Jacobson & Truax, 1991). These analyses used logistic regression and included baseline ISI as a covariate. The RCI is a function of the pretreatment standard deviation and the reliability of the assessment. The RCI provides a benchmark against which to compare whether an individual's change score over the course of treatment is statistically greater than a difference that could have occurred solely due to measurement error. That is, it tells us whether a person's change reflects more than mere fluctuations of an imprecise instrument. Patients exceeding the RCI are typically thought to have experienced clinically meaningful change on the outcome of interest; as such, in addition to the overall change scores, we were also interested in variables that predicted this outcome. In this sample, the baseline alpha coefficient for the ISI total was .76 with standard deviation 4.6, which at the 5% level of confidence (i.e., $z = 1.96$) defines the RCI as 6.3, i.e., 7 points or more.

After selecting final models for each outcome (i.e., ISI change and RCI), we then sought to determine predictor importance within each model using a dominance analysis (Azen & Budescu, 2003). Dominance analysis is particularly useful in helping assess the relative importance of individual predictors when there is a high level of multicollinearity between predictors, as in the current study. Functionally, as a first step, a dominance analysis is conducted in multiple or logistic regression by estimating the R^2 values of all possible combinations of predictors. One then constructs a matrix table to examine how much each variable adds to the R^2 of each of the models that did not previously include it. Such a table allows one to see how much, on average, any given variable contributes across all or a within a particular subset of models, thereby providing additional information beyond the conventional interpretation of increases in R^2 (i.e., variables that increase R^2 more than others are deemed to be more important). However, while the average increase in R^2 provides some clue as to what variables are more important than others across all or a subset of the models, it is possible (and, in fact, likely) that many of the variables may produce increases in R^2 that are comparable to one another. Therefore, we employed a second step involving dominance analysis (Azen & Budescu, 2003), where one can examine each pair of variables and compare the proportion of times that a variable, X, increases R^2 relative to another variable, Y, when they are each added separately to all of the models that did not previously include either of them. These proportions are arranged into what is called a "dominance matrix," which provides nuanced information about each variable's relative importance compared to another one. Though different levels and types of dominance are discussed in the extant literature, we focused on two types: complete and partial dominance. Variable X was said to be completely dominant over Variable Y if it increased R^2 more than Variable Y 100% of the time. Variable X was said to be partially dominant if it increased R^2 more than Variable Y 51% to 99% of the time, and neither variable was considered dominant nor submissive if they each increased R^2 more than the other did exactly 50% of the time. The dominance analyses were done using a downloadable set of SAS macros (available at http://sites.uwm.edu/azen/damacros).

Results

BASELINE INSOMNIA SEVERITY AND CHANGE

The raw correlation between baseline ISI and ISI change was -.39 ($p < .0001$). We used the method described by McNemar (1958) to estimate the attenuation-corrected correlation between initial value and true change (i.e., correct for change due to regression to the mean). The correction uses the pre- and posttreatment reliabilities and standard deviations of the ISI to correct the observed correlation. In this sample, the alpha coefficients

were .76 at baseline and .92 at posttreatment, with standard deviations of 4.6 and 6.6, respectively. The corrected estimate of the correlation between the initial level and true change was reduced to -.29. Efron's bootstrap with 1,000 replications estimated the standard error of this adjusted correlation as .108. A normal curve test based on this estimate and the confidence limits of the bootstrap sampling distribution both yielded $p = .006$, indicating that higher baseline ISI was associated with larger pre-post improvement over and above regression to the mean.

PREDICTING INSOMNIA SEVERITY CHANGE SCORES

A stepwise regression model predicting ISI change scores (post-pre) was significant, $F(4, 93) = 9.25$, $p < .0001$, incremental $R^2 = .24$. Over and above baseline ISI, there were four baseline predictors in the final selected model with unadjusted $p < .05$, three of which remained significant after false discovery rate (FDR) p-value adjustment for 27 variables: depression symptoms ($b = 0.22$, $t[93] = 3.44$, $p = .0009$, FDR $p = .024$); total sleep time ($b = -1.54$, $t[93] = -3.20$, $p = .0019$, FDR $p = .026$), history of head injury ($b = 3.76$, $t[93] = 3.02$, $p = .003$, FDR $p = .030$), and male gender ($b = 3.88$, $t = -2.68$, $p = .009$, FDR $p = .059$). Improvement on the ISI means the score is decreasing, so negative coefficients indicate improvement and positive values indicate worsening. Thus, higher total sleep time and being male (at $p = .06$) were associated with improvement in insomnia over the course of treatment. In contrast, having a history of head injury and higher depression severity at baseline were associated with less improvement in insomnia.

We then ran several regression models using all possible subsets of these four predictors and used the resulting R^2 estimates from each model to conduct a dominance analysis. Results of this analysis are presented in Tables 2 and 3. Table 2 shows the increase in R^2 resulting from adding the variable in the column to a model that already includes only the variables listed in the row and baseline ISI. It also shows the average increase in R^2 due to the column variable when that variable is added to models with one, two, and three previously entered variables, as well as the average increase in R^2 due to the column variable across all

Table 2
Dominance Analysis for Models Predicting Insomnia Severity Index Change Scores

		R^2 increase due to adding only:			
Subset model	R^2	BDI	TST	HHI	Male
Baseline ISI total only	15.5%	8.6%	4.6%	5.3%	4.3%
Depression (BDI)	8.6%	.	5.4%	5.5%	2.8%
Total sleep time (TST)	4.6%	9.4%	.	5.2%	5.9%
History of head injury (HHI)	5.3%	8.8%	4.5%	.	4.9%
Male gender (Male)	4.3%	7.1%	6.2%	5.9%	.
$k = 1$ average		8.4%	5.3%	5.5%	4.5%
BDI, TST	14.0%	.	.	5.4%	4.1%
BDI, HHI	14.1%	.	5.3%	.	3.3%
BDI, Male	11.4%	.	6.7%	6.0%	.
TST, HHI	9.8%	9.6%	.	.	6.5%
TST, Male	10.5%	7.6%	.	5.8%	.
HHI, Male	10.2%	7.2%	6.1%	.	.
$k = 2$ average		8.1%	6.0%	5.7%	4.6%
BDI, TST, HHI	19.4%	.	.		4.7%
BDI, TST, Male	18.1%	.	.	5.9%	.
BDI, HHI, Male	17.4%	.	6.7%	.	.
TST, HHI, MALE	16.3%	7.7%	.	.	.
Overall Average		8.2%	5.7%	5.6%	4.6%

Note. BDI = Beck Depression Inventory; ISI = Insomnia Severity Index; HHI = history of head injury; TST = total sleep time. All models included baseline ISI total. The R^2 column is the incremental R^2 from the model adding only the variables on the corresponding row to baseline ISI. Columns represent additional contributions to the explained variance gained by the addition of the column variable to the row model. Rows with the designation "k" describe the average of the additional contributions to the variance for that particular column variable across all of the row models for that particular block. The label "k" is the number of predictors in the model other than the focal predictor. "Overall average" is the average increase in R^2 across all the subset models. Higher values indicate that the column model increases R^2 more on average than columns with lower values.

Table 3
Dominance Matrix for Models Predicting Insomnia Severity Change

	Depression severity	Total sleep time	History of head Injury	Male gender
Depression severity	–	100%	100%	100%
Total sleep time	0%	–	50%	75%
History of head injury	0%	50%	–	75%
Male gender	0%	25%	25%	–

Note. Numbers represent the proportion of subset models excluding both the row and the column variables in which the inclusion of the row variable results in a larger increase in R^2 than does the inclusion of the column variable.

subsets. For the most part, the results are consistent whether the predictor is entered early or late. Baseline depression is clearly the most important predictor, followed by history of head injury and total sleep time, which are comparable in strength. Male gender was the weakest, with all incremental values below 5%.

As noted in the data analytic plan, while the average increase in R^2 provides some clue as to what variables are more important than others across all the subset models, the values in Table 2 can be used to produce a dominance matrix (Table 3) that provides nuanced details about the proportion of times a variable, X, increases R^2 relative to another variable, Y, when they are each added separately to models that did not previously include them. For all pairwise comparisons of the four significant predictors, there were four models for each predictor in which neither variable in a given pair was included. Table 3 shows the proportion of times that the variable in the row increased the value of R^2 more than did the variable in the column. As can be seen, baseline depression scores were completely dominant over the other three predictors, increasing R^2 more than the other variables 100% of the time. Total sleep time and history of head injury were partially dominant over male gender, increasing R^2 in three of the four models that did not include either, and neither dominant nor submissive to each other. Male gender was the least important predictor.

RESPONSE AND REMISSION

Response was defined by the RCI definition of having at least a 7-point decrease in ISI scores at posttreatment. In the current sample, 59% of the patients exceeded this threshold. Using the same predictors and criteria to enter ($p = .50$) and remain in the model ($p = .05$), a stepwise logistic regression model predicting RCI selected only baseline depression ($b = -.094$, Wald $\chi^2 = 9.84$, $p = .002$). Remission was defined as being below the clinical insomnia cutoff of an ISI score of less than 15 at posttreatment. In the current sample, 76% of the patients were considered to be in remission at posttreatment.

Discussion

Insomnia is highly prevalent in military populations and typically presents with comorbid physical health and mental health problems (Kelly et al., 2019; Taylor et al., 2016). CBTi is the first-line recommended treatment for insomnia. This study utilized psychometrically sound assessments to examine predictors of response to CBTi in a large sample of active-duty military personnel ($n = 99$) with a range of comorbidities. This study found that higher baseline insomnia severity was associated with a better response to CBTi over and above regression to the mean. After controlling for baseline insomnia severity, this study also found that higher levels of baseline total sleep time predicted a better response (i.e., larger improvement on ISI), while higher depression symptoms and a history of head injury predicted a worse response (i.e., less improvement on ISI). Dominance matrix analyses indicated that baseline depression severity was the most important predictor, followed by total sleep time and head injury, which were comparable. In addition, men had better ISI outcomes, but that was the weakest predictor and its significance fell to $p = .06$ after adjustment for multiple tests. Clinically meaningful improvement, as measured by the RCI, was reported by 59% of the sample. Over and above baseline ISI, the only significant predictor was higher depression, an unsurprising result given that the RCI is a dichotomized version of ISI change and the depression measure was the strongest predictor of the full-scale ISI change criterion over and above baseline ISI total score.

Baseline depression symptoms were the most important predictor of CBTi outcomes. This is consistent with findings of one study of CBTi conducted in a primary care setting (Espie et al., 2001) but in contrast to other studies that found depression was not a significant predictor of CBTi treatment outcomes (Currie et al., 2002; Gagné & Morin, 2001; Tremblay, Savard, & Ivers, 2009; See Table 1). It is well established that insomnia and

depression are best viewed as comorbid conditions, rather than considering insomnia as only a secondary symptom of depression. This is because insomnia increases risk for depression, typically does not remit when depression is treated, and residual insomnia increases risk for relapse. Notably, treating insomnia with CBTi results in significant small to medium effects in comorbid depression symptomatology (Taylor & Pruiksma, 2014). When implementing CBTi for patients with comorbid insomnia and depression, behavioral activation can be logically integrated with stimulus control instructions and sleep restriction by helping the patient identify pleasant and meaningful activities to engage in during their bedtime routine, during nighttime awakenings, and to help them wake up and get out of bed at the same time every morning. More suggestions for treating comorbid insomnia and depression are discussed by Manber and Carney (2015) and by Martell, Dimidjian, and Herman-Dunn (2010). Further research is needed to identify how best to treat insomnia and depression when they are comorbid.

These findings replicated previous results showing that baseline insomnia severity predicted significant decreases in insomnia following in-person treatment with CBTi (Currie et al., 2002; Espie et al., 2001; Van Houdenhove et al., 2011). Those with higher insomnia severity at baseline have more room to improve, but they may not end with scores as low as those who begin treatment with lower insomnia severity at baseline. This finding is important to note, as it may be in contrast to clinician expectations that individuals with worse insomnia may be less likely to improve. These data could be important for patients with severe insomnia, who should understand that they are likely to benefit from CBTi. That observation could increase buy-in and adherence to treatment procedures (e.g., maintaining a sleep diary or following a sleep schedule).

Our finding that higher baseline total sleep time predicts good outcomes is consistent with Bathgate et al. (2017), who found that individuals with normal sleep duration (i.e., >6 hours) were more likely to respond to treatment. Taken together, the findings that baseline insomnia severity and total sleep time are both associated with improvements in insomnia may seem contradictory. However, it is important to recognize that it is possible to have severe insomnia (i.e., difficulties falling and staying asleep) while still experiencing a normal total sleep time (i.e., >6 hours) but with sleep that is fragmented over a longer period of time in bed (e.g., sleeping 7 hours over the course of 9 hours in bed). It is hypothesized that there are two phenotypes of insomnia: insomnia with normal sleep duration and insomnia with short sleep duration.

Insomnia with short sleep duration is characterized by physiological hyperarousal and a persistent, unremitting course which can prove to be more difficult to treat (Vgontzas & Fernandez-Mendoza, 2013). Our finding that longer total sleep time predicts better response to CBTi is consistent with this hypothesis, although 75% ($n = 74$) of the sample had short sleep duration (< 6 hours per night on average) at baseline. It may also be that individuals with insomnia and short sleep duration experience sleep state misperception, in which they feel they are awake when they are in light stages of sleep. For example, one participant reported an average total sleep time of 1.7 hours per night, which is likely to be sleep state misperception; however, this was not assessed in this study with polysomnography, so cannot be verified. Sleep state misperception is a different condition from insomnia or, when it is comorbid with insomnia, may impede accurate self-monitoring of sleep. Vgontzas and Fernandez-Mendoza (2013) suggest that individuals with insomnia with short sleep duration may respond better to treatments that aim to decrease cognitive-emotional hyperarousal (e.g., rumination) and alter sleep misperception (e.g., sleep restriction, cognitive restructuring, behavioral experiments, or emotion regulation techniques). Research is needed to examine how best to treat insomnia with a short sleep duration and sleep state misperception.

No previous study has examined history of head injuries as a predictor of CBTi treatment outcome. This is important to consider, since 30%–85% of individuals who experience TBI report sleep disturbances (e.g., Wickwire et al., 2016). In the current study, 26% reported a history of head injuries, which is likely a higher rate than in civilian populations. Currently, limited research has examined the efficacy of CBTi among individuals who have experienced head injuries. Research is also needed to identify the mechanisms through which head injuries impede CBTi outcomes (Wickwire et al., 2016). These findings would guide modifications to improve treatment outcomes in this population.

The finding that 59% of the sample attained reliable change (using a decrease of ≥7 on the ISI) is higher than the 20%–26% rate found in active-duty service members treated in a military sleep disorders clinic (Lee et al., 2019) and the 47% rate found in veterans with PTSD-related insomnia (El-Solh et al., 2019), both of which used a less stringent criteria (decrease of ≥6 on the ISI) to operationalize meaningful change. The rate of

change in insomnia in this study is similar to the rate found in a community sample with chronic pain (57%), even though a different measure was used to assess change (i.e., Currie et al., 2002). While this rate of reliable and clinically meaningful change is encouraging, especially alongside findings that CBTi improves insomnia, future studies are needed to find ways to increase the proportion of individuals who will attain clinically meaningful benefits from CBTi.

LIMITATIONS

Replication of these results will increase confidence in the importance of the predictors identified. Although this is one of the larger studies to examine predictors of CBTi outcomes (see Supplemental Table 1), the sample size still limits statistical power for the number of predictors examined. Furthermore, the multiple testing methods used do capitalize on chance, although we attempted to correct for multiple tests. Another limitation of this study is that the definition of positive outcome was based solely on retrospective self-report using the ISI and not on objective measures of sleep (e.g., polysomnography) that have been used in other studies. However, we chose to focus this study on the ISI for two reasons. First, the ISI is the most commonly used and clinically relevant self-report questionnaire of insomnia. Second, we wanted to minimize the potential for statistical error, given that we had a number of predictor variables based on previous research. Future directions in the field include determining recommended definitions of good outcomes, which could help to identify more consistent predictors of outcome. Future directions also include examining the "insomnia identity," or the conviction that one "has insomnia" as a relatively permanent personality trait, as a predictor of treatment response (Lichstein, 2017). In addition to addressing the shortage of providers trained in delivering CBTi, future studies are needed to identify patients with insomnia who may be more likely to benefit from CBTi or from versions that have fewer and shorter sessions (i.e., Brief Behavioral Treatment for Insomnia; Troxel, Germain, & Buysse, 2012) and self-management approaches to insomnia treatment, such as mobile apps that have been piloted in a veteran population (Reilly et al., 2019).

CONCLUSIONS

The current study adds to the growing research into predictors of good response to CBTi. Among active-duty service members receiving CBTi, this study found that higher levels of baseline insomnia and total sleep time predicted better response (i.e., larger improvements on ISI). Higher baseline depression and a history of head injury predicted worse response (i.e., less improvements on ISI) in insomnia. Men had better outcomes, but that result needs replication. Future studies should examine if strategies for addressing predictors of poor response can improve outcomes in order to further alleviate the burden of insomnia and associated symptoms.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.beth.2020.02.001.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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