The Effects of App-Delivered Cognitive Behavioral Therapy for Insomnia (CBT-I) on Sleep Quality, Dysfunctional Beliefs, and Sleep Hygiene

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ABSTRACT. Sleep quality is correlated with physical and mental health and is an important target for overall well-being. CBT-I is an evidence-based strategy to improve sleep quality; however, shortage of qualified providers; logistical issues such as cost, travel, and time; privacy concerns; and a desire to resolve symptoms on one’s own limit access to CBT-I. Compared to traditional face-to-face or web-based delivery of CBT-I, app-delivered CBT-I may be an efficacious alternative capitalizing on the portability, privacy, and accessibility of mobile phones. The present study examined the effectiveness of the CBT-I Coach for educating participants about the importance of healthy sleep practices and dysfunctional beliefs about sleep and targeted sleep. The use of the CBT-I Coach resulted in significant improvements in sleep quality, dysfunctional beliefs about sleep, sleep hygiene behaviors, and sleep efficiency. This study supports the use of CBT-I Coach as an effective intervention for improving sleep quality.

Keywords: sleep, technology, mobile applications, cognitive behavioral therapy for insomnia

Sleep quality has been well-researched and supported as a predictor of physical and mental health (Ohayon et al., 2017). In 2016, The National Sleep Foundation provided an evidence-based set of recommendations regarding indicators of good sleep quality. Across the 277 studies included in the review, shorter sleep onset latencies, fewer awakenings, and higher sleep efficiency were indicators of good sleep quality across the lifespan (Ohayon et al., 2017). In contrast, poor sleep quality has been linked to a myriad of adverse consequences including increased stress responsivity, cognitive, memory, and performance deficits, impairment in emotion regulation, and increases in negative emotions (Medic et al., 2017; O’Leary et al., 2016). Poor sleep quality is also linked to long-term physical health difficulties including hypertension, cardiovascular disease, and weight-related issues (Medic et al., 2017). There is evidence that sleep disturbances and comorbid psychological and medical diagnoses have a cyclical influence such that sleep problems lead to greater decline in general and psychological health, which in turn worsens sleep problems (Kaplan & Harvey, 2014).

Cognitive behavioral therapy for insomnia (CBT-I) is a psychological treatment comprised of sleep hygiene strategies including stimulus control, relaxation, and cognitive restructuring of dysfunctional beliefs about sleep. CBT-I posits that maladaptive beliefs about sleep are critical targets in treatment (Kaplan & Harvey, 2014). A randomized control trial conducted by Eidelman et al. (2016) found that individuals who participated in CBT-I had a significant decrease in dysfunctional beliefs about sleep and had reduced insomnia symptoms and impairment at both post-treatment and follow-up when compared to behavioral or cognitive therapy alone. A meta-analysis conducted by Geiger-Brown et al. (2015) found that CBT-I improved subjective sleep quality post-treatment, reduced sleep onset latency, improved total sleep time, and increased sleep efficiency among those with comorbid diagnoses, and treatment effects were stable at follow-up.
However, several factors limit access to traditional CBT-I, including shortage of qualified providers; logistical issues such as cost, travel, and time; privacy concerns; and a desire for self-help (Manber et al., 2015; Miner et al., 2016). These limitations have led to finding ways to increase access to treatment while still retaining effectiveness (Manber et al., 2015). Researchers have emphasized the need to disseminate CBT-I in ways other than traditional face-to-face individual therapy sessions (Blom et al., 2015). Compared to face-to-face delivery of psychological care, technology enables expanded access to mental health services, psychoeducational information, and self-management tools with little to no professional involvement (Miner et al., 2016). Similarly, technology-based interventions for insomnia decreased sleep difficulties and reduced insomnia severity when compared to traditional care and control groups (Blom et al., 2015; Kaldo et al., 2015; Miner et al., 2016).

Although internet-delivered treatments are beneficial, mobile phone apps may have an even broader reach. Interventions involving smartphones, including mobile apps, are readily accessible as smartphone usage has steadily increased with over three-quarters (81%) of American adults currently owning smartphones (Pew Research Center, 2019). Of the age cohorts surveyed, young adults between the ages of 18–29 accounted for the largest share of smartphone ownership, reporting that 96% own a smartphone (Pew Research Center, 2019). App-delivered treatment could potentially exceed the advantages of internet-delivered treatment because mobile phones are portable, private, and usually with the person at all times (Horsch et al., 2017). Furthermore, app-delivered interventions have the potential to be less structured, less time intensive, and have reduced to no professional contact while still maintaining effectiveness. Researchers have demonstrated that app-delivered interventions are both feasible and efficacious (Babson et al., 2015; Horsch et al., 2017).

Limitations identified in previous research studies on technology-delivered interventions call for new approaches to examine the efficacy of app-delivered CBT-I. For example, Horsch et al. (2017) observed no change in dysfunctional beliefs about sleep, a major theoretical component in the maintenance of sleep disturbance (Kaplan & Harvey, 2014), due to the Sleepcare app having no clear cognitive component or stimulus control exercise (Horsch et al., 2017). Although researchers have demonstrated the effectiveness of internet-based interventions on reducing insomnia symptoms (Blom et al., 2015; Kaldo et al., 2015) and that smartphone apps can improve insomnia, PTSD, depression, and anxiety symptoms (Donker et al., 2013; Horsch et al., 2017; Miner et al., 2016), there is a need for further investigation into the effect of mobile app-delivered CBT-I in a nonclinical population.

**Current Study**
The CBT-I Coach is an app-based CBT-I approach developed by the U.S. Department of Veterans Affairs (VA) to be used as a companion to face-to-face CBT-I treatment. The CBT-I Coach app has not been evaluated outside of this context with a nonclinical population. The intervention being tested includes one face-to-face meeting with a brief psychoeducational component at the start of the intervention period paired with participants’ use of the CBT-I Coach. The aim of the current study was to test the effectiveness of the CBT-I Coach in facilitating growth in participants’ understanding of the importance of healthy sleep practices, dysfunctional beliefs about sleep, and sleep quality. It was hypothesized that, at the completion of the study, individuals would endorse fewer dysfunctional beliefs about sleep, engage in more sleep hygiene practices, and report better sleep quality when compared to pretest scores.

1. The intervention would result in sleep quality improvement from pretreatment to posttreatment as reported on the Pittsburgh Sleep Quality Index.
2. The intervention would result in decreased dysfunctional beliefs about sleep as measured on the Dysfunctional Beliefs about Sleep Scale from pretreatment to posttreatment.
3. The intervention would result in increased healthy sleep behaviors as measured on the Sleep Hygiene Practice Scale from pretreatment to posttreatment.
4. The intervention would result in increased sleep efficiency from pretreatment to posttreatment as measured through the daily sleep diary entries.

**Method**

**Participants**
Participants were recruited from a midsized Midwestern university during the academic year. Eligible participants were smartphone owners, over the age of 18, and not currently in treatment for sleep difficulties. Participating psychology faculty
members made announcements about the opportunity to participate in the study to students enrolled in undergraduate psychology courses. Participants were awarded course credit points set at the professors’ discretion. All participants who completed the study were entered into a gift card drawing. A total of 41 participants enrolled in the study. Participants’ ages ranged from 18–62 years with a mean age of 22 (SD = 9.42) years and included 13.6% first-year students, 45.5% sophomores, 27.3% juniors, and 13.6% seniors. Most participants were women (77%), and 23% were men. During the study period, 19 participants withdrew due to not consenting to text messaging, missing more than 2 out of 7 sleep diaries per week, absence at the in-person meeting, and/or incomplete or missing posttreatment surveys. Therefore, 22 out of 41 participants completed the study and were included in the final sample.

Materials

Demographic Questionnaire

Participants completed a demographic questionnaire assessing age, gender, and class standing.

Sleep Diary

All participants completed a daily sleep diary throughout the four-week study. The use of sleep diaries, especially in electronic form, were intended to capture experiences close to the time of occurrence, thereby limiting memory lapses and bias, producing more accurate and reliable information than self-report sleep questionnaires alone. Participants completed sleep diaries daily for the duration of the study. The sleep diaries addressed bedtime, sleep onset latency, number of awakenings, wake time, and quality of sleep. During the pretreatment week, participants were sent a link to an online sleep diary each morning to submit the daily sleep diary data from the previous night. Participants utilized the in-app sleep diary for the final three weeks of the study by reporting the previous night’s sleep data within the app each day. Although participants were asked to capture daily data, the data were not collected by the researchers each day. Instead, the data were collected at the end of each week through a link where participants would transfer their week’s data from the app to the survey.

Pittsburgh Sleep Quality Index (PSQI)

The PSQI is a 19-item self-rated questionnaire that assesses sleep quality and disturbances over a 1-month time interval (Buysse et al., 1989). The items on the PSQI generate 7 component scores in the areas of (a) subjective sleep quality, (b) sleep latency, (c) sleep duration, (d) habitual sleep efficiency, (e) sleep disturbances, (f) use of sleeping medication, and (g) daytime dysfunction. There are four open-ended items and 15 items that are rated using Likert-type scales assessing frequency, satisfaction, and severity, respectively. Each question is assigned a score from 0 (no difficulty) to 3 (severe difficulty; see Buysse et al., 1989, for individual item scoring instructions). The component scores are calculated and then summed to yield one global score that has a range of 0–21 with higher scores indicating worse sleep quality (Buysse et al., 1989). A score of 5 or above is indicative of sleep disturbance. In comparable studies, reported pretreatment scores on the PSQI were between 6.29 and 6.98 for nonclinical populations (Kloss et al., 2016; Peach et al., 2016) and between 10.6 and 11.0 for a clinical population (Horsch et al., 2017). The PSQI demonstrated strong convergent validity when compared to related constructs such as sleep problems and sleep restlessness (r = .69) and significant divergent validity when compared to nausea, vomiting, and taste changes (r = .37; Carpenter & Andrykowski, 1998). Furthermore, samples differentiated by PSQI scores were also differentiated by polysomnographic measures of sleep (Buysse et al., 1989). The PSQI is found to be a reliable measure with evidence of strong correlations of the seven components to the global construct (α = .83) and performance consistency with a reliability coefficient of .85 (Buysse et al., 1989). In the current sample, Cronbach’s alpha for the PSQI global score was .64.

Dysfunctional Beliefs and Attitudes About Sleep Scale (DBAS-16)

The DBAS-16 is a 16-item self-report measure designed to evaluate sleep-related cognitions in the following four domains: perceived consequences of insomnia, worry/helplessness about insomnia, sleep expectations, and medication (Morin et al., 2007). Participants rate their beliefs about the item on a 10-point Likert-type scale from 0 (strongly disagree) to 10 (strongly agree). The items on the DBAS-16 are summed and averaged for a total score. With a range from 0–10, a higher score indicates a stronger endorsement of dysfunctional beliefs. Comparable studies focused on cognitive components of sleep disturbance within clinical samples reported pretreatment scores between 4.21 and 5.3 (Eidelman et al., 2016; Horsch et al., 2017).
The DBAS-16 demonstrated significant convergent validity \((r = .18-.45)\) when compared to other self-report measures of insomnia severity and acceptable discriminant validity \((r = -.12 -.20)\) when compared to demographic characteristics of age, gender, and education level (Morin et al., 2007). The DBAS-16 was found to be a reliable measure as evidenced by acceptable internal consistency \((\alpha = .79,\) research sample; \(\alpha = .77,\) clinical sample) and test-retest reliability \((r = .83;\) Morin et al., 2007). In the current sample, Cronbach’s \(\alpha\) for the total scale was .83 and subscale coefficients ranged from .60 (sleep expectations) to .83 (worry/helplessness).

**Sleep Hygiene Practice Scale (SHPS)**

The SHPS is a 30-item self-report scale designed to assess sleep hygiene behaviors that may have a negative impact on the circadian system (Yang et al., 2010). These sleep habits are classified into four domains including arousal-related behavior, sleep scheduling and timing, eating/drinking behaviors, and sleep environment. Participants rate how often they engaged in the behavior using a 6-point Likert-type scale from 1 (never) to 6 (always). The items on the SHPS are summed for a total score with a range from 30–180. A higher score indicates a stronger endorsement of poor sleep hygiene practices. In comparable studies, pretreatment scores on the SHPS were between 70.18 and 91.78 (Peach et al., 2016; Yang et al., 2010). The SHPS was found to be a valid measure as it correlated significantly with measures of insomnia and sleep quality (Yang et al., 2010). The SHPS demonstrated sound internal consistency among items in each of the following domains: arousal-related behavior \((\alpha = .70,\) good sleepers; \(\alpha = .58,\) with insomnia), sleep scheduling and timing \((\alpha = .82,\) good sleepers; \(\alpha = .74,\) with insomnia), eating/drinking behaviors \((\alpha = .72,\) good sleepers; \(\alpha = .70,\) with insomnia), and sleep environment \((\alpha = .67,\) good sleepers; \(\alpha = .65,\) with insomnia; Yang et al., 2010). In the present study, the internal consistency estimate for the total scale was .81 and subscale coefficients ranged from .63 (eating/drinking behaviors) to .72 (sleep environment).

**CBT-I Coach Application**

CBT-I was administered using the CBT-I Coach mobile application. The content of the CBT-I Coach is adapted from critical components from *Cognitive Behavioral Therapy for Insomnia in Veterans* (Manber et al., 2014). The app was developed by the U.S. Department of Veterans Affairs in collaboration with the Stanford University Medical Center and the Department of Defense’s National Center for Telehealth & Technology (U.S. Department of VA, 2013).

The CBT-I Coach includes four main categories including My Sleep, Tools, Learn, and Reminders. My Sleep displays data collected through the sleep diary function of the app including graphs that depict a personalized sleep summary, containing time in bed and hours asleep by date, sleep efficiency, sleep onset latency, number and duration of awakenings, and wake times. The Tools section demonstrates how to incorporate new sleep habits into a nighttime routine, schedule worry time, and change irrational perspectives about sleep. The Learn component of the application includes psychoeducation on CBT-I, the importance of healthy sleep, the stages of sleep, what regulates sleep, and additional information about sleep disorders as well as a glossary of terms such as stimulus control. Finally, the Reminders component aids the individual in setting reminders for critical components of CBT-I discussed above. The CBT-I Coach can be downloaded for free from Google and iTunes stores.

Participants completed daily sleep diaries for three weeks using the CBT-I Coach. Participants utilized the reminders function of the application most notably to complete the daily sleep diary but also for wind down, worry, bed and wake times, and time to restrict caffeine intake. The app does not have a structured program for use, so the participants determined how they wished to use the app outside of the daily sleep diaries and reminders.

**Mobile Application Rating Scale (MARS)**

The MARS is a 23-item tool used to assess the quality of mobile health apps (Stoyanov et al., 2015). There are four objective quality scales including engagement, functionality, aesthetics, and information quality. There is one subjective quality scale, which includes four items: recommendation for others, future use, worth the price, and overall rating of the app. All of the items are rated on a 5-point Likert-type scale from 1 (inadequate) to 5 (excellent). The MARS is scored by calculating the mean of the four objective quality subscales and an overall mean app quality score. When compared to iTunes star ratings, the total MARS score showed a moderate correlation \((r = .55)\). Testing on the MARS total score indicated a high level of internal consistency \((\alpha = .90;\) Stoyanov et al., 2015). The MARS subscales were also found to be internally consistent \((\alpha = .80 -.89)\) and demonstrated an
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Preliminary Analyses

Data were cleaned by two investigators to achieve interrater agreement among final scores. This process involved downloading data sheets from SurveyMonkey and hand-scoring the PSQI, DBAS, and SHPS for each participant who provided both pre and posttest data. Sleep diary information was organized for each day the participant provided data by converting time into a decimal consistent with a 24-hour system (e.g., 11:30 p.m. was converted to 23.5). Length of time as reported in sleep onset latency and length of awakenings were converted into a decimal by dividing the minutes reported by 60 (e.g., 25 minutes was converted to 0.42). When participants reported ranges, such as 10–15 minutes, the midpoint was used. Tests for outliers and normality of distributions showed all variables were in the acceptable range. Participants who had missing data and still met completion criteria (e.g., 5 out of 7 sleep diaries completed per week), were still included in final analyses but their data for that day were omitted.

Variables of interest were overall PSQI pre- and posttreatment scores, overall DBAS pre- and posttreatment scores, SHPS pre and posttreatment scores, and average sleep efficiency scores from pretreatment Week 1 and posttreatment Week 4. Due to multiple comparisons, the significance level for the four overall scores were adjusted using the Bonferroni correction. Subscale components for each measure are also reported for exploratory purposes and as such, their significance levels were not adjusted.

Descriptive Data

At baseline, participants demonstrated poor overall sleep quality, reported low frequency of sleep hygiene practices, and held unrealistic expectations of sleep and thoughts about the ability to cope with sleep difficulties.

Participants spent an average of 33 minutes in the app (SD = 9 minutes) during posttreatment Week 1, 38 minutes in the app (SD = 18 minutes) during posttreatment Week 2, and 39 minutes in the app (SD = 9 minutes) during posttreatment
Week 3. All participants reported use of the My Sleep component where sleep diaries were filled out within the app. Of the Learn subsection of CBT-I Coach, 41% engaged with Habits & Sleep, 36% explored Sleep 101, and 9% utilized the CBT-I glossary. The Tools section included both cognitive and behavioral interventions and troubleshooting techniques and 55% of participants utilized Quiet Your Mind tools and 41% used the Create New Sleep Habits tools.

**Changes in Subjective Sleep Quality**
The first hypothesis stated that the intervention would result in sleep quality improvement from pretreatment to posttreatment as measured by the PSQI. Mean changes from pretreatment to posttreatment were compared using paired-samples t tests. When pre- and posttest measures of sleep quality using the PSQI (pretest: *M* = 7.82, *SD* = 3.25; posttest: *M* = 5.55, *SD* = 2.4) were compared, a significant improvement was found, PSQI *t*(21) = 4.38, *p* < .001, *d* = 0.93. Of the seven component scores, significant mean changes were most apparent on subjective sleep quality, sleep latency, and daytime dysfunction. Changes in sleep quality overall and by subscale from pre to posttest can be seen in Table 1.

**Changes in Sleep Hygiene Practices**
The third hypothesis focused on changes in the practice of sleep hygiene behaviors as rated using the SHPS at baseline and at 4-weeks. Mean changes from pretreatment to posttreatment were compared using paired-samples t tests. When pre and posttest measures of sleep hygiene behaviors (pretest: *M* = 85.27, *SD* = 18.88; posttest: *M* = 73.46, *SD* = 16.41) were compared, a significant improvement was found, SHPS *t*(21) = 3.26, *p* = .001, *d* = 0.70. Changes in sleep hygiene practices overall and by subscale can be seen in Table 3.

**Changes in Sleep Efficiency**

The fourth hypothesis stated that sleep efficiency would improve over the course of the study. Sleep efficiency was calculated using the daily sleep diary

### TABLE 1
Comparison of Pre and Posttreatment Scores of Sleep Quality

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th><em>t</em> (22)</th>
<th><em>p</em></th>
<th><em>d</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective sleep quality</td>
<td>1.36</td>
<td>1.05</td>
<td>2.31</td>
<td>.031</td>
<td>0.49</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>1.68</td>
<td>0.99</td>
<td>0.86</td>
<td>0.95</td>
<td>4.23</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>0.77</td>
<td>0.81</td>
<td>0.55</td>
<td>0.96</td>
<td>1.23</td>
</tr>
<tr>
<td>Habitual sleep efficiency</td>
<td>0.86</td>
<td>1.13</td>
<td>0.64</td>
<td>0.73</td>
<td>1.00</td>
</tr>
<tr>
<td>Sleep disturbances</td>
<td>1.23</td>
<td>0.61</td>
<td>1.14</td>
<td>0.64</td>
<td>0.81</td>
</tr>
<tr>
<td>Use of sleeping medication</td>
<td>0.50</td>
<td>1.01</td>
<td>0.55</td>
<td>1.01</td>
<td>−0.58</td>
</tr>
<tr>
<td>Daytime dysfunction</td>
<td>1.41</td>
<td>1.01</td>
<td>0.77</td>
<td>0.81</td>
<td>3.31</td>
</tr>
<tr>
<td>Total</td>
<td>7.82</td>
<td>5.45</td>
<td>2.40</td>
<td>4.38</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Note. Subscale scores range from 0 (no difficulty) to 3 (severe difficulty). Total score has a range of 0 (no difficulty) to 21 (severe difficulties in all areas). Higher scores indicate worse sleep quality. The total score *p* value was adjusted for multiple comparisons using a Bonferroni correction.

### TABLE 2
Comparison of Pre and Posttreatment Scores for Dysfunctional Beliefs About Sleep

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th><em>t</em> (22)</th>
<th><em>p</em></th>
<th><em>d</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived consequences</td>
<td>5.65</td>
<td>4.36</td>
<td>3.72</td>
<td>.001</td>
<td>0.79</td>
</tr>
<tr>
<td>Worry/helplessness</td>
<td>4.34</td>
<td>3.73</td>
<td>1.52</td>
<td>.143</td>
<td>0.32</td>
</tr>
<tr>
<td>Sleep expectations</td>
<td>6.14</td>
<td>5.14</td>
<td>2.06</td>
<td>.052</td>
<td>0.44</td>
</tr>
<tr>
<td>Medication</td>
<td>3.58</td>
<td>3.14</td>
<td>1.36</td>
<td>.188</td>
<td>0.29</td>
</tr>
<tr>
<td>Total</td>
<td>4.83</td>
<td>3.99</td>
<td>3.12</td>
<td>.001</td>
<td>0.66</td>
</tr>
</tbody>
</table>

Note. Scores range from 0–10, a higher score indicates a stronger endorsement of dysfunctional beliefs. The total score *p* value was adjusted for multiple comparisons using a Bonferroni correction.

### TABLE 3
Comparison of Pre and Posttreatment Scores for Sleep Hygiene Practice

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
<th><em>t</em> (22)</th>
<th><em>p</em></th>
<th><em>d</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Arousal-related behavior</td>
<td>29.64</td>
<td>22.50</td>
<td>4.49</td>
<td>&lt;.001</td>
<td>0.96</td>
</tr>
<tr>
<td>Sleep scheduling and timing</td>
<td>24.23</td>
<td>21.55</td>
<td>1.93</td>
<td>.067</td>
<td>0.41</td>
</tr>
<tr>
<td>Eating/drinking behaviors</td>
<td>12.86</td>
<td>13.55</td>
<td>−0.65</td>
<td>.522</td>
<td>0.14</td>
</tr>
<tr>
<td>Sleep environment</td>
<td>18.55</td>
<td>15.96</td>
<td>1.88</td>
<td>.074</td>
<td>0.40</td>
</tr>
<tr>
<td>Total</td>
<td>85.27</td>
<td>68.88</td>
<td>3.26</td>
<td>.001</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Note. Scores range from 30–180. A higher score indicates a stronger endorsement of poor sleep hygiene practices. The total score *p* value was adjusted for multiple comparisons using a Bonferroni correction.
data. Changes in sleep efficiency were evaluated using the daily sleep efficiency calculations for the pretreatment week to the final posttreatment week using a paired-samples t test. As hypothesized, when pre- and posttreatment weeks of sleep efficiency data (pretreatment: \( M = 83.14, SD = 9.05 \); posttreatment: \( M = 90.56, SD = 5.83 \)) were compared, a significant improvement was found, \( t(21) = -4.93, p < .001, d = 1.05 \). Improvements were observed in sleep onset latency and number of awakenings. No change was found in total sleep time. Changes in overall sleep efficiency and by component can be seen in Table 4.

### Attitudes Toward CBT-I Coach

The MARS survey indicated participants’ overall positive attitudes toward the CBT-I Coach app. Participants rated the app as moderate to high. The overall score was consistent with the subscale scores for engagement, functionality, aesthetics, and information quality with a range of means from 3.27 to 4.12. The highest rated objective components were functionality \((M = 4.06, SD = 0.80)\) and information quality \((M = 4.12, SD = 0.66)\). Means and standard deviations for each quality scale can be found in Table 5.

### Discussion

In one of the first studies investigating the effect of a brief psychological intervention and app-delivered CBT-I on sleep quality in a nonclinical population, we found that overall intervention significantly improved sleep quality, decreased dysfunctional beliefs about sleep, decreased problematic sleep behaviors, and improved sleep efficiency over 3 weeks. The primary aim of the study was to investigate the effectiveness of the CBT-I Coach for improving sleep quality. The CBT-I Coach app offered participants continued access to efficacious treatment strategies and educational components about the importance of healthy sleep practices and dysfunctional beliefs about sleep. Overall, the improvement in outcome measures due to the brief face-to-face orientation and psychoeducation and use of the CBT-I Coach app is comparable to other internet-delivered CBT-I and traditional face-to-face CBT-I treatments (Blom et al., 2015; Eidelman et al., 2016; Geiger-Brown et al., 2015; Kaldo et al., 2015).

Dysfunctional beliefs about sleep have a significant impact on perceived sleep quality (Ohayon et al., 2017), and results from this study indicate that beliefs can be significantly modified through a CBT-I intervention. Participants in this study endorsed fewer dysfunctional beliefs about sleep over the course of the intervention. Even after a brief, 3-week intervention period, these results were consistent with reductions in dysfunctional beliefs about sleep in participants who completed 8 weeks of cognitive therapy, behavioral therapy, or CBT-I (Eidelman et al., 2016; Harvey et al., 2007). However, face-to-face interventions demonstrated larger effect sizes (Harvey et al., 2007). Furthermore, when compared to a study with a college population that used two psychoeducational workshops on sleep, the current study found similar reductions in dysfunctional beliefs but with larger effect sizes (Kloss et al., 2016).

A similar study utilizing app-delivered CBT-I with pretreatment DBAS scores matching those of the current study found no reduction in mean scores after 6 weeks of intervention for...
dysfunctional beliefs about sleep (Horsch et al., 2017). Horsch and colleagues (2017) posited that this was due to their app having no component that directly targeted cognitions. The similarity of these interventions and the clear difference in outcomes provide preliminary support for the efficacy of the cognitive interventions within the CBT-I Coach.

Sleep hygiene behaviors were addressed as part of the psychoeducation components and the tools component of the CBT-I Coach. Sleep scheduling was specifically targeted through the scheduling and push notification reminders of a wind-down time prior to sleeping, which has been established in past research to promote relaxation before bed and regularity in sleep and wake times (Kaplan & Harvey, 2014). The practice of sleep hygiene behaviors significantly improved over the course of the study. These benefits were also found in Kloss and colleagues’ (2016) study with a college population. This significant improvement is preliminary evidence supporting the use of the app to promote, troubleshoot, and remind participants of healthy sleep hygiene behaviors.

Self-reports of sleep quality were significantly improved over the course of the study, which offers consilience with significant decreases in endorsement of dysfunctional sleep beliefs and increases in sleep hygiene behaviors. Significant improvements from pretreatment to posttreatment on the current study’s PSQI scores were similar to score differences in studies involving longer treatment intervention and regular meetings with a licensed professional (Geiger-Brown et al., 2015). Sleep quality differences were greater, statistically significant, and garnered a larger effect size than that of a similar study with the college population utilizing psychoeducation as an intervention alone (Kloss et al., 2016). Additionally, when compared to another app-delivered intervention study, PSQI changes and effect sizes were consistent (Horsch et al., 2017).

Pretreatment and posttreatment self-report measures corroborated results found through daily sleep diary entries. When baseline and posttreatment sleep efficiency percentages were compared, there was a 7% increase. This improvement in sleep efficiency is substantiated by Geiger-Brown et al.’s (2015) meta-analysis that reported an average 9% increase in sleep efficiency. However, the studies included in the meta-analysis were face-to-face individual or group delivered CBT-I over a 4- to 8-week time frame. Participants in the current study experienced similar sleep efficiency improvements during a shorter time period without the help of continuous professional contact. Participants’ average sleep efficiency percentage at pretreatment was only slightly below the recommended 85% or above for good quality sleep as outlined by the National Sleep Foundation (Ohayon et al., 2017) but posttreatment scores exceeded the recommended efficiency score. Improvements were also observed in sleep onset latency and awakenings after sleep onset consistent with the recommended ranges indicative of good quality sleep. Previous research has also demonstrated a significant reduction in sleep onset latency with the use of CBT-I ranging from a reduction of 15 to 21 minutes (Harvey et al., 2007; Geiger-Brown et al., 2015).

Although there are several mobile apps that target and track sleep, there is little information available about their perceived quality and usability (Miner et al., 2016). Participants’ attitudes about CBT-I Coach quality were assessed using the MARS. Overall, participants indicated positive attitudes toward the CBT-I Coach app. Participants rated information quality and functionality highest among the quality subscales, which is a reflection of participant satisfaction and might have also enhanced the impact of the intervention. Although still indicating positive impressions, participants reported lower ratings for aesthetics and engagement. This may also be reflected in participants’ reported average time spent in the app, which was only 33–39 minutes per week.

Despite seemingly low engagement, sleep outcomes were significantly improved. The in-app components are brief, in-the-moment interventions, which may explain the discrepancy between time and significant outcomes. The outcome measures in contrast with the participants’ reported use of the app may provide preliminary evidence that time in the app does not directly reflect sleep improvement or more broadly, the effectiveness of the intervention. Most comparison studies were structured and involved continuous therapeutic contact and included 4 to 8 hours of planned intervention over a 4- to 8-week period. The current study found improvements consistent with previous research but with only 1 structured contact and much less participant time investment.

Potential Limitations and Future Research Directions

Certain limitations should be noted. First, due to our use of a convenience sample of undergraduate college students taken from a mid-sized Midwestern
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university, generalizability may be limited, even among nonclinical populations. Second, over the course of the study, we experienced a 46% attrition rate leaving us with a relatively small sample. The sample size might have increased the chance of Type II error. Additionally, the high rate of attrition is potentially indicative of attrition bias where the participants who completed the study might have held greater expectations of the intervention’s effectiveness. Third, there was no control group and thus no definitive way to rule out that improvement was due to passage of time or increased awareness of sleep-related behaviors and cognitions from participants. We controlled for this by having participants complete a sleep diary every day before the introduction of any intervention so that the sample group also served as their own control. Additionally, some of the alpha coefficients of measures for the current study fell below the .70 range, which is considered to be acceptable. Fourth, this study relied solely on participants’ self-report for data collection in the pretreatment measures, daily sleep diaries, app use, and posttreatment measures. Daily sleep diaries do demonstrate some convergent validity when compared to physiological measures of sleep (Tonetti et al., 2016), and future research can be improved by utilizing objective methods of data collection to compare against this sample’s self-report measures. Fifth, there were no outcome measures taken immediately following the face-to-face meeting. Although we have compelling evidence that participants’ use of the app improved their overall sleep quality, without a more extensive assessment procedure, it is not possible to separate the impact of the face-to-face meeting alone and participants’ use of the app. Finally, it is unknown if frequency of use, total time in app, and/or engagement in particular components of the app were specific variables affecting change.

The results of this study suggest the need for future research to evaluate app-delivered CBT-I and its effects on sleep quality, sleep hygiene practices, and endorsement of dysfunctional beliefs about sleep. Future research may address some of the current study’s limitations by evaluating app-delivered treatments using well-constructed longitudinal experimental research designs. The use of a control group, objective measurement tools, and a more robust assessment procedure would allow for richer information to be derived about the variables of change and more detail about the effects of those changes. Specific to app-delivered treatment, future research would include an objective measure of interaction and engagement with the app to collect specific and detailed data about content that produced the most interest and where participants spent most of their time when using the app. Collecting information about the durability of the treatment effect is also of interest. Future studies should focus on follow-up assessments at 3 months, 6 months, and 12 months to investigate long-term effects of a brief, technology-based intervention.

Conclusions

To our knowledge, this is the first known study to evaluate a mobile app for treatment of sleep difficulties with a brief, structured psychoeducational session among a nonclinical population. The results of this study are consistent with the improvements seen with face-to-face CBT-I, internet-delivered CBT-I, and group CBT-I. This study achieved significant results with large effect sizes within a condensed timeframe with only one face-to-face structured contact, suggesting that even a brief intervention with little to no structured, clinical involvement can lead to changes in sleep quality indicators. The findings are encouraging and support the use of psychoeducation and app-delivered CBT-I to reduce maladaptive beliefs about sleep, increase sleep hygiene knowledge and practice, and improve overall sleep quality. Furthermore, this is a cost-effective and easily disseminated way to improve sleep (even when clinical criteria for a sleep disorder may not be met) and perhaps serve as a protective measure against the development of a sleep disorder. The results of this study support the use of technology for improving sleep quality, reducing sleep onset latency and number of awakenings, aiding in creating consistent healthy sleep behaviors, and can serve as a preventative strategy for nonclinical populations and clinical populations alike.

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