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RESEARCH ARTICLE

Digital cognitive behaviour therapy for insomnia in individuals with self-reported insomnia and chronic fatigue: A secondary analysis of a large scale randomized controlled trial

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Summary

Insomnia is associated with fatigue, but it is unclear whether response to cognitive behaviour therapy for insomnia is altered in individuals with co-occurring symptoms of insomnia and chronic fatigue. This is a secondary analysis using data from 1717 participants with self-reported insomnia in a community-based randomized controlled trial of digital cognitive behaviour therapy for insomnia compared with patient education. We employed baseline ratings of the Chalder Fatigue Questionnaire to identify participants with more or fewer symptoms of self-reported chronic fatigue (chronic fatigue, $n = 592$; no chronic fatigue, $n = 1125$). We used linear mixed models with Insomnia Severity Index, Short Form-12 mental health, Short Form-12 physical health, and the Hospital Anxiety and Depression Scale separately as outcome variables. The main covariates were main effects and interactions for time (baseline versus 9-week follow-up), intervention, and chronic fatigue. Participants with chronic fatigue reported significantly greater improvements following digital cognitive behaviour therapy for insomnia compared with patient education on the Insomnia Severity Index (Cohen's $d = 1.36$, $p < 0.001$), Short Form-12 mental health (Cohen's $d = 0.19$, $p = 0.029$), and Hospital Anxiety and Depression Scale (Cohen's $d = 0.18$, $p = 0.010$). There were no significant differences in the effectiveness of digital cognitive behaviour therapy for insomnia between chronic fatigue and no chronic fatigue participants on any outcome. We conclude that in a large community-based sample of adults with insomnia, co-occurring chronic fatigue did not moderate the effectiveness of digital cognitive behaviour therapy for insomnia on any of the tested outcomes. This may further establish digital cognitive behaviour therapy for insomnia as an adjunctive intervention in individuals with physical and mental disorders.

KEYWORDS
chronic fatigue, digital cognitive behaviour therapy for insomnia, insomnia, moderator, randomized controlled trial, sleep difficulties

1 | INTRODUCTION

Insomnia affects ~10% of the population (Baglioni et al., 2020), and is characterized by difficulty initiating or maintaining sleep, accompanied by negative daytime consequences (Sateia, 2014). Daytime fatigue, defined as overwhelming mental and physical sustained exhaustion that hampers an individual's ability to function well in daily life (Chalder et al., 1993; Shen et al., 2006), is one of the most commonly reported daytime symptoms of insomnia (Kim et al., 2019; Moul et al., 2002). Randomized controlled trials (RCTs) have repeatedly demonstrated that face-to-face and digital cognitive behavioural therapy for insomnia (CBT-I) are highly efficacious interventions for insomnia and related symptoms, and benefit individuals recruited from the general population (Hasan et al., 2022; Van Straten et al., 2018; Vedaa et al., 2020), from psychiatric populations (Hertenstein et al., 2019) and patients known to be at higher risk of reporting fatigue (e.g. patients with cancer; Squires et al., 2022). Furthermore, although CBT-I does not target daytime fatigue directly, several studies demonstrate improvements in fatigue following this intervention (Benz et al., 2020; Vedaa et al., 2020).

These findings are important for several reasons. For example, whilst daytime fatigue might be a consequence of insomnia, research demonstrates that sleep disturbances and fatigue may show independent associations with many mental disorders (McCallum et al., 2019). If CBT-I is effective for both insomnia and chronic fatigue (CF), this may further establish its utility as an adjunctive psychological intervention for other mental and physical disorders. Many individuals with diagnosis of CF (fatigue that has persisted for at least 6 months) are offered exercise therapies or CBT-type interventions that prioritize daytime functioning. Not only are the short-term and longer-term benefits relatively modest, there is little evidence of any improvements in sleep disturbances (Larun et al., 2019). Because CBT-I is a treatment that requires behavioural changes, the treatment can potentially be challenging for individuals with CF and insomnia. Studies have demonstrated that a common side-effect of these behavioural changes is increased levels of fatigue (Perlis et al., 2022). However, there is little knowledge about the comparative effectiveness of CBT-I in individuals with insomnia with or without CF in the general population. We hypothesized that dCBT-I would have lower effectiveness for individuals with CF compared with individuals without CF. That is, we considered that it was clinically important to test the hypothesis that the presence or absence of self-reported CF at baseline was a moderator of effect of dCBT-I.

Our previously reported RCT of > 1700 adults offered an opportunity to explore changes in self-ratings of sleep, mental and physical health, and psychological distress before and after exposure to dCBT-I or patient education about insomnia (PE; Vedaa et al., 2020). In summary, in this secondary analysis of a large RCT dataset we test whether the presence of co-occurring higher symptoms of self-reported CF:

i. moderated the effect of dCBT-I on insomnia severity at 9-week follow-up compared with PE;
ii. moderated the effect of dCBT-I on perceived mental and physical health, and psychological distress at 9-week follow-up compared with PE.

2 | MATERIALS AND METHODS

The current study represents a secondary analysis of data from a recently published RCT that investigated the efficacy of dCBT-I compared with an active control intervention (PE) in a Norwegian community-based sample of 1721 participants with self-reported insomnia. The trial is registered with ClinicalTrials.gov (NCT02558647) and was approved by the Regional Committee for Medical and Health Research Ethics in Southeast Norway (2015/134). Details on the trial protocol, procedures and key outcomes are published elsewhere (Kallestad et al., 2018; Vedaa et al., 2020).

2.1 | Trial design

2.1.1 | Participants and recruitment

Participants were recruited between February 2016 and July 2018 through information posters in general practitioners' offices and healthcare facilities, advertisements from the Norwegian University of Science and Technology, and other relevant social media. Potential participants were directed to a webpage containing information about the study and were offered the opportunity to participate in a screening assessment. All eligible participants signed an online written informed consent form and completed baseline self-rating assessments (including 10 days of sleep diaries) prior to randomization.

2.1.2 | Eligibility criteria

Individuals were eligible to participate in the trial if they were aged 18 years or older and scored ≥ 12 on the Insomnia Severity Index (ISI). Individuals were excluded if they met one or more of the following: scored > 10 on the Epworth Sleepiness Scale (indicated risk of sleep apnea and hypersomnia); were at risk of sleep apnea assessed through screening questions about snoring and breathing problems; had a self-reported medical condition for which dCTB-I might be contraindicated; and were currently engaged in night-time shift work.

2.1.3 | Interventions

More details about each intervention are provided in the supplementary materials. The following sections provide brief summaries.

Digital CBT-I (dCBT-I)

Sleep Healthy Using the Internet (SHUTi) is a fully automated interactive web-based programme that consists of six treatment cores usually considered to be the primary components of CBT-I (Perlis et al., 2022; Ritterband et al., 2009), with the exception of relaxation training. Objectives, activity review, feedback, new content and homework were provided for each of the six cores. The programme provided tailored feedback to each participant based on information from sleep diaries and self-reported treatment goals. The six cores were administered sequentially, and all six cores were designed to be completed within the intervention period of 9 weeks.

Patient education about insomnia (PE)

The PE was delivered through an online website that consisted of written text. The intervention informed the participants about sleep hygiene advice and psychoeducation about insomnia. PE did not provide the participants with any feedback. The PE condition also included the option of downloading printable sleep diaries. Participants who received PE were encouraged to visit the website at the start of the study and as often as they liked throughout the intervention period without further notifications.

2.2 | Data analysed in this study

For the purpose of the current moderator analysis, we extracted data from baseline and 9-week follow-up assessments for the following measures.

2.2.1 | Primary outcome measure

Insomnia severity index (ISI)

The ISI is a self-report measure that consists of seven items designed to measure the participants' overall insomnia severity. Items are rated on a five-point Likert scale, and the total score ranges from 0 to 28, with a higher score indicating greater insomnia severity (Bastien et al., 2001). A reduction of eight points on the ISI from baseline to 9-week follow-up was used to measure response, and a score below eight indicated remission (Morin, 1993). The ISI has good psychometric properties, and has been validated for online use (Thorndike et al., 2011).

2.2.2 | Secondary outcome measures

The 12-item Short-Form Health Survey (SF-12)

The SF-12 is a self-report measure that consists of 12 items designed to assess the participants' perceived physical and mental health status. The SF-12 was scored according to the procedure described by Ware et al. (1996), which composes two summary scores for mental health and physical health. A higher score on the SF-12 indicates better mental/physical function.

The Hospital Anxiety and Depression Scale (HADS)

The HADS is a self-report measure that consists of 14 items designed to measure psychological distress. Items are rated on a four-point Likert scale, with a total score ranging from 0 to 42 (Zigmond & Snaith, 1983). A higher total score on the HADS indicates greater psychological distress.

2.3 | Statistical methods

2.3.1 | Operationalization of CF subgroups

To optimize our analyses of the impact of CF on outcomes of dCBT-I, we decided a priori to categorize participants as individuals with more symptoms of self-reported CF problems (CF) and those with fewer self-reported symptoms of CF, that is, non-CF individuals (nCF). To ensure the CF category closely matches the diagnostic criteria for CF syndrome (Sharpe, 1991), we undertook the following transformation of scores on the Chalder Fatigue Questionnaire (CFQ; Chalder et al., 1993). First, we determined that CF would only be considered in individuals with a self-reported duration (of the fatigued state) of ≥ 6 months and who reported that ≥ 50% of their wake time was affected by fatigue (persistence). Further, to operationalize the severity of impairment/symptoms, we applied a bimodal scoring system to the other nine CFQ items. This reduced the scores on the original four-point Likert scale to 0 (i.e. no or less impairment or lower severity) or 1 (worse symptoms, etc.). To be classified as CF, the individual had to score > 5 (on these nine items). In contrast, participants that did not meet the criteria for CF were categorized as nCF, operationalized as a bimodal score ≤ 5, duration < 6 months and persistence < 50%. Our definition is in line with diagnostic criteria for CF syndrome (Sharpe, 1991), and similar criteria have been employed previously to categorize CF in a Norwegian population (Loge et al., 1998).

2.3.2 | Planned analyses

Independent samples *t*-tests were used to investigate baseline differences for outcomes between the CF and nCF categorizations. The proportions of participants who completed dCBT-I in CF and nCF categorizations and the proportions of participants per categorization and intervention who met the ISI criteria for response and remission were compared using Pearson chi-square tests.

To investigate intervention response, linear mixed models were conducted separately with ISI, HADS, SF-12 mental health score and SF-12 physical health score as dependent variables. Time (baseline versus 9-week follow-up), intervention (dCBT-I versus PE) and categorization (CF versus nCF) were included as covariates as follows: main effect of time and categorization, the two-way interactions "intervention × time and time × categorization", and the three-way interaction: "intervention × time × categorization". We adjusted analyses for baseline

TABLE 1 Baseline characteristics by group and treatment condition – presented as % (*n*) or mean (SD)

	CF, *n* = 592		nCF, *n* = 1125	
Variable	**dCBT-I *n* = 294**	**PE *n* = 298**	**dCBT-I *n* = 572**	**PE *n* = 553**
Age	43 (12.7)	45 (12.4)	45 (14.5)	45 (15.1)
Female sex	76% (223)	68% (201)	66% (376)	67% (372)
Years of education	16.6 (3.0)	15.8 (3.0)	16.4 (3.0)	16.2 (2.8)
Employment status				
Full-time employment	46% (134)	46% (138)	51% (293)	52% (289)
Part-time employment	13% (39)	16% (49)	14% (82)	13% (71)
Unemployed	9% (26)	6% (18)	6% (35)	5% (27)
Retired	6% (17)	6% (19)	10% (57)	10% (55)
Student	10% (29)	4% (13)	7% (40)	10% (54)
Other	17% (49)	21% (61)	11% (65)	10% (57)
Married or cohabiting with partner	62% (183)	60% (179)	62% (355)	64% (354)
Children living in household	38% (111)	44% (132)	33% (191)	33% (183)
Sleep problem duration				
< 6 years	1% (3)	0% (0)	5% (26)	3% (19)
6–11 months	1% (3)	2% (6)	2% (13)	2.% (11)
1–5 years	32% (95)	29% (86)	26% (150)	30% (164)
6–10 years	26% (77)	28% (83)	26% (149)	24% (133)
> 10 years	39% (114)	40% (119)	40% (229)	39% (218)
Comorbidity				
Medical condition	11% (33)	10% (30)	12% (69)	14% (79)
Mental health condition	47% (137)	41% (122)	29% (166)	27% (164)
Medical and mental health condition	14% (40)	22% (66)	7% (41)	9% (52)
No comorbidity	29% (84)	27% (80)	52% (296)	47% (258)
ISI	20.8 (3.7)	21.1 (3.6)	18.4 (3.7)	18.8 (3.9)
CFQ	21.7 (3.8)	21.5 (3.7)	14.8 (3.8)	15.1 (4.1)
SF-12 mental	32.1 (10.2)	31.7 (10.9)	38.4 (11.4)	37.9 (10.9)
SF-12 physical	39.7 (7.6)	40.1 (7.8)	42.7 (6.1)	42.7 (6.2)
HADS	15.9 (7.2)	16.2 (7.7)	11.9 (6.3)	11.9 (6.4)
Use of over-the-counter or prescription medication(s) for sleep ("yes")	83% (243)	76% (226)	84% (483)	85% (468)

Abbreviation: CF, chronic fatigue; CFQ, Chalder Fatigue Questionnaire; dCBT-I, digital cognitive behaviour therapy for insomnia; HADS, Hospital Anxiety and Depression Scale; ISI, Insomnia Severity Index; nCF, no chronic fatigue; PE, patient education about insomnia; SF-12, 12-item Short-Form Health Survey.

assessments by omitting a (systematic) main effect of treatment condition (at baseline) and the interaction of intervention × categorization (at baseline) as recommended by Twisk et al. (2018). Analyses were adjusted for age and sex. The three-way interaction terms were used to test whether the estimated mean differences between interventions were different between the two categorizations (CF versus nCF). At the 9-week follow-up, the effects of interventions for the outcome variables (ISI, HADS, SF-12) were estimated as the difference from baseline to 9-week follow-up for the interventions in terms of the coefficient of the corresponding interaction term "intervention × time". In a linear mixed model, participants with missing data at follow-up contribute to the estimation with data from baseline. The results are unbiased under the missing at random assumption, whereas a complete case analysis would have been unbiased only under the more restrictive assumption of missing completely at random.

Standard effect sizes (Cohen's *d*) were calculated for the between-groups assessments using estimated difference/pooled standard deviation. Two-sided *p*-values less than 0.05 were regarded to represent as statistical significance. All statistical analyses were conducted using SPSS version 26.

3 | RESULTS

Among the 1721 included participants, 592 met criteria for CF, and were randomized to the dCBT-I (50%, *n* = 294) or PE (50%, *n* = 298)

conditions. Four participants had missing baseline data on the CFQ, and were not categorized as CF or nCF and are not included in the analyses. Baseline characteristics are shown in Table 1. The mean age was about 45 years, and most participants were women (> 65%), married (> 60%) and > 45% were in full-time employment.

Analysis of baseline assessments demonstrated statistically significant differences between the CF and nCF categorizations on the ISI (nCF: $M = 18.6$, SD = 3.8; CF: $M = 20.9$, SD = 3.7; $p < 0.001$), SF-12 mental health (nCF: $M = 38.2$, SD = 11.2; CF: $M = 31.9$, SD = 10.6; $p < 0.001$), SF-12 physical health (nCF: $M = 42.7$, SD = 6.1; CF: $M = 39.9$, SD = 7.7; $p < 0.001$) and HADS (nCF: $M = 11.9$, SD = 6.4; CF: $M = 16.0$, SD = 7.5; $p < 0.001$).

A total of 85% ($n = 250$) of the CF participants completed the first core of dCBT-I compared with 87% ($n = 496$) in the nCF categorization. Approximately 49% of the CF and 45% of nCF categorizations completed all six cores ($p = 0.202$).

3.1 | Primary outcome measure

The three-way interaction of categorization (CF versus nCF), intervention (dCBT-I versus PE) and time (baseline versus 9-week follow-up) showed no differences in the efficacy of dCBT-I on the ISI between individuals with or without CF ($p = 0.184$). There was no statistically significant difference in remission rates among participants in the CF categorization allocated to dCBT-I (31.3%, $n = 63$), compared with participants in the nCF categorization (40.8%, $n = 156$) allocated to dCBT-I ($p = 0.061$). For participants allocated to PE, 5% ($n = 8$) in the CF categorization reached clinical remission from insomnia, compared with 10% ($n = 34$) in the nCF categorization ($p = 0.026$). For participants allocated to dCBT-I, 54% ($n = 109$) in the CF categorization qualified as responders, compared with 60% ($n = 228$) in the nCF categorization ($p = 0.426$). For participants allocated to PE, 20% ($n = 36$) in the CF categorization qualified as responders, compared with 22% ($n = 78$) in the nCF categorization ($p = 0.408$).

As shown in Figure 1, there were significant between-group differences on the ISI between dCBT-I and PE for participants in the CF and nCF categorizations after 9 weeks. Moreover, the between-group effect sizes for the estimated mean difference after 9 weeks were large for participants with CF (Cohen's $d = 1.36$) and for participants in the nCF categorization (Cohen's $d = 1.17$).

3.2 | Secondary outcome measures

The three-way interaction of categorization, intervention and time showed no differences in the effectiveness of dCBT-I on the SF-12 mental health score between individuals with or without CF ($p = 0.110$). There were significant between-group differences in favour of dCBT-I on the SF-12 mental health score between dCBT-I and PE for participants in the CF and nCF categorizations after 9 weeks. Estimated between-group effect sizes for the estimated mean difference were small for the CF categorization (Cohen's $d = 0.19$) and small-to-medium for the nCF categorization (Cohen's $d = 0.36$).

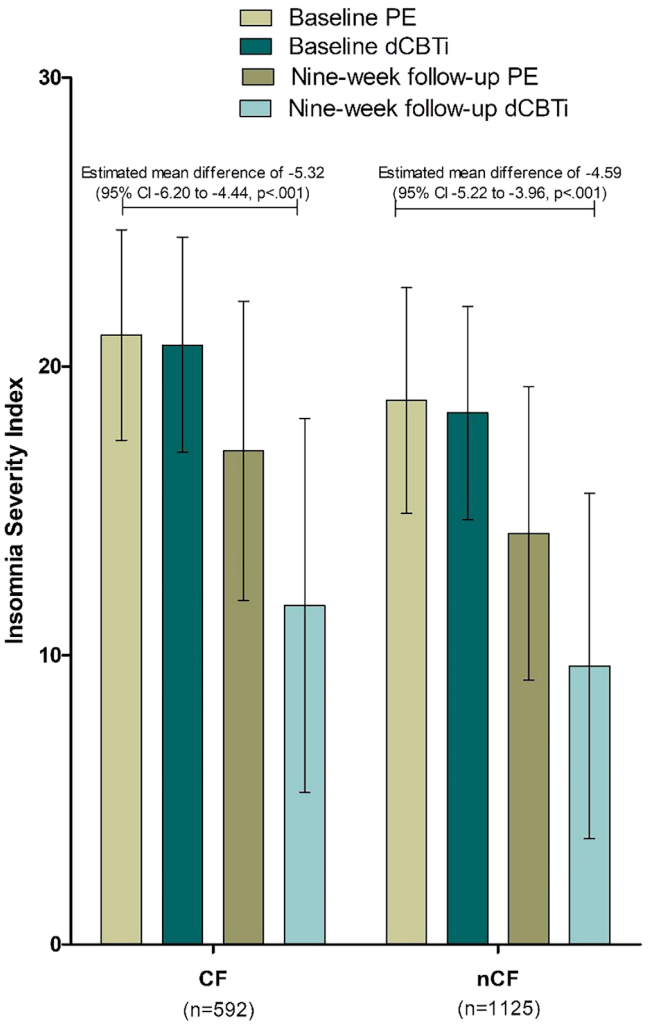

FIGURE 1 Observed means and standard deviations for each group allocated to either digital cognitive behaviour therapy for insomnia (dCBT-I) or patient education about insomnia (PE) at baseline and at 9-week follow-up with the Insomnia Severity Index (ISI) as the dependent variable. Estimated mean differences between groups in change from baseline to 9 weeks (categorization × time interaction term in the linear mixed model)

The three-way interaction of categorization, intervention and time showed no differences in the effectiveness of dCBT-I on the SF-12 physical health score between individuals with or without CF ($p = 0.618$). There were no significant between-group differences on the SF-12 physical health score between dCBT-I and PE for participants in the CF and nCF categorizations after 9 weeks. Estimated between-group effect sizes for the estimated mean differences were small for the CF categorization (Cohen's $d = 0.00$) and nCF categorization (Cohen's $d = 0.05$).

The three-way interaction of categorization, intervention and time showed no differences in the effectiveness of dCBT-I on the HADS between individuals with or without CF ($p = 0.952$). There were significant between-group differences in favour of dCBT-I on

TABLE 2 Primary and secondary outcomes at 9-week follow-up assessment for participants with CF or nCF allocated to either dCBT-I ($n = 867$) or PE ($n = 853$)

	dCBT-I			PE			Adjusted mean difference			
Variable	*n*	Mean	SD	*n*	Mean	SD	Difference estimate	95% CI	*p*-Value	Cohen's *d*
ISI										
CF	201	11.7	6.5	177	17.1	5.2	−5.32	−6.20 to −4.44	< 0.001	−1.36
nCF	382	9.6	6.0	356	14.2	5.1	−4.59	−5.22 to −3.96	< 0.001	−1.17
SF-12 mental health score										
CF	198	38.4	13.2	174	35.8	11.9	2.13	0.22 to 4.04	0.029	0.19
nCF	378	45.4	11.6	351	41.0	11.3	4.04	2.68 to 5.41	< 0.001	0.36
SF-12 physical health score										
CF	198	39.7	7.6	174	40.2	7.8	0.01	−1.11 to 1.13	0.990	0.00
nCF	378	42.5	5.9	351	42.2	5.8	0.36	−0.44 to 1.16	0.381	0.05
HADS										
CF	194	12.5	7.6	172	13.9	7.7	−1.28	−2.25 to −0.30	0.010	−0.18
nCF	374	9.0	6.3	346	10.2	6.2	−1.24	−1.93 to −0.54	< 0.001	−0.18

Note: The difference estimates are results from the baseline-adjusted linear mixed models (negative values favour dCBT-I for all outcomes except for SF-12, because a greater SF-12 score indicates better mental/physical function).
Abbreviation: CF, chronic fatigue; dCBT-I, digital cognitive behaviour therapy for insomnia; HADS, Hospital Anxiety and Depression Scale; ISI, Insomnia Severity Index; nCF, no chronic fatigue; PE, patient education about insomnia; SF-12, 12-item Short-Form Health Survey.

the HADS between dCBT-I and PE for participants in the CF and nCF categorizations after 9 weeks. Estimated between-group effect sizes for the estimated mean difference were small for the CF categorization (Cohen's $d = 0.18$) and nCF categorization (Cohen's $d = 0.18$). Table 2 displays information about the primary and secondary outcomes.

4 | DISCUSSION

Our recent large-scale community-based RCT of individuals with self-rated insomnia demonstrated the superiority of dCBT-I over PE on outcomes for insomnia (Vedaa et al., 2020). In this secondary analysis, we examined whether the benefits of dCBT-I were influenced by the level of self-rated symptoms of CF at baseline. This is important as these phenomena overlap significantly, and CF may exacerbate the functional and social impairments experienced by poor sleepers. Our key finding was that a fully automated digital version of CBT-I is an acceptable and effective intervention for night- and daytime symptoms in individuals with and without co-occurring self-reported CF. Both CF and nCF experienced reductions in levels of insomnia, psychological distress and improvements in mental health. No effect was found on physical health measured by SF-12 for individuals with insomnia in the presence or absence of CF. In this section we discuss the potential implications of our findings in the context of acknowledged limitations of this study.

Our study found that dCBT-I reduces symptoms of insomnia with effects similar to what has been reported in previous studies, demonstrating that psychological interventions can improve sleep in individuals with CF (Kallestad et al., 2015; Powell et al., 2001; Vethe et al., 2018). In our population, the prevalence of self-reported CF was 34% (592 of 1717 participants, within participants with insomnia). While we cannot be certain of the exact nature of any shared pathophysiology, the high prevalence of CF in individuals with insomnia, the lack of differences in dropout rates, and the similar treatment outcomes on night- and daytime symptoms, raise the possibility that insomnia and fatigue share possible mechanisms and are inter-related concepts. Moreover, a recent meta-analysis demonstrated small to moderate effect size improvements on daytime symptoms following CBT-I, and suggests that concepts and techniques from other therapies should be included in CBT-I to enhance outcomes on daytime symptoms (Benz et al., 2020). We suggest that insomnia treatment is tailored with fatigue-specific interventions if the patient presents with CF at baseline, and that the management of CF should include an assessment of the patient's sleep difficulties and follow this up with an appropriate intervention.

We employed the CFQ to examine the degree of CF in the current sample. Several CFQ items that ask about fatigue and its associated symptoms can also identify individuals with insomnia. For example, the CFQ examines whether the individual lacks energy, feels sleepy or drowsy, has an increased need for rest, has less muscle strength, feels weak, and whether the individual can think as clearly as usual. These are symptoms that overlap with daytime complaints often described by people with insomnia (Moul et al., 2002). An obvious conclusion is that insomnia and fatigue have overlapping rather than distinct clinical constructs. It is possible that the levels of CF identified in this study might represent fatigue that has arisen in the wake of having insomnia, but there are other possibilities, for example, the individual might experience fatigue and tiredness as a side-effect of medication (as medication for insomnia may have daytime sedative effects, etc.).

We found significant improvements in psychological distress for individuals with and without CF who received dCBT-I compared with PE. Psychological distress is highly correlated with both insomnia and fatigue (Nishiura et al., 2015; Theobald, 2004), and there is substantial research that demonstrates that sleep difficulties contribute to anxiety and depression (Baglioni et al., 2011; Hertenstein et al., 2019). This may be a bidirectional relationship as CF can lead to more psychological distress and poor sleep (Steptoe et al., 2008). Improvement in psychological distress has been identified as important for outcome and response to treatment in individuals with CF (Hadlandsmyth & Vowles, 2009). Hence, this may have influenced improvements on other parameters such as insomnia severity. Future research should investigate in what way reduction of psychological distress may mediate treatment outcome following dCBT-I.

There are some limitations that should be considered when interpreting our results. First, our results present as a secondary analysis, and therefore the power calculations were determined for a previously reported RCT (Vedaa et al., 2020). However, the trial was powered to be able to perform moderator analyses, and the large sample size allows for moderator analyses with appropriate statistical methods. Second, the CF categorization was based on self-reported levels of fatigue rather than clinical diagnostic assessments. However, we used a more strict definition than reported in previous studies (Kallestad et al., 2015; Loge et al., 1998) to determine the CF categorization, and our definition is in line with diagnostic criteria for CF syndrome (Sharpe, 1991). Similar criteria have been employed previously to categorize CF cases in the Norwegian population (Loge et al., 1998). Nonetheless, the self-reported CF and the broad variety of defining and measuring CF (Bathen et al., 2022; Finsterer & Mahjoub, 2014) reduces generalization of our results across different medical disorders. Also, insomnia was determined by the ISI rather than clinical diagnostic assessment. Because most existing studies that report outcomes of sleep in participants with CF have employed a brief sleep measure (Jenkins et al., 1988; Russell et al., 2017), the ISI as an outcome measure is a strength of our study and it is a recommended outcome in insomnia research (Bastien et al., 2001; Riemann et al., 2017). Another limitation is that we did not screen participants specifically for restless legs syndrome. Lastly, this study focuses on immediate post-intervention outcomes. We do not know if the findings show further change during extended follow-up, which is information that could provide insights into mechanisms of CF and insomnia.

In addition to extended follow-ups, we suggest that future studies include fatigue-specific components to dCBT-I for those who experience fatigue, and test if this improves daytime symptoms such as fatigue and physical function. Although we did not find any moderators in this study, previous studies have demonstrated that improvements in insomnia have mediated and predicted outcomes in fatigue following other psychological interventions (Heckler et al., 2016; Kallestad et al., 2015). A previous study has highlighted that the subjective perception of sleep quality predicts fatigue the following day in individuals with CF syndrome (Russell et al., 2016), and the inclusion of sleep diaries to mediation analyses could further clarify the relationship between attitudes and beliefs towards rest and sleep. Moreover, to investigate the fluctuating nature of fatigue, future studies should measure fatigue frequently during and after treatment to exhibit a comprehensive understanding of mechanisms of change.

In conclusion, our results demonstrate that participants with high levels of self-reported fatigue and insomnia yield significant improvements in insomnia symptoms following dCBT-I. This has clinical implications that are relevant to the management of insomnia, as fatigue is among the most commonly reported comorbid symptoms. Moreover, this may further establish dCBT-I as an adjunctive intervention in individuals with physical and mental disorders.

AUTHOR CONTRIBUTIONS

Patrick Faaland: investigation, data curation, writing – review and editing, supervision, formal analyses. Jan Scott: conceptualization, methodology, investigation, writing – review and editing. Simen Berg Saksvik: conceptualization, writing – review and editing, supervision. Stian Lydersen: methodology, formal analyses. Øystein Vedaa: conceptualization, investigation, data curation, project administration, resources, writing – review and editing. Nikolaj Kahn: writing – review and editing. Knut Langsrud: conceptualization, methodology, investigation. Tore C. Stiles: conceptualization, writing – review and editing. Lee M. Ritterband: conceptualization, writing – review and editing, resources. Allison G. Harvey: conceptualization, writing – review and editing. Børge Sivertsen: conceptualization, methodology, investigation, funding acquisition. Håvard Kallestad: conceptualization, methodology, investigation, supervision, project administration, resources, writing – review and editing, funding acquisition. Lina Stålesen Ramfjord: writing – original draft, data curation, investigation, formal analyses.

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CONFLICT OF INTEREST STATEMENT

LMR report financial or business interests in BeHealth Solutions and Pear Therapeutics, two companies that develop and disseminate digital therapeutics (including by licensing the therapeutic developed) based in part on early versions of the software from the University of Virginia, which is used in the research reported in this article. These companies had no role in preparing this manuscript. LMR is also a consultant to Mahana Therapeutics, a separate digital therapeutic company not affiliated with this research. All other authors declare no competing interests.

DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions. The data that support the findings of this study are available on request from

the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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