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Dysfunctional beliefs and attitudes about sleep (DBAS) mediate outcomes in dCBT-I on psychological distress, fatigue, and insomnia severity☆

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ABSTRACT

Objective/background: Digital cognitive behavioral therapy for insomnia (dCBT-I) improves several sleep and health outcomes in individuals with insomnia. This study investigates whether changes in Dysfunctional Beliefs and Attitudes about Sleep (DBAS) during dCBT-I mediate changes in psychological distress, fatigue, and insomnia severity.

Patients/methods: The study presents a secondary planned analysis of data from 1073 participants in a randomized control trial (Total sample = 1721) of dCBT-I compared with patient education (PE). Self-ratings with the Dysfunctional Beliefs and Attitudes about Sleep (DBAS), the Hospital Anxiety Depression Scale (HADS), the Chalder Fatigue Scale (CFQ), and the Insomnia Severity Index (ISI) were obtained at baseline and 9-week follow-up. Hayes PROCESS mediation analyses were conducted to test for mediation.

Results and conclusion: sDBAS scores were significantly reduced at 9-week follow-up for those randomized to dCBT-I (n = 566) compared with PE (n = 507). The estimated mean difference was −1.49 (95% CI -1.66 to −1.31, $p < .001$, Cohen's *d.* = 0.93). DBAS mediated all the effect of dCBT-I on the HADS and the CFQ, and 64% of the change on the ISI (Estimated indirect effect −3.14, 95% CI -3.60 to −2.68) at 9-week follow-up compared with PE.

Changes in the DBAS fully mediated the effects of dCBT-I on psychological distress and fatigue, and the DBAS partially mediated the effects on insomnia severity. These findings may have implications for understanding how dCBT-I works and highlights the role of changing cognitions in dCBT-I.

1. Introduction

Cognitive behavioral therapy for insomnia (CBT-I) is a preferred treatment for chronic insomnia [1,2]. The gold standard approach for CBT-I is Face-to-Face therapy, but increasing evidence demonstrates that the therapy can be delivered via online or app programs (so-called digital CBT-I; dCBT-I) [3–5]. dCBT-I can potentially address the difficulty individuals with insomnia face in accessing treatment [6]. Both Face-to-Face CBT-I and dCBT-I are more efficacious than psychoeducation or sleep hygiene interventions, with large effect sizes for improvement across a range of sleep, psychosocial and functional

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Abbreviations:

CBT	Cognitive Behavioral Therapy
dCBT-I	Digital Cognitive Behavioral Therapy for Insomnia
CBT-I	Cognitive Behavioral Therapy for Insomnia
CFQ	Chalder Fatigue Scale
ISI	Insomnia Severity Index
DBAS	Dysfunctional Beliefs and Attitudes about Sleep
HADS	Hospital Anxiety Depression Scale
CI	Confidence Interval
PE	Patient Education
SHUTi	Sleep Healthy Using the Internet
SD	standard deviations
CI	Confidence Interval
RCT	Randomized Controlled Trial

outcomes for individuals with insomnia [3,5,7,8]. Despite this evidence of efficacy, about 20%–30% of individuals offered CBT-I, and 30%–60% of individuals offered dCBT-I do not demonstrate clinically significant benefits [4,5,9,10]. Although the effects of the treatment have been widely studied, there has been comparatively little research on mediators of the effects of CBT-I and dCBT-I [3,11,12]. To identify potential mediators of intervention outcomes might help provide a better understanding of how the intervention works [11,13], and provide information that can guide the further development and integration of more targeted therapeutic interventions.

An important therapeutic component of CBT-I is changing dysfunctional beliefs and attitudes about sleep, most often assessed with the Dysfunctional Beliefs and Attitudes about Sleep scale (DBAS) [14]. Dysfunctional beliefs and attitudes are negative, unrealistic worries, biases, or faulty sleep-related cognitions, that perpetuate or exacerbate insomnia [15]. Most dCBT-I interventions include strategies for recognizing and modifying such beliefs [4] and encourage changes in behavior patterns that may lead to changes in unhelpful or maladaptive sleep-related cognitions [16]. In a recent meta-analysis Thakral et al. (2020) found moderate to large effect size (g = −0.90, 95% CI -1.19, −0.62) improvements in the Dysfunctional Beliefs and Attitudes about Sleep (DBAS) after CBT-I, though there were considerable differences in the studies included and the variance in effect size was between Hedges's g −0.05 and −2.09 [13]. Moreover, in another recent meta-analysis of mediators of changes in CBT-I, based on seven studies that reported outcomes on the DBAS, the authors found that changes in the DBAS mediate insomnia symptoms following CBT-I and dCBT-I [17]. This indicates that changes in dysfunctional beliefs about sleep, as assessed by the DBAS, may be an important target for change in insomnia severity following CBT-I [18,19].

Fatigue and psychological distress are also common daytime complaints of individuals with insomnia [20]. Between 20% and 33% of individuals with insomnia report "severe" and elevated levels of both fatigue and psychological distress [21]. Both CBT-I and dCBT-I have shown promise in improving psychological distress and fatigue in individuals with insomnia [4,5,7,11,22–27] without an established mediator for explaining these changes. However, studies on individuals with depression, anxiety, and fatigue have found that changes in symptom-related dysfunctional beliefs mediate the treatment outcomes following CBT [28–30]. As such, it is plausible that changes in dysfunctional beliefs about sleep, as assessed with the DBAS, might be a potential mediator of improvements in fatigue and psychological distress among individuals with insomnia who receive CBT-I. However, there are gaps in the evidence base and uncertainty related to whether changes in dysfunctional beliefs and attitudes about sleep also mediate changes in psychological distress and fatigue following dCBT-I.

Moreover, due to the varying effect size found following dCBT-I on DBAS, and different mediation effects found in studies of insomnia severity, there is a need for more data from large-scale trials that may provide more precise estimates. The current study represents a secondary analysis of data from a recently published RCT on the effects of dCBT-I compared with patient education about insomnia (PE) in a large community-based sample of adults with self-reported insomnia [5].

Our primary aim was to investigate if the DBAS mediates changes in psychological distress and fatigue at 9-week follow-up. A secondary aim was to investigate the effect of dCBT-I on DBAS, and if DBAS mediates the effect of dCBT-I on levels of insomnia severity at 9-week follow-up.

2. Method

2.1. Design

This is a secondary analysis of data from a community-based sample of 1721 Norwegian adults with self-reported insomnia recruited to a parallel group superiority RCT of dCBT-I compared with PE. Details of the study protocol, procedures, and key outcomes are published elsewhere [5,31]. The trial is registered on clinicaltrials.gov (registration number: NCT02558647) and was approved by the Regional Committee for Medical and Health Research in South-East Norway (2015/134).

2.2. Participants

Participants were recruited from February 2016 through August 2018. Participants completed an online screening procedure that included an online written informed consent form. Inclusion criteria were: age ≥18 and a score ≥12 on the Insomnia Severity Index (ISI) [32]. Exclusion criteria were: scored ≥10 on the Epworth Sleepiness Scale, and/or self-reported symptoms of sleep apnea, other self-reported medical conditions that may be a contra-indication for CBT-I (e.g., recent myocardial infarct); and/or being engaged in night work.

2.3. Procedure

Participants completed baseline assessments and were subsequently randomized to either dCBT-I or PE. All participants completed the same self-reported assessments following the 9-week intervention period (i.e. 9-week follow-up).

Digital CBT-I (dCBT-I): Sleep Healthy Using the Internet (SHUTi) is an online, evidence-based program designed to help individuals overcome insomnia. It delivers the primary components of CBT-I, including stimulus control, sleep restriction, cognitive restructuring, sleep hygiene, and relapse prevention, in an engaging and interactive format [33]. One of the key features of SHUTi is its personalized approach. Users go through an initial assessment process, where they provide information about their sleep patterns, habits, and concerns as well as desired goals. Based on this information, the program tailors the intervention to meet each individual's specific needs. Personalization helps to maximize the effectiveness of the program and ensures that participants receive the most relevant and targeted strategies and techniques for improving their sleep.

Throughout program use, participants track their sleep patterns and progress using interactive tools and sleep diaries. They receive feedback and recommendations based on their data, enabling them to monitor their improvement and make necessary adjustments. There are six cores to SHUTi with each core becoming available seven days after the completion of the previous one (see Table 1 for core details). Cores are designed to contain the essential treatment elements of CBT-I and consist of objectives, review and feedback of the submitted sleep diary data, new content, and instructions on what to do with respect to sleep in the subsequent week. Each core typically requires between 45 and 60 min to complete. For a more detailed description of SHUTi, see Thorndike et al., 2008 [34].

Patient education (PE): The PE group received access to a website

Table 1
Description of sessions during the intervention.

	Description of session
Core 1: Overview	Reviews the nature of insomnia and how the programme works; the participants identify their sleep problems and set up personal treatment goals
Core 2: behaviour and sleep 1	Focuses on how behavioral changes can improve sleep, with a special emphasis on sleep restriction
Core 3: behaviour and sleep 2	Focuses on how behavioral changes can improve sleep, with a special emphasis on stimulus control
Core 4: sleep and thoughts	Focuses on addressing and changing beliefs and thoughts that might impair sleep (e.g., excessive worrying about the possible consequences of insomnia)
Core 5: sleep hygiene	Educates about lifestyle and environmental factors that might interfere with sleep (e.g., caffeine and nicotine intake, and electronic media use in bed)
Core 6: relapse prevention	Focuses on integrating the behavioural, educational, and cognitive components from the former cores to develop strategies to avoid future episodes of poor sleep from developing into chronic insomnia

Notes.

containing information on sleep hygiene and education about insomnia. The PE website consisted of static text made available for the participants immediately after the baseline assessment, and the content could be accessed throughout the study period. The participants in the PE group were encouraged to visit the website at the start of the study without further notifications or encouragement to use the content. Both the dCBT-I and PE conditions incorporated basic CBT-I principles, although PE received this information in a short and very simplified form. Further, the PE site did not have online tools for self-monitoring or feedback.

2.4. Data extraction

For the purposes of this study, we extracted de-identified individual data from baseline and 9-week (post-intervention) follow-up assessments for the following measures:

The Dysfunctional Beliefs and Attitudes about Sleep scale (DBAS): The DBAS consists of 16 items assessing sleep-related cognitions [35]. The items are rated on a 10-point Likert scale from 0 to 10, indicating to what degree the participant agrees with the statement. The total score ranges from 0 to 160, where higher scores indicate a greater agreement with the statements.

The Hospital Anxiety and Depression Scale (HADS): The HADS consists of 14 items concerning symptoms of anxiety and depression to assess general psychological distress. The items are rated on a 4-point Likert scale from 0 to 3, with a range from 0 to 42 [36]. The total score was used as a measure of psychological distress, with higher scores indicating more psychological distress.

The Chalder Fatigue Scale (CFQ): The CFQ consists of 13 items addressing physical and psychological fatigue, including two items addressing the duration and intensity of fatigue complaints. Each item is scored on a 4-point scale ranging from asymptomatic to maximum symptomatology. A composite score is calculated by combining the 13 items, with a total fatigue scale ranging from 0 to 39 points. Higher scores indicate more fatigue symptoms [37].

The Insomnia Severity Index (ISI): The ISI consists of seven items that assess the participants' overall level of insomnia severity [38]. The items are rated on a 5-point Likert scale from 0 to 4, and the total score ranges from 0 to 28. Higher scores indicate greater insomnia severity. The ISI has good psychometric properties [38,39].

2.5. Statistical analysis

Descriptive statistics are reported as means and standard deviations (SD) or counts and percentages. Mediation analyses were undertaken using the PROCESS package (simple model for mediation 4) [40]. This package implements a series of regression analyses and estimates the direct and indirect effects of a predictor (X) on an outcome of interest (Y) considering the role of the intermediately variable as mediator (M). Age, sex, and baseline values of Y (ISI, HADS, and CFQ) and M (DBAS) were included as covariates. Groups (dCBT-I and PE) were included as X within the three mediator analyses. The 95% confidence intervals (CI) of the direct and the indirect effect were obtained via bootstrapping with 10,000 bootstrap samples. The percentage of mediation was calculated by dividing the indirect effect by the total effect. Individuals with missing data were excluded from the mediator analysis. Demographic and clinical variables characteristics at baseline for participants who were included (n = 1073) or excluded (n = 648) in PROCESS mediator analysis are shown in Supplement table 1.

Initially, we performed a linear mixed model to test if dCBT-I is associated with a reduction in the DBAS score between baseline and 9-week assessments, compared with PE. The individual was included as a random effect, we adjusted for baseline as recommended by others [41]. Standardized effect sizes (Cohen's *d*) were calculated for the between-group assessments using (mean score for group 2 – mean score for group 1)/SD_{pooled} at baseline. Normality of residuals was checked by visual inspection of QQ plots. Statistical analyses were conducted using SPSS 25, and we regarded two-sided p-values less than 0.05 to indicate statistical significance for all analyses.

3. Results

In the total sample of N = 1721, 1167 (68%) participants were female, with a mean (SD) age of 44.8 (14.2) years. Mean (SD) baseline demographic and clinical variables scores are shown in Table 2.

The mediation analyses of the DBAS included 1073 individuals (62%) of the original sample. Mediator analysis is shown in Table 3. There were no significant differences in the demographic (age, sex) and clinical variables (ISI, HADS, CFQ, DBAS) at baseline between the individuals who were included versus those who were excluded from the main analyses, see supplement table 1.

As shown in Fig. 1, there was no significant difference between treatment groups on the HADS at 9-week follow-up when including the DBAS as a mediator, and changes in the DBAS mediated the treatment effects on the HADS at 9-week follow-up. The total, direct and indirect effects are shown in Table 3. The DBAS mediated all the effect of dCBT-I on the HADS at 9-week follow-up compared to PE.

As seen in Fig. 2, there was no significant difference between treatment groups on the CFQ at 9-week follow-up, when including the DBAS as a mediator, and changes in the DBAS mediated the treatment effects on the CFQ at 9-week follow-up. The total, direct and indirect effects are shown in Table 2. The DBAS mediated all the effect of dCBT-I on the CFQ at 9-week follow-up compared to PE.

Significant differences were found on the DBAS scores at 9-week follow-up between dCBT-I (mean 3.7, SD 2.0, n = 566) and PE (mean 5.3, SD 1.8, n = 507), with an estimated mean difference of −1.49 (95% CI -1.66 to −1.31, $p < .001$, Cohen's $d. = 0.93$). As shown in Fig. 3, there

Table 2
Demographic and clinical variables characteristics at baseline for participants who were allocated to either dCBT-I (n = 867) or PE (n = 853).

	dCBT-I		Patient Education (PE)	
Age Mean (SD)	44.2	13.9	44.8	13.7
Gender (%) female	596	69	571	67
Employed (%) Yes	589	68	601	70
Years of Education Mean (SD)	16.4	3.0	16.2	2.9
Marital status (%) married	538	62	535	63
Living with children (%) Yes	303	35	318	37
ISI Baseline Mean (SD)	19.2	3.9	19.6	4.0
HADS Baseline mean (SD)	13.2	6.9	13.4	7.2
CFQ Baseline mean (SD)	20.8	5.9	20.9	6.0
DBAS Baseline mean (SD)	5.9	1.6	6.0	1.6

Table 3
Mediator analyses with groups dCBT-I and PE as predictor (X), ISI, CFQ and HADS as outcome (Y) and DBAS at 9-week follow-up as mediator (M).

	Total effect (c)			Direct effect (c')			Indirect effect (c-c')	
	Estimate	SE	p value	Estimate	SE	p value	Estimate	BootCI
DBAS on ISI	−4.91	0.32	<0.001	−1.77	0.30	<0.001	−3.14	−3.60 to −2.68
DBAS on HADS	−1.25	0.30	<0.001	0.37	0.32	0.251	−1.61	−1.97 to −1.28
DBAS on CFQ	−2.38	0.38	<0.001	0,10	0.39	0.790	−2.48	−2.97 to −2.01

Notes: Three mediator analysis for each outcome variable (Y). Covariates: Gender, age, and baseline values of X and Y.

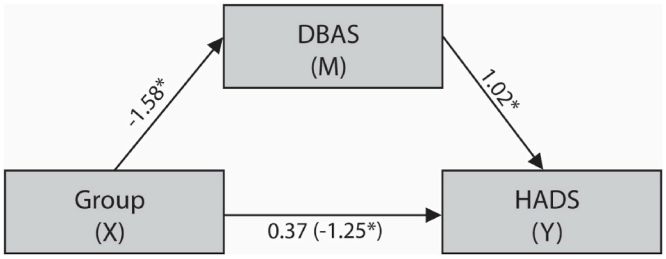

Fig. 1. Mediation model with Dysfunctional Beliefs and Attributes about Sleep (DBAS) as mediator, dCBT-I and PE as predictor (Group) and Hospital Anxiety and Depression Scale (HADS) as outcome. Beta values represent unstandardized regression coefficients. Value in parenthesis represents total effect. Covariates: Age, gender, baseline values of DBAS and HADS. *: p < .0001.

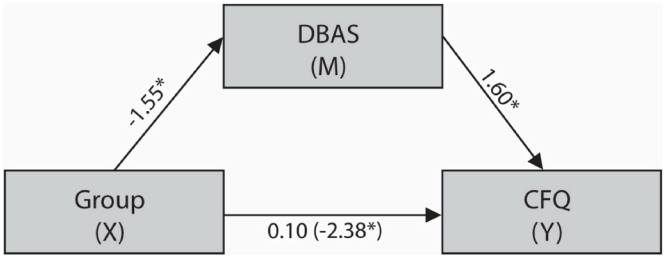

Fig. 2. Mediation model with Dysfunctional Beliefs and Attributes about Sleep (DBAS) as mediator, dCBT-I and PE as predictor (Group) and Chalder Fatigue Scale (CFQ) as outcome. Beta values represent unstandardized regression coefficients. Value in parenthesis represents total effect. Covariates: Age, gender, baseline values of DBAS and CFQ. *: p < .0001.

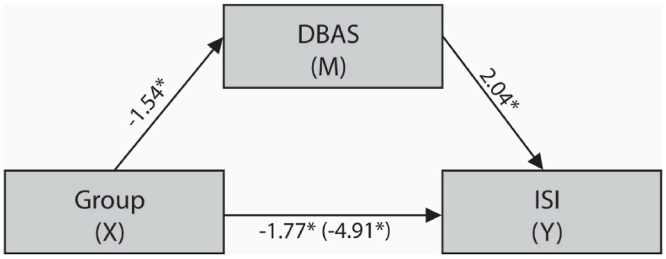

Fig. 3. Mediation model with Dysfunctional Beliefs and Attributes about Sleep (DBAS) as mediator, dCBT-I and PE as predictor (Group) and Insomnia Severity Index (ISI) as outcome. Beta values represent unstandardized regression coefficients. Value in parenthesis represents total effect. Covariates: Age, gender, baseline values of DBAS and ISI. *: p < .0001.

were significant differences on both the DBAS and the ISI between therapy groups (i.e., PE and dCBT-I) at 9-week follow-up when including the DBAS as a mediator, and changes in the DBAS mediated the treatment effects on the ISI at 9-week follow-up. The total, direct and indirect effects are shown in Table 3. The DBAS partially mediates the change on the ISI (accounts for 64% of the change on ISI), at 9-week follow-up compared to PE.

4. Discussion

This study examined whether the DBAS mediated the effect of dCBT-I on psychological distress, fatigue and insomnia severity following a 9-week intervention period compared to PE. Changes in the DBAS fully mediated the changes on the HADS and the CFQ, after dCBT-I compared with PE. A greater reduction of the DBAS scores was found after dCBT-I compared with PE, with a large effect size. Additionally, the DBAS partially mediated the changes in insomnia severity after dCBT-I compared with PE, accounting for 64% of the improvement on the ISI.

To our knowledge, no previous dCBT-I studies have investigated whether dysfunctional beliefs about sleep mediate changes in psychological distress and fatigue in individuals with insomnia. CBT-I and the dCBT-I intervention used in the present study have been shown to be associated with small to large effect size improvements on psychological distress and fatigue [5,8,11]. The DBAS has also been shown to correlate highly with depressive symptoms, insomnia severity and anxiety symptoms [15]. In other study populations, general and disorder-specific dysfunctional beliefs mediate the effects of CBT on outcomes of anxiety, depression, obsessive-compulsive disorder, and fatigue [28,30,42,43]. One explanation for how changes in dysfunctional beliefs about sleep affected both psychological distress and fatigue in our study might be understood through the impact of thoughts on physiological sensations, emotions, and behavior [44].

In the Harvey (2002) cognitive model for insomnia, dysfunctional beliefs about sleep are proposed to play a key role in maintaining insomnia and the associated impact on daytime functioning. Specifically, dysfunctional beliefs about sleep are proposed to increase worry and rumination. These negatively toned thoughts are proposed to increase arousal and increase bias attention towards monitoring of sleep-related threats in an escalating cycle [45]. In light of our findings, we theorize that changes in dysfunctional beliefs reduce psychological distress and reduce daytime fatigue through the reduction of rumination and worry behavior. However, arousal-related behavior, like rumination and worry, might have overlapping mediating effects on both fatigue and psychological distress. A large scale RCT from Cheng and colleagues (2020) showed that rumination partial mediates insomnia severity and depressive symptoms after dCBT-I [46]. Future research should investigate if reduction in arousal-related behavior might be a key mechanism by which dCBT-I reduces daytime symptoms such as psychological distress, and fatigue.

Our findings also extend to previous studies that examine the effect of dCBT-I in reducing the DBAS, which have shown effect size changes varying from −0.05 to −2.09 (mean Hedges's g of −0.9) [13], with change in the DBAS accounting for a between 42 and 64% of the change in the ISI [17]. The high variance in effect size in previous studies of CBT-I might be explained by differences in the samples, sample sizes, and interventions delivered. In terms of the observed total effect on the ISI and the mediating effect of the DBAS on the ISI, we found somewhat larger total effects. This indicates that in this study, the DBAS explains more of the changes on the ISI compared with the estimated effect sizes and mean percentage of mediation from a newly published metanalysis [17].

Clinically, these findings highlight the importance of dysfunctional beliefs about sleep for understanding insomnia and treatment with dCBT-I. Sleep restriction might play an important role in changing

dysfunctional beliefs [47] as it decreases sleep onset latency and improves sleep maintenance [48]. It is likely that repeated positive sleep experiences challenge and change dysfunctional beliefs about sleep and create new narratives. The dCBT-I intervention used in this study includes a cognitive restructuring module in which potentially dysfunctional beliefs and attitudes about sleep are challenged. Participants are offered strategies to adopt more appropriate ways to deal with sleep and sleep difficulties. An interesting domain for future research would be to investigate how dCBT-I changes dysfunctional beliefs about sleep.

Taken together, our findings demonstrate that dysfunctional beliefs about sleep mediate changes in symptoms of psychological distress, fatigue, and insomnia severity after dCBT-I. Changes in the DBAS fully mediated changes on the CFQ and the HADS after dCBT-I compared with PE. Additionally, the DBAS partially mediated the improvement on insomnia severity. These findings emphasize the importance of the cognitive components of dCBT-I and how modified beliefs and reduced dysfunctional attitudes and beliefs about sleep lead to symptomatic improvement, both on insomnia severity, daytime function, and psychological distress.

5. Strengths and limitations

The large sample size and the RCT design are major strengths of the present study. The sample size of this study provides sufficient statistical power to detect effects with higher precision compared with previous studies and, in addition, enables robust mediation analyses. However, our findings should also be evaluated in light of some limitations. First, participants in this trial were primarily self-referred. Thus, self-selection bias may have occurred. Second, at 9-week follow-up, half of the participants did not complete the assessment. However, this follow-up completion rate is within the range of comparable RCT studies [7,8,33]. Third, the mediation analysis can be biased by hidden confounding factors between the mediator and outcome, and the mediator of this study was only measured at baseline and follow-up. Future studies should include more timepoints for the DBAS and the outcome variable [13]. Last, this RCT did not include a third arm (no intervention), thus we do not know the impact of the passage of time on the outcomes reported herein.

Statement from authors

All authors have seen and approved the manuscript.

Declaration for clinical trials

The trial is registered on clinicaltrials.gov (registration number: NCT02558647) and was approved by the Regional Committee for Medical and Health Research in South-East Norway (2015/134).

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CRediT authorship contribution statement

Patrick Faaland: Writing – original draft, Data curation, Investigation. **Øystein Vedaa:** Conceptualization, Methodology, Investigation, Data curation, Supervision, Project administration, Resources, Writing – review & editing. **Knut Langsrud:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Børge Sivertsen:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Funding acquisition. **Stian Lydersen:** Methodology, Formal analysis, Writing – review & editing. **Simen Berg Saksvik:** Data curation, Investigation, Data curation, Writing – review & editing, Visualization. **Cecilie L. Vestergaard:** Data curation, Investigation, Writing – review & editing. **Kaia Kjørstad:** Investigation, Writing – review & editing. **Daniel Vethe:** Investigation, Writing – review & editing. **Lee M. Ritterband:** Conceptualization, Writing – review & editing, Resources. **Allison G. Harvey:** Conceptualization, Writing – review & editing. **Tore C. Stiles:** Conceptualization, Writing – review & editing. **Jan Scott:** Conceptualization, Methodology, Investigation, Supervision, Writing – review & editing. **Håvard Kallestad:** Conceptualization, Methodology, Investigation, Supervision, Project administration, Resources, Writing – review & editing, Funding acquisition.

Declaration of competing interest

Lee M. Ritterband reports 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. Lee M. Ritterband is also a consultant to Mahana Therapeutics, a separate digital therapeutic company not affiliated with this research. All other authors declare no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2023.07.018.

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