Graduate thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Psychology

Mai Sharoni

The outcome effects of change in intraindividual variability in sleep timing in a randomized controlled trial comparing face-to-face Cognitive Behavioral Therapy (CBT) to digital CBT for patients with insomnia

Graduate thesis in Clinical Psychology Programme, 6 years

Supervisor: Tore Stiles

January 2021

NTNU
Norwegian University of
Science and Technology

Mai Sharoni

The outcome effects of change in intraindividual variability in sleep timing in a randomized controlled trial comparing face-to-face Cognitive Behavioral Therapy (CBT) to digital CBT for patients with insomnia

Graduate thesis in Clinical Psychology Programme, 6 years
Supervisor: Tore Stiles
January 2021

Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Psychology

NTNU
Norwegian University of
Science and Technology

Preface

This graduate thesis marks the finalization of a 6-year degree in clinical psychology from the Norwegian University of Science and Technology (NTNU). I have long been fascinated by the seemingly magic world of sleep and interested in making it a little more comprehensible. Therefore, I decided to devote my thesis work to exploring this field of study. For making this work possible, I would like to thank Trondheim Sleep And Chronobiology Research group (SACR) for letting me use data from the Norse 2 study, Tore Stiles, Håvard Kallestad and Daniel Vethe for guiding me in developing the research questions, and Cecilie Lund Vestergaard for helping me in the analysis of the data. I would also like to thank Håvard Kallestad and Tore Stiles for supporting and guiding me at different crucial points of the work associated with this thesis. I want to thank Allison Harvey at the University of California, Berkeley, for supervising and supporting me in the writing of the introduction. I would like to give a special thanks to Cecilie Lund Vestergaard for encouraging, guiding and supervising me throughout the majority of the work on this thesis, both in person and digitally, and for reading through several drafts to make the thesis reach its final point of submission.

Finally, I would like to thank my parents, Ilan and Tamar Sharoni, and my dear friend, Marion Fløysvik, for their feedback and for motivating me when I was struggling. Thank you to my partner, Eric Shaw, for your support, for being a native English-speaking proofreader of this thesis, and for never letting me give up. Lastly, a thank you to all who have supported me, given me feedback, and asked questions that have reminded me of how interesting this field and my research topic are.

List of Abbreviations and Acronyms

CBT-I……..Cognitive Behavioral Therapy for Insomnia

dCBT-I……digital Cognitive Behavioral Therapy for Insomnia. Generally used as an umbrella term for partially of fully digitally administered CBT-I. In this thesis dCBT-I refers to the Fully Automated dCBT-I program used in the current trial, namely Sleep Healthy Using The internet (SHUTi)

DSM-V…..…Diagnostic and Statistical Manual of Mental Disorders, fifth edition

F2F…..……...Face to Face

HADS……Hospital Anxiety and Depression Scale

IIV…….Intraindividual variability

ISI……..Insomnia Severity Index

SACR……Trondheim Sleep And Chronobiology Research group

SHUTi..…..…Sleep Healthy Using The internet

Abstract

Background and aims: Cognitive Behavioral Therapy for Insomnia (CBT-I) is effective in treating insomnia, but its action mechanisms are less known. One presumed key action mechanism is reducing variability in sleep timing. This thesis examines whether intraindividual variability (IIV) in bed-and-risetime, respectively, is reduced following CBT-I. Further, it compares face-to-face (F2F) CBT-I with digital CBT-I (dCBT-I) in their effect on reducing IIV in bed-and-risetime. Lastly, associations between changes in bed-and-risetime IIV and changes in insomnia symptoms and psychological distress are examined.

Methods: One hundred and one participants diagnosed with insomnia were randomized to F2F CBT-I (n=52) or dCBT-I (n=49). Participants completed sleep diaries, the Insomnia Severity Index (ISI), and the Hospital Anxiety and Depression Scale (HADS), at baseline, treatment termination, and 6 months follow-up. Statistical analyses were performed using dependent and independent samples t-tests and hierarchical linear regression analysis.

Results: There were no significant decreases in either bed-or-risetime IIV during or following CBT-I (-10–12 minutes; p's≥.09), nor significant differences between F2F CBT-I and dCBT-I (3.0–13.2 minutes; p's>.10), at either treatment termination or follow-up. However, bedtime and risetime IIV significantly increased in the follow-up period (10.3–27.5 minutes; p's<.001). In contrast to what was expected, reductions in bedtime and risetime IIV were not significantly associated with decreased insomnia severity either during or following treatment (p's>.05), or with reductions in psychological distress during treatment (p's>.20). However, in the follow-up period reduction in IIV in bedtime, but not risetime, was significantly associated with lower levels of psychological distress (p=.006).

Conclusions: This study indicates that CBT-I, as administered in this trial, is not effective in decreasing bed-and-risetime IIV. Meanwhile, evidence is offered towards bedtime, rather than risetime, being important in reducing psychological distress, but not insomnia symptoms. However, this effect relies on longer-term behavioral change.

Keywords: sleep hygiene, intraindividual variability, CBT-I, dCBT-I, insomnia, psychological distress

Sammendrag

Bakgrunn og mål: Kognitiv Atferdsterapi for Insomni (CBT-I) er effektiv i behandling av insomni, men kunnskap om metodens virkemåter er mangelfull. En antatt virkemåte er å redusere variabilitet i stå opp og leggetid. Denne oppgaven undersøker om intraindividuell variabilitet (IIV) i stå opp og leggetid, respektivt, reduseres etter CBT-I. Videre sammenlignes ansikt-til-ansikt (F2F) CBT-I med digital CBT-I (dCBT-I), for deres effekt i reduksjon av IIV i stå opp og leggetid. Til sist undersøkes sammenhenger mellom endringer i IIV i stå opp og leggetid, og insomnisymptomer og psykologisk symptombelastning («distress»).

Metode: Hundre og en deltakere diagnostiert med insomni ble randomisert til F2F CBT-I (n=52) eller dCBT-I (n=49). Deltakerne fylte ut søvndagbøker, «Insomnia Severity Index» (ISI), og «Hospital Anxiety and Depression Scale» (HADS), prebehandling, ved behandlingsslutt og ved 6 måneders oppfølging. Avhengige og uavhengige t-tester og hierarkiske lineære regresjonsanalyser ble brukt i den statistiske analysen.

Resultater: Studien fant ingen signifikante reduksjoner i IIV i stå opp eller leggetid etterfølgende CBT-I (-10–12 minutter; p's≥.09), samt ingen signifikante forskjeller mellom F2F CBT-I og dCBT-I (3.0–13.2 minutter; p's>.10), verken ved behandlingsslutt eller ved 6 måneders oppfølging. Derimot fant studien en signifikant økning i IIV i både stå opp og leggetid i oppfølgingsperioden (10.3–27.5 minutter; p's<.001). Mot forventning var det ingen signifikante assosiasjoner mellom IIV i stå opp og leggetid og insomnisymptomer, verken under eller etter behandling (p>.05), og heller ikke mellom IIV og psykologisk distress under behandling (p>.20). I oppfølgingsperioden var derimot reduksjon i IIV i leggetid en signifikant predikator for reduksjon i psykologisk distress (p=.006).

Konklusjoner: Studien tyder på at CBT-I, slik den ble administrert, ikke er effektiv i å redusere IIV i stå opp og legge tid. Det er derimot evidens som tyder på at IIV i leggetid, heller enn stå opp tid, er den viktige faktoren for reduksjon av psykologisk distress. Dette imidlertid kun ved vedvarende reduksjon etter endt behandling.

Nøkkelord: søvnhygiene, intraindividuell variabilitet, CBT-I, dCBT-I, insomni, psykologisk distress

Table of Contents

Introduction

Relevance of the current study

Sleep and sleep health are becoming increasingly popular research topics. Reported sleep problems, especially insomnia – a diagnosis characterized by difficulties falling or staying asleep – are rising rapidly worldwide (Roth, 2007). The empirical knowledge in the field is, however, still in its infancy. Despite the lack of empirical evidence, there are many theories and "common knowledge facts" on how to improve sleep and what is healthy and unhealthy sleep behavior. Sleep behavior refers to the environmental factors and daily activities that are related to the maintenance of sleep quality and good daytime functioning, and is also referred to as sleep hygiene (American Academy of Sleep, 2005). Interventions relating to sleep hygiene are some of the most widely known methods for alleviating sleep problems (Harvey, 2000). One popular advice commonly given by professionals to improve sleep is to maintain a regular sleep schedule. That is, to go to bed and wake up at the same time every day, also known as keeping a low intraindividual variability (IIV) in one's bedtime and risetime. Maintaining a regular sleep schedule is also a key focus in Cognitive Behavioral Therapy for Insomnia (CBT-I), the intervention considered as the golden standard for treatment of sleep problems, specifically insomnia (Markwald et al., 2018; Morin et al., 2006; Wilson et al., 2010).

The rationale for keeping a low bedtime and risetime IIV is to regularize homeostatic processes related to sleep and to avoid changes in the patterns of light exposure, which in turn can shift both the circadian clock and homeostatic processes (Markwald et al., 2018). Shifts to the circadian clock and in homeostatic processes is for the body and brain like switching between time zones without the surrounding environment switching accordingly. This virtual travelling between time zones can consequently lead to and maintain sleep problems (Markwald et al., 2018). Meanwhile, the empirical fundament on the relation between insomnia treatment, IIV in bedtime and risetime, and treatment outcomes such as sleep quality and daytime functioning is sparse and mixed. There is some evidence showing that good sleepers, on average, do not have better sleep hygiene than insomnia patients (Harvey, 2000). Harvey (2000) did not find sleep hygiene, such as maintaining a consistent bed-and-risetime, to be a significant predictor of sleep health. These findings question the inclusion of stabilizing bed-and-risetime IIV in treatment models for insomnia, such as CBT-I.

Although there is good evidence of the effect of CBT-I for treating insomnia, lack of funding and knowledge within the mental health profession makes the treatment hard to access and limited for those in need. Different digital programs have and are being developed to deal with this lack of availability of insomnia treatments. Well-established and effective digital programs can significantly lower the costs and increase the availability of treatment. However, a digital program cannot provide the same amount of specific and tailored support as face-to-face (F2F) treatment. Amongst others in offering relief and support for difficult and worrying thoughts and emotions. Patients also have a tendency to comply more with F2F treatments than with digital treatments (Eysenbach, 2005; Lie et al., 2017). Maintaining a constant bedtime and risetime that is different from what an individual is used to requires a high amount of compliance. Consequently, there is reason to assume that F2F CBT-I would be better at creating a strong alliance with the patient and thus also lead to a greater reduction in bed-and-risetime IIV than digital CBT-I. Meanwhile, several studies have found digital CBT-I to be as effective as F2F CBT-I in other aspects of treatment such as reducing symptoms of insomnia (Freeman et al., 2017), anxiety and depression (Batterham et al., 2017) Ye et al., 2015). This gives reason to hypothesize that digital CBT-I could potentially also be as effective as F2F CBT-I in reducing bed-and-risetime IIV.

Finding empirical evidence of the effect of CBT-I on IIV in bedtime and risetime, both administered by a therapist and through a computer program, and finding a relation between IIV in bedtime and risetime and sleep quality and daytime functioning could add high value to optimizing interventions for improving sleep. Such research can in turn lead to further development in the field of sleep health holistically. The associations between CBT-I, IIV in bedtime and risetime and sleep quality and daytime functioning are thus the main focuses of the current thesis. Following is background information on insomnia, CBT-I, and bedtime and risetime IIV. Thereafter, the specific research questions and hypothesis of the thesis are presented. It is important to note that the current study does not assess the direct effect of CBT-I on treatment outcomes, but the associations between CBT-I, IIV in bedtime and risetime and specific treatment outcomes.

Insomnia

Prevalence, effects and costs

While humans can survive for up to a month without food, we can only survive for a mere week without sleep (Gooley, 2016). Good and sufficient sleep is essential for a healthy life, and sleep problems give rise to tremendous costs, both on an individual and societal level. Sleep disorders are a major worldwide problem, with insomnia being the most common. According to multinational studies, the worldwide prevalence of insomnia disorder ranges between approximately 4% and 22% depending on the diagnostic manual used (Roth et al., 2011), with an average prevalence of about 10% (Morin et al., 2015; Ohayon & Reynolds, 2009). The prevalence of insomnia symptoms is around 30-35% (Morin et al., 2015).

The costs of insomnia can be divided into direct, indirect, and emotional costs. The direct costs are the costs of treatment and medication that are directly associated with the insomnia symptoms. Indirect costs include reduced productivity, increased absenteeism, the short- and long-term costs of accidents related to insomnia, costs related to increased mortality and morbidity, and alcoholism amongst others. The emotional costs of insomnia are vast and include higher stress levels and reduced life satisfaction, not only for the person suffering from insomnia, but also for family, friends, colleagues and other peers (Stoller, 1997).

In addition to the effects described above, insomnia causes significant costs to individuals and societies associated with comorbid somatic and mental illnesses. Sivertsen et al. (2009) found that reporting symptoms of insomnia correlated significantly with reported pain conditions, different problematic mental conditions, and other conditions of uncertain etiology. Somatic complaints that are typically associated with reporting insomnia symptoms include gastrointestinal problems, tension headaches, nonspecific pains and aches, and allergies (Kales et al., 1984). Insomnia is also found to be a precursor for heart attacks (Carney et al., 1990). Mental health disorders and symptoms associated with insomnia include depression, anxiety, alcoholism and nicotine abuse, amongst others, with depression having the strongest correlations (Breslau et al., 1996; Carney et al., 1990; Kales et al., 1984; Simon & Vonkorff, 1997; Stoller, 1997). Although the direction of causality is unclear, the relationship between insomnia and other mental health and somatic complaints is likely to be reciprocal. Indeed, several studies show that treating the insomnia symptoms have a

significant treatment effect on other mental health problems as well as on psychosocial functioning (Germain et al., 2007; Krakow et al., 2001; Manber et al., 2008; Myers et al., 2011; Talbot et al., 2014).

The above described effects and cost of insomnia lead to an increased demand on health services and social services for affected individuals and their peers, compared to people who do not suffer from insomnia or insomnia symptoms (Sivertsen et al., 2009; Simon & Vonkorff, 1997; Stoller, 1997). According to Kessler et al. (2011) the provisional annual estimates of lost workdays due to insomnia in the US alone is 252.7 days a year, with a population-level human capita value of USD 63.2 million per year. In Norway, based on figures from Stoller (1997) and Kessler et al. (2011), and adjusted for population differences (Kallestad et al., 2018), the cost of reduced work force productivity is estimated to be approximately NOK 4 billion per year. The yearly cost of treatment of insomnia is estimated to NOK 1 billion, and the cost of fatigue related car accidents estimates are NOK 160 million (Kallestad et al., 2018; Kessler et al., 2011; Stoller, 1994, 1997). Taken together, the costs of insomnia globally and to Norway are staggering.

Diagnosis

The Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V) defines insomnia as "a predominant complaint of dissatisfaction with sleep quantity or quality, associated with one (or more) of the following symptoms: difficulty initiating sleep (…); difficulty maintaining sleep (…); early morning awakening with inability to return to sleep" (American Psychiatric Association, 2013, p. 362). The sleep related symptoms must lead to harmful dysfunction in important areas of life, such as work, school, or in relations with others. See Table 1 for the full diagnostic criteria. Insomnia is thus a subjective feeling of not getting enough sleep resulting in lowered life quality. The lack of a more objective diagnosis of insomnia shows how little is known about the condition. Considering the extensive effects described above, understanding the mechanisms underlying insomnia, and developing and disseminating effective interventions should be a high health priority.

Table 1

DSM-V diagnostic criteria for insomnia disorder (American Psychiatric Association, 2013, p. 362)

Name: Insomnia Disorder
Disorder Class: Sleep-Wake Disorders
A. A predominant complaint of dissatisfaction with sleep quantity or quality, associated with one (or more) of the following symptoms: 1. Difficulty initiating sleep. (In children, this may manifest as difficulty initiating sleep without caregiver intervention.) 2. Difficulty maintaining sleep, characterized by frequent awakenings or problems returning to sleep after awakenings. (In children, this may manifest as difficulty returning to sleep without caregiver intervention.) 3. Early-morning awakening with inability to return to sleep.
B. The sleep disturbance causes clinically significant distress or impairment in social, occupational, educational, academic, behavioral, or other important areas of functioning.
C. The sleep difficulty occurs at least 3 nights per week.
D. The sleep difficulty is present for at least 3 months.
E. The sleep difficulty occurs despite adequate opportunity for sleep.
F. The insomnia is not better explained by and does not occur exclusively during the course of another sleep-wake disorder (e.g., narcolepsy, a breathing-related sleep disorder, a circadian rhythm sleep-wake disorder, a parasomnia).
H. Coexisting mental disorders and medical conditions do not adequately explain the predominant complaint of insomnia.
G. The insomnia is not attributable to the physiological effects of a substance (e.g., a drug of abuse, a medication).

Treatment

The two most effective treatments of insomnia have been shown to be benzodiazepine-receptor agonists (BzRAs) and CBT-I (Morin & Benca, 2012). Advantages of medication are that they demand little time and effort from both health professionals and patients and can be easily distributed. Some of the disadvantages are the addictive nature of many pharmaceutical treatment options, and their costs, especially as they are often taken long term – despite recommendations of sleep medications being short-term solutions (Gabe et al., 2016; Kallestad et al., 2018). Moreover, while medications can treat the symptoms of insomnia, they do not address possible underlying problems (Tibbitts, 2008).

Advantages of CBT-I are that it has shown to have long-term effects, without patients having to continue long-term treatment (Edinger & Means, 2005), and it has significantly lower risks of side effects, relative to medication (Mitchell et al., 2012). CBT-I has clinically significant outcomes in treating and alleviating insomnia (Morin et al., 2006). Disadvantages of CBT-I are that it requires more effort and time of both the patient and the therapist in the short term. Reviews on a multitude of treatment studies have shown that 70%-80% of insomnia patients benefit from nonpharmaceutical treatment, with consistent positive effects over time (Morin et al., 2006). CBT-I is indeed considered the number one treatment choice for insomnia (Morin et al., 2006; Wilson et al., 2010).

Unfortunately, insomnia is not being given enough attention in the mental health sector. In a survey of 212 directors of clinical psychology graduate and internship programs, only 6% of the programs included courses on sleep disorders (Rosen et al., 1993). The problem is not lack of effective treatment, but the lack of education and dissemination, including education about assessment, diagnosis, and treatment, in addition to lacking financial support (Hagatun et al., 2018). This in turn limits the availability of treatment, especially nonpharmaceutical treatment, for people in need (Morin & Benca, 2012).

To enhance the availability of CBT-I, different digital intervention programs are being developed. Recent research is finding digital versions of CBT-I to be effective, both at treating insomnia, and comorbid problems, such as anxiety and depression symptoms (Christensen et al., 2016; Hagatun et al., 2018; Ye et al., 2015). Digital CBT-I comes in different versions. These are classified as Digital CBT-I as Support, Guided Digital CBT-I, and Fully Automated Digital CBT-I. Digital CBT-I as Support is F2F CBT-I that uses digital

components as a support for the in-person therapy. Guided digital CBT-I combines automated Digital CBT-I programs with therapist support, either through phone, email or in-person sessions. Fully Automated Digital CBT-I are fully automated and tailored programs that function without the need of therapist support, although in some programs, therapist support is still offered (Luik et al., 2017). As Fully Automated Digital CBT-I does not require therapist engagement, it has a greater capacity to be widely distributed, and is therefore regarded as a more viable solution for a widespread dissemination of CBT-I.

One Fully Automated Digital CBT-I program that is starting to prove effective in treating insomnia is Sleep Healthy Using The internet (SHUTi). SHUTi is an interactive digital computer programmed version of CBT-I, where each individual patient receives their own personalized CBT-I treatment, based on the information they report in the program. This intervention has the advantage of requiring minimal amount of time and effort from health professionals, in addition to avoiding the possible side effects of medications (Ritterband et al., 2009). There is an increasing base of evidence showing the effect of SHUTi in the treatment of insomnia. Recent research has shown that participants receiving SHUTi are more likely to report insomnia symptom remission than participants receiving online patient education (Kallestad et al., Submitted; Shaffer et al., 2020; Vedaa et al., 2020). In the current study, conventional F2F CBT-I is compared with SHUTi (hereafter referred to as dCBT-I).

IIV in bedtime and risetime

One of the core mechanisms of CBT-I is maintaining a regular bed-and-risetime, with the aim of finding a bedtime and risetime that is natural for the individual. Bedtime and risetime are sleep parameters that in theory can be changed by an individual without the need of tools or interventions from outside of the individual's own control or availability. Moreover, in insomnia disorder IIV in sleep timing constitutes an important clinical feature (Edinger et al., 1991; Thomas et al., 1981). However, despite being one of the key action mechanisms in CBT-I, there is little empirical evidence showing that CBT-I actually leads to a decrease in bed-and-risetime IIV, nor linking decreased IIV in bedtime and risetime with a decrease in insomnia symptoms and psychological distress. Being able to show whether CBT-I leads to a lowering in bedtime and risetime IIV and whether lowered bedtime and risetime IIV leads to a significant increase in sleep quality and psychological wellbeing, would be of high value for further development of CBT-I and other interventions for sleep problems. Furthermore, as the demand for F2F CBT-I is higher than the supply (Vedaa et al., 2020),

there is a high need for finding effective interventions that are less resource demanding and more easily distributable, such as dCBT-I. Meanwhile, F2F CBT-I has a therapist who can follow up an individual's bed-and-risetimes in a more complex way than a computer program. Additionally people tend to show a higher degree of compliance to in-person therapists than to digital programs. Thus, there is reason to assume that dCBT-I is less effective than F2F CBT-I in reducing IIV in bed-and-risetime. There is, however, no research on the relative effectiveness of F2F CBT-I compared with dCBT-I when it comes to stabilizing bed-and-risetime IIV.

Effects on health

Studies show that having higher IIV in bed-and-risetimes are associated with more frequent insufficient sleep (Strine & Chapman, 2005; Wittmann et al., 2006), a more negative mood (Bei, Manber et al., 2017), delayed circadian rhythm, weight gain, poorer academic performance (Phillips et al., 2017), poor metabolic health and increased insulin resistance (Gooley, 2016), and higher inflammatory biomarkers and responses (Irwin et al. 2016; Wright et al., 2015). Duncan et al. (2016) found that having bedtimes that varied more than 30 minutes was associated with more frequent insufficient sleep, higher sitting times, lower dietary quality, higher alcohol consumption and overall poorer patterns of lifestyle behaviors. They had similar, but less consistent findings for risetime variations. Interestingly, IIV in bedtime and risetime have been associated with specific demographic groups, where a higher bed-and-risetime IIV is found in the younger population, in non-white ethnicities, in single people, people with health conditions and in individuals with a higher BMI (Bei et al., 2016).

Some common causes of a high IIV are shift work, and circadian rhythm disorders, such as chronic jet lag. Studies on mice have found that constantly shifting sleep schedules increases mortality through tumor growth (Davidson et al., 2006; Filipski et al., 2004). Other studies show increased risk of heart disease and breast cancer in humans with chronic jet lag (Schernhammer et al., 2001; Vetter et al., 2016). A study of college students found that regular sleepers (where sleep/wake time varied less than 2 hours) had increased time in rapid eye movement (REM) and slow wave sleep and better mood and psychomotor performance than irregular sleepers (where sleep/wake time varied more than 2 hours) (Phillips et al., 2017). Regular sleepers also reported getting more sleep during the clock night (22:00-10:00) than the clock day (10:00-22:00) while irregular sleepers reported poorer sleep quality and got less sleep during the clock night and more during the clock day (Phillips et al., 2017).

Moreover, studies on adults have shown a higher IIV in bed-and-risetime to be associated with poorer somatic and mental health and insomnia (Bei et al., 2016). There is also some evidence suggesting that a high bed-and-risetime IIV plays a role in the onset and maintenance of depression, suggesting a link between bed-and-risetime IIV and mood disorders (Mullin et al, 2011).

According to Bei, Manber et al. (2017), the association between mood and bed-and-risetime IIV is mediated by perceived sleep quality. This is supported by findings showing that bed-and-risetime IIV are associated with subjective measures of sleep quality and mood in adolescent populations, where higher IIV in bedtime and risetime correlated with self-reported more negative mood and lower sleep quality (Bei, Manber et al., 2017). Interestingly, sleep irregularity, or high bed-and-risetime IIV, is not found to be correlated with sleep duration. This suggests that sleep schedule variability, independent of sleep deprivation, contributes to worsened health (Phillips et al., 2017), pointing out the importance of looking at these mechanisms separately.

Limitations in existing research

Despite all the negative consequences of an irregular sleep schedule found in the studies reviewed above, the overall literature on IIV in bedtime and risetime is sparse and unsystematic with inconsistent methodologies. Most of the existing research have small sample sizes, and no standardized procedures for measuring IIV in bedtime and risetime, nor for how to define high contra low bedtime and risetime IIV. In addition, findings on the clinical impact and relevance of IIV in bed-and-risetime to insomnia and other treatment outcomes are sparse and mixed (Bei et al., 2016; Sánches-Ortuño & Edinger, 2012). This is partially due to the lack of a well-established framework to understand the etiology of IIV in bed-and-risetime and associated mechanisms and effects. W there is substantial research associating a high bed-and-risetime IIV with poor health, and some have found bed-and-risetime IIV to be reduced by CBT-I (Bei et al., 2013; Sousa et al., 2013), there is no clear evidence linking the three variables together. Looking at daytime functioning, mood and reduction in insomnia severity after CBT-I treatment, there are no significant differences between individuals with low versus high pre -and -post treatment IIV in bedtime and risetime (Bei, Seeman et al., 2017; Bei et al., 2016). Furthermore, it is not yet known how much of a role IIV in bed-and-risetime plays in insomnia as a key symptom. While insomnia patients consistently show a greater self-reported IIV in bedtime and risetime, the findings from more

objective measures, such as actigraphs, are less consistent (Lemola et al., 2013). Some researchers have even suggested that some bedtime and risetime IIV can be beneficial when not associated with sleep complaints, in that it supports evening social life and thus protects mood or reflects higher functioning through having part-time jobs (Bei, Manber et al., 2017).

Aims of the current study

The lack of understanding and mixed findings on the relations between CBT-I, bedtime and risetime IIV and health consequences raises a need for more and methodically wise better-quality research on the topic. Moreover, there is a great incongruity between knowledge about the effect of IIV in bedtime and risetime on health, and the knowledge on possibilities to reduce said IIV. There is a lack of empirical knowledge on the effect of CBT-I, both administered by a therapist, and digitally, on reducing IIV in bedtime and risetime. Studies are needed to investigate the possibilities to reduce bed-and-risetime IIV and on the effects of bedtime and risetime IIV on health, in different contexts, and both the adaptive and non-adaptive aspects of bedtime and risetime IIV. Furthermore, there is little known about the relationship between IIV in bed-and-risetime and health in the long term. Studies demonstrating a possible relationship between bedtime and risetime IIV, insomnia symptoms and different aspects of health are important to be able to construct optimal interventions for sleep problems and better recommendations for healthy sleep behavior. Finding effective and easily available treatments for sleep problems and understanding the underlying factors in healthy and unhealthy sleep is an important field of study both for decreasing societal and individual costs and for increasing individual and societal wellbeing and quality of life. In light of these findings and gaps in the existing research, the current study will address the following research questions and hypotheses:

1. Does CBT-I reduce IIV in bedtime and risetime, from baseline to both treatment termination and 6 months follow-up?
2. Are there differences in the effectiveness between dCBT-I and F2F CBT-I on reducing IIV in bedtime and risetime, measured at treatment termination and 6 months follow-up?
3. Is change in IIV in bedtime and risetime associated with change in insomnia symptoms and psychological distress, measured from baseline to both treatment termination and 6 months follow-up?

Hypothesis 1: Treatment of insomnia with CBT-I will decrease IIV in bedtime and risetime from baseline to both treatment termination and 6 months follow-up

Hypothesis 2: F2F CBT-I will be more effective than dCBT-I in decreasing IIV in bedtime and risetime both at treatment termination and at 6 months follow-up.

Hypothesis 3: decreased IIV in bedtime and risetime in the sleep-wake cycle will be associated with reductions in insomnia symptoms and psychological distress from baseline to both treatment termination and 6 months follow-up.

Methods

Trial design

The current thesis is a secondary analysis of a randomized controlled treatment trial comparing the effectiveness of two different modalities of CBT-I, namely F2F CBT-I and dCBT-I. The trial was conducted in Trondheim, Norway between October 2014 and January 2016 (Kallestad et al., Submitted). The main study by Kallestad et al. (submitted) is registered on the open access site ClinicalTrials.gov (NCT02044263), where details of the protocol can be found.

Summary of the trial procedure and patient flow

The participants were recruited from the sleep clinic at St. Olavs Hospital in Trondheim, Norway. All the participants were patients who had been referred to the clinic by other health care providers for specialist treatment of insomnia. Once referred to the clinic, the patients received sleep diaries to record their sleep patterns for 14 days prior to assessment. After this preliminary 14-day period, the patients met a psychiatrist or clinical psychologist at the clinic for a diagnostic assessment. Tools used in the diagnostic assessment were the sleep diary, a semi-structured interview, and the Insomnia Interview Schedule. Patients were additionally screened for sleep apnea, using oximetry recordings, for specialized treatment if necessary.

Inclusion and exclusion criteria for the study are as for the main study by Kallestad et al. (submitted), and are listed below:

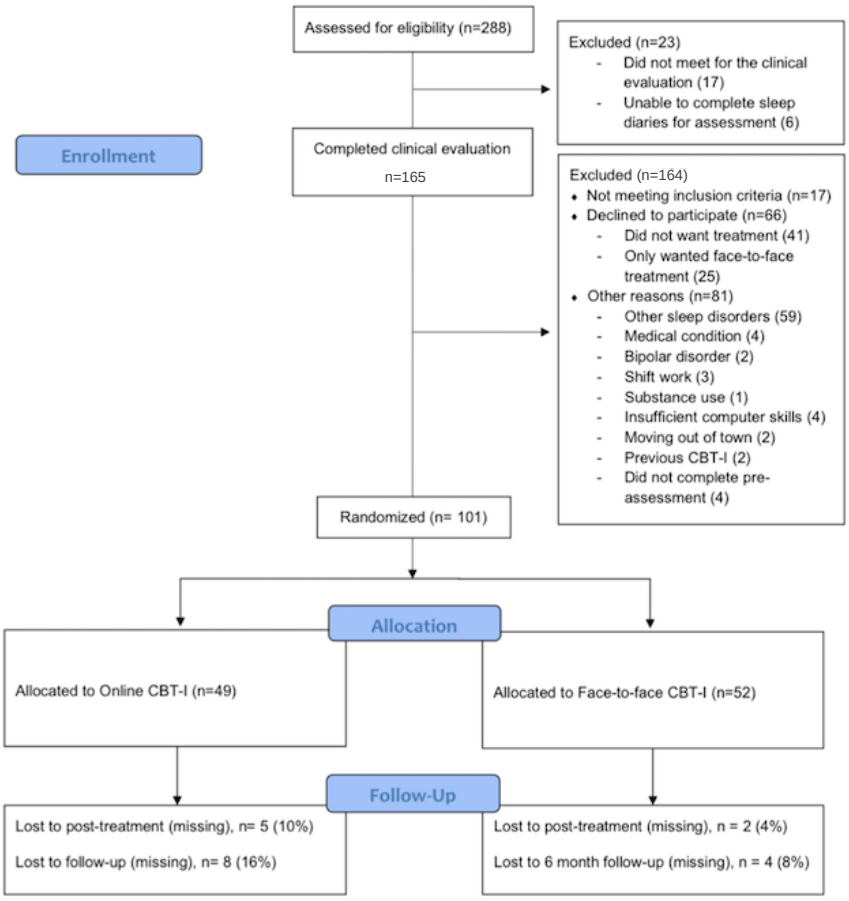
Inclusion criteria: 1) meeting the DSM-V diagnostic criteria for insomnia, and 2) being at least 18 years old.

Exclusion criteria: 1) A condition that rendered the individual incapable of understanding the treatment (e.g. actively psychotic, mental retardation, or dementia); 2) Ongoing substance abuse problems; 3) Other organic sleep disturbances or circadian sleep disturbance; 4) Ongoing medical condition where treatment of insomnia was not indicated (e.g. an attack phase of Multiple Sclerosis); 5) Working night shifts and unable to discontinue this work pattern; 6) Not sufficiently fluent in Norwegian to understand the assessments or treatment; 7) Lack of necessary computer skills needed to log on to the digital treatment program.

There were 288 individuals assessed for eligibility to the study. Of these 23 were excluded due to not meeting for the clinical evaluation (n=17) and for being unable to complete the preliminary sleep diary (n=6). Out of the 265 individuals who completed the clinical evaluations, 164 were excluded: 17 for not meeting the inclusion criteria, 66 declined to participate and 81 were excluded for other reasons, such as other sleep disorders or medical conditions, shift work or substance use. This resulted in 101 participants who were randomized to dCBT-I (n=49) and F2F CBT-I (n=52). Participants were randomized to one of the two study groups by a web-based system that is developed and administered by the Unit of Applied Clinical Research at the Norwegian University of Science and Technology. Following treatment and in the follow-up period another 12 individuals were lost in the dCBT-I group and 6 in the F2F CBT-I group. See Figure 1 for an overview of the study design.

Figure 1

Study design (Kallestad et al., Submitted)



Interventions

Interventions used in this study were F2F CBT-I and dCBT-I. Below is a brief description of F2F CBT-I, the dCBT-I version used in the current study, and treatment procedures.

F2F CBT-I

CBT-I is an intervention method involving multiple components, with four overarching treatment modalities (Morin, 1993). The four overarching components, or treatment modalities of CBT-I are: cognitive therapy; stimulus control therapy; sleep restriction therapy; and relaxation therapy (Morin, 1993). In the cognitive therapy modality,

the main goal is to identify and challenge dysfunctional beliefs about sleep and non-sleep related thoughts. Thereby empowering patients to be effective change agents of their thoughts and behaviors (Morin, 1993). The goal of stimulus control therapy is to return the sleep environment from being associated with arousal and negative emotions, which is usually seen in insomnia patients, to natural associations of rapid sleep and not being awake. This may be done by instructing patients to only use the bedroom for sleep and sex, only being in bed when sleepy, maintaining a regular wake time, and restricting daytime napping (Morin, 1993). Sleep restriction therapy uses mild sleep deprivation, by limiting time in bed to time spent asleep, aiming at increasing sleep quality through more rapid sleep onset and increased deep sleep (Spielman et al., 1987). The last overarching component of CBT-I, relaxation therapy, aims to empower patients to manage their own arousal. Common relaxation techniques used in CBT-I include meditation and yoga, and guided imagery (Morin, 2004). Sleep restriction therapy and stimulus control therapy have been shown to be the most individually effective therapy techniques (Morin et al., 2006). Within those two modalities, maintaining a stable sleep/wake schedule – going to bed and waking up at consistent times every day – works as a fundamental core behavioral mechanism (Schutte-Rodin et al., 2008). This core behavioral mechanism is based on circadian and homeostatic sleep regulating processes (Flynn-Evans et al., 2017), amongst others through increasing the consistency of light exposure, an important circadian synchronizer (Duffy & Czeisler, 2009; Duffy & Wright Jr, 2005)

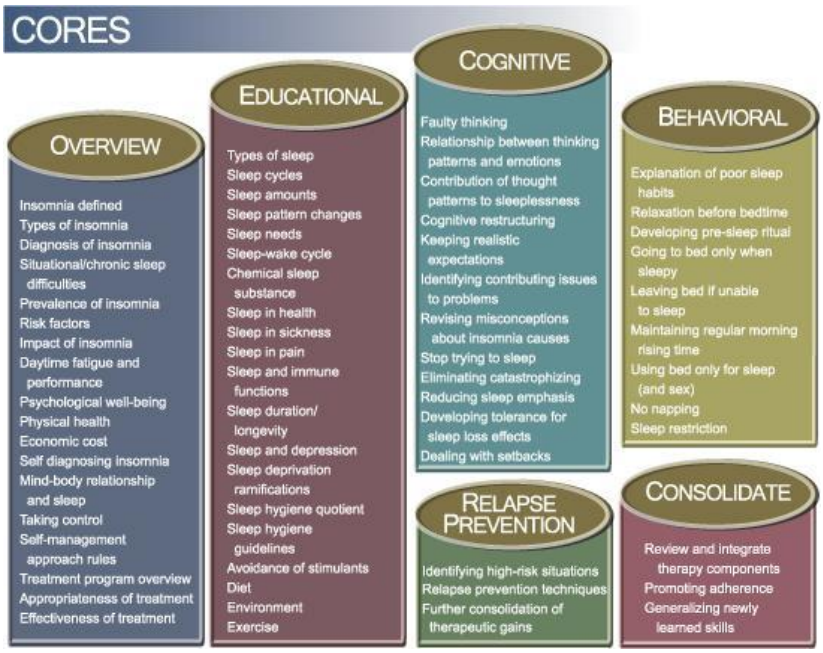
dCBT-I

The current study used the fully automated digital CBT-I program, SHUTi. Similar to F2F CBT-I, SHUTi is comprised of several modalities, referred to as core modules. These act as online equivalents to the weekly sessions of F2F CBT-I. The core modules are overview, educational, cognitive, behavioral, relapse prevention, and consolidation. The educational, cognitive, and behavioral are the main treatment modules (Kallestad et al., Submitted). The educational module introduces sleep hygiene – environmental and lifestyle factors that influence sleep, such as caffeine intake, light exposure etc. The cognitive module is, as in F2F CBT-I, looking at beliefs about sleep, and aims at challenging and changing dysfunctional beliefs. The behavioral module includes sleep restriction and stimulus control, as described above for F2F CBT-I (Thorndike et al., 2008). The remaining three modules are necessary for an overall comprehensive treatment (Kallestad et al., Submitted). An overview of the core modules and their content is presented in Figure 2. The program is completely automated and

tailored to each individual user. The different core modules become available for the users according to their activity on the website (Shaffer et al., 2020). When first creating a profile, each user gets a personalized homepage. New modules only become available for the users upon completion of previous modules. The information in each module is presented in a variety of interactive ways and requires the user to actively input data in order to progress. In addition to the core modules, each user has to complete assessments and keep a sleep diary, which further customizes their homepage, based on individual traits and needs. The personalization of the web page is a key element of making this internet intervention different from other sleep interventions available online. Similar to F2F CBT-I, setting and maintaining a regular sleep/wake schedule is a key overarching fundamental element in SHUTi (Thorndike et al., 2008).

Figure 2

Core modules of SHUTi (Kallestad et al., Submitted)



Treatment procedures

F2F CBT-I: the F2F CBT-I in the current study was delivered according to the manual of Morin (1993). Treatment was provided by three therapists, of which two were clinical

psychologists and one a psychiatrist. The therapists had three, eight, and ten years of clinical experience using CBT-I. The patients received 4 to 8 sessions of treatment with their therapist. The number of sessions and the timing of these were assessed by the therapist on the basis of the patients' progress.

dCBT-I: In the dCBT-I intervention each participant received a unique log in to the program. The homepage provided the participants with all relevant information and instructions for using the program. Each user's dCBT-I version was personalized through what specific content was made available to each user at specific times throughout the treatment period. The content available for each individual user was based on personal factors, such as treatment progress and personal needs. SHUTi was originally created at the University of Virginia. It is translated to Norwegian by the Norwegian Institute of Public Health. Participants used the program for six weeks and had access to it for 6 months.

In both intervention groups, the participants were guided through setting a sleep window based on their sleep diaries, with the intention of maintaining a regular sleep/wake schedule. Participants were instructed on maintaining a regular bedtime and constant risetime throughout the complete treatment period.

Outcomes

Background assessments

Demographic data and socioeconomic status were collected. Demographic data included age and gender. Socioeconomic status assessments included family structure, marital status, education, and work variables (employment status, income). Additionally, the duration of insomnia symptoms was assessed.

Outcome assessments

Sleep diaries: a sleep diary is a measure of one's daily sleep-wake behaviors. The sleep diary used in the current trial was an online version of the Consensus Sleep Diary (Carney et al., 2012). It included information about bedtime, sleep onset latency, wake after sleep onset, number of nocturnal awakenings, early morning awakenings, total sleep time, total time in bed, and sleep efficiency for 10 days out of the previous 14 consecutive days. Participants registered information into the sleep diaries on a daily basis for 14 consecutive

days immediately before randomization (baseline), at termination of treatment (week 9), and at 6 months follow-up (week 33) (Kallestad et al., Submitted). In the present study, bedtime and risetime IIV were assessed using self-reported bed and wake times registered in the sleep diaries. An individual's bedtime IIV was calculated as the mean of the standard deviations of the participant's bedtimes per two-week sleep diary period. The same procedure was used to find the risetime IIV, this time using the mean of the participant's standard deviations in risetime per two-week assessment period. The group bedtime and risetime IIVs were defined as the mean of all the individual bedtime and risetime IIVs per group.

Insomnia Severity Index (ISI): The primary outcome assessment on sleep quality was based on insomnia symptoms according to ISI scores. ISI is a well-established outcome assessment in insomnia research (Morin et al., 2006) and has good psychometric properties (Morin et al., 2011). ISI consists of seven questions, and the scores range from 0 to 28 points, with higher scores indicating higher insomnia symptom severity.

Hospital Anxiety and Depression Scale (HADS): The secondary outcome assessment of anxiety and depression symptoms, together representing level of psychological distress, was measured using the Norwegian adaptation of HADS (Leiknes et al., 2016). HADS is a well-established and validated screening instrument, with the Norwegian adaptation also showing good internal consistency (Leiknes et al., 2016; Zigmond & Snaith, 1983). HADS consists of 14 questions, seven of which relate to anxiety symptoms, and seven relating to depressive symptoms. It has a range of 0 to 42 points, with higher scores indicating more psychological distress.

Data collection

All data collection was done online for both treatment groups. Assessments were performed at baseline, week 9 and week 33.

Data Analysis

All data analyses were carried out using the statistical program IBM SPSS Statistics version 27. Descriptive statistics and frequencies were used to find relevant descriptive information of the participants. To analyze research hypothesis one, IIVs in bedtime and risetime were compared between baseline and week 9, baseline and week 33, and week 9 and week 33, using paired t-tests. For research hypothesis two, IIVs in bedtime and risetime at

week 9 and week 33 were compared between F2F CBT-I and dCBT-I using independent t-tests. To test research hypothesis three eight hierarchical linear regression analyses were conducted. ISI-scores at week 9, ISI-scores at week 33, HADS-scores at week 9 or HADS-scores at week 33 were used as dependent variables in separate analyses. Age and gender were entered in the first two steps in all analyses to control for their potential confounding effects. When the dependent variable was ISI-scores at week 9, ISI-scores at baseline was entered in the third step. When the dependent variable was HADS-scores at week 9, HADS-scores at baseline was entered in the third step. When ISI-scores at week 33 was the dependent variable, ISI-scores at week 9 was entered in step three. Finally, when HADS-scores at week 33 was the dependent variable, HADS-scores at week 9 was entered in the third step. In the fourth step, IIV in either bedtime or risetime at baseline was entered when the dependent variable was ISI-or-HADS-scores at week 9. When the dependent variable was either ISI-or-HADS-scores at week 33, IIVs in bedtime and risetime, respectively, at week 9 were entered in the fourth step. In the fifth and final step, IIV in either bedtime or risetime at baseline was entered when the dependent variable was ISI-or-HADS-scores at week 9. When the dependent variable was ISI-or-HADS-scores at week 33, bedtime and risetime IIVs at week 9 was entered. Since this study included two outcome measures and two potential mediators of change, the p-value was Bonferroni corrected to $p<.0125$.

Standardized effect sizes were estimated using Cohen's *d*, which is calculated by subtracting the mean of one of the treatment groups from the mean of the other treatment group, and dividing this on the standard deviation of the whole study sample (McLeod, 2019):

$$Cohen's\ d = \frac{\text{mean of group 1} - \text{mean of group 2}}{\text{Standard deviation}}$$

Results

Demographics and outcome assessment data

Data was analyzed from 101 participants who completed one of the two treatment programs. The age of the participants ranged from 18 to 65, with a mean age of 40.9 (*SD*=11.6). In the F2F CBT-I group the age range was 18-65 with a mean age of 41.3 (*SD*=12.5), while the age range in the dCBT-I group was 19-62 with a mean age of 41.4 (*SD*=10.5). The participants reported sleep problems ranging from less than one year, to their whole lifetime. The mean time of suffering from sleep problems was 13 years (*SD*=12 years). Table 2 shows further demographic and socioeconomic descriptive statistics of the participants who took part in the treatment program, including gender, marital status, family structure, education and employment.

As shown in Table 2, there was an even distribution of participants in the two study groups, with 52 participants in the F2F CBT-I group and 49 participants in the dCBT-I group. There was, however, an unequal gender distribution, with approximately 75% of the participants being female. In the F2F CBT-I group, almost 80% of the participants were female, and just above 70% were female in the dCBT-I groups. In both study groups almost two thirds of the participants were either married or cohabitant. In the F2F CBT-I group around 30% of the participants were married, and about 30% were cohabitant, while the remaining 40% of the participants were single. In the dCBT-I group almost half of the participants were married, and almost 40% where single, while the remaining 14% were cohabitant. In both groups, about 40% of the participants were living with children and adolescents under 18 years old. Around a fourth of the participants in both groups were unemployed.

Table 2

Descriptive statistics and frequencies of demographics and social information

Baseline characteristics	Number of participants (*N*)			Percentage (%)	
	F2F CBT-I	dCBT-I	Total	F2F CBT-I	dCBT-I
Participants	52	49	101	51.5	48.5
Gender					
Female	41	35	76	78.8	71.4
Male	11	14	25	21.2	28.6
Marital status					
Married	15	23	38	28.8	46.9
Cohabitant	16	7	23	30.8	14.3
Single	21	19	40	40.4	38.8
Living with individuals younger than 18 years old					
Yes	20	20	40	38.5	40.8
No	32	29	61	61.5	59.2
Education (highest completed degree)					
Not relevant	4	1	5	7.7	2.0
Educational training	6	7	13	11.5	14.3
High school	10	9	19	19.2	18.4
Two-year college degree	9	5	14	17.3	10.2
Bachelor's degree (cand. mag.)	16	19	35	30.8	38.8
Master's degree (cand. polit., cand.med, cand.psychol, etc.)	6	5	11	11.5	10.2
Doctorate (PhD, dr.med, dr.psychol, dr. scient., etc.)	1	3	4	1.9	6.1
Employment					
Currently employed					
Yes	39	38	77	75.0	77.6
No	13	11	24	25.0	22.4
Monthly salary					
Less than NOK23000	5	7	12	9.6	14.2
NOK23000 – 52000	16	13	29	30.8	26.5
More than NOK52000	28	24	52	53.9	48.9
Missing	3	5	8	5.7	10.2

From the 101 participants who were included in the study, there was a small attrition during post treatment and follow-up. Additionally, several participants were partially missing data in different outcome assessments. Missing data can be seen from the number of responses (*N*) in the following tables. The results listed in the following tables are therefore subject to some missing data.

Changes in bedtime and risetime IIV following treatment

Bedtime and Risetime IIVs for the whole study sample and in the different treatment groups at baseline, week 9 and week 33 are summarized in Table 3. IIVs in bedtime and risetime are also shown in Figures 3 and 4. Differences in bed-and-risetime IIVs between baseline and week 9, baseline and week 33 and between week 9 and week 33 with statistical analyses are summarized in Table 4.

Table 3

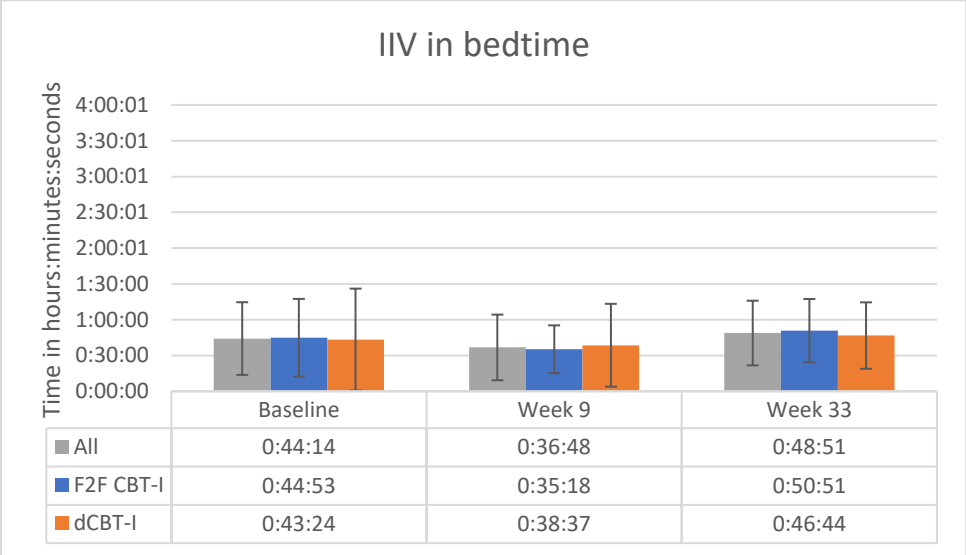
Descriptive statistics of IIV in bedtime and risetime at the different assessment points.

Group	All		F2F CBT-I		dCBT-I	
Measure	IIV in bedtime in hh:mm:ss	IIV in risetime in hh:mm:ss	IIV in bedtime in hh:mm:ss	IIV in risetime in hh:mm:ss	IIV in bedtime in hh:mm:ss	IIV in risetime in hh:mm:ss
Baseline						
M	00:44:14	01:00:59	00:44:53	01:01:29	00:43:24	01:00:21
SD	(00:30:27)	(00:41:48)	(00:32:36)	(00:41:48)	(00:28:13)	(00:42:42)
N	54	54	30	30	24	24
Week 9						
M	00:36:48	00:52:22	00:35:18	00:38:57	00:38:37	01:04:38
SD	(00:27:31)	(00:43:16)	(00:20:02)	(00:32:43)	(00:34:44)	(00:35:34)
N	82	82	45	45	37	37
Week 33						
M	00:48:51	01:14:04	00:50:51	01:59:09	00:46:44	01:11:34
SD	(00:27:07)	(00:46:14)	(00:26:32)	(01:42:53)	(00:27:51)	(00:25:53)
N	99	99	51	51	48	48

Note. Means (*M*) and standard deviations (*SD*) are shown in hours (hh), minutes (mm) and seconds (ss).

Figure 3

IIVs in bedtime for the whole study sample and for the F2F CBT-I and dCBT-I groups separately at baseline, week 9 and week 33.

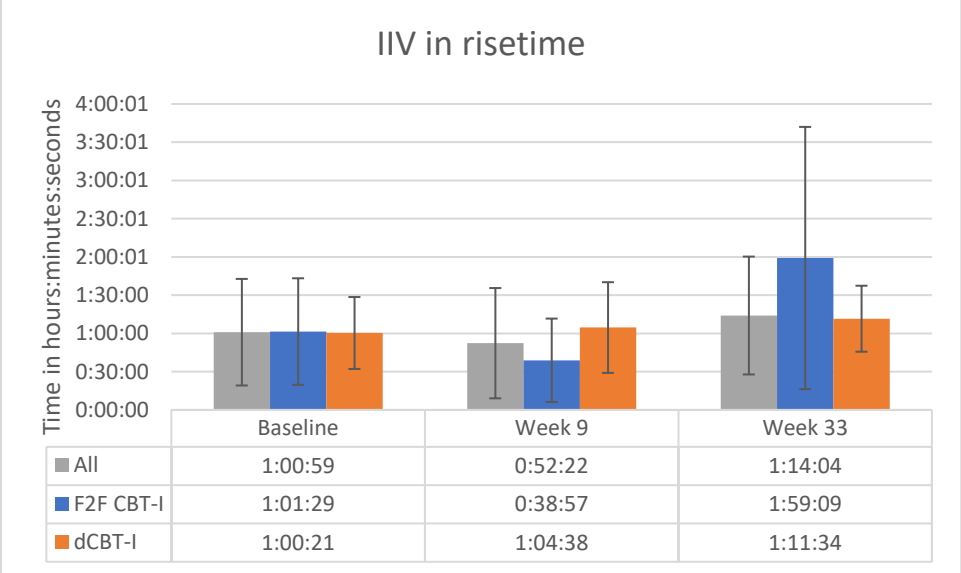


	Baseline	Week 9	Week 33
All	0:44:14	0:36:48	0:48:51
F2F CBT-I	0:44:53	0:35:18	0:50:51
dCBT-I	0:43:24	0:38:37	0:46:44

Note. The bars show the mean IIV per group per time-period, while the error bars represent standard deviations.

Figure 4

IIVs in risetime for the whole study sample and for the F2F CBT-I and dCBT-I groups separately at baseline, week 9 and week 33.



	Baseline	Week 9	Week 33
All	1:00:59	0:52:22	1:14:04
F2F CBT-I	1:01:29	0:38:57	1:59:09
dCBT-I	1:00:21	1:04:38	1:11:34

Note. The bars show the mean IIV per group per time-period, while the error bars represent standard deviations.

As seen in Table 4, the dependent t-tests indicated that there were no significant changes in neither bedtime nor risetime IIV between baseline and week 9 (*p*'s > .17 in all analyses). Also between baseline and week 33 no significant changes were found in either bedtime or risetime IIV (*p*'s > .05 in all analyses). However, between week 9 and week 33, there were significant increases in both bedtime and risetime IIV, both when looking at the whole study sample, and when looking at the F2F CBT-I group separately (*p*'s ≤ .001 for both bedtime and risetime IIV in both groups). Meanwhile, in the dCBT-I group, there were no significant changes in neither bedtime nor risetime IIV between week 9 and week 33 (*p* = .181 for bedtime and *p* = .41 risetime). See Table 4 for further details.

Table 4

Differences in IIV for each treatment group, between the different measurement points (baseline, week 9 and week 33).

	All		F2F CBT-I		dCBT-I	
	Bedtime	Risetime	Bedtime	Risetime	Bedtime	Risetime
Baseline-week 9 (*N*)	(52)		(29)		(23)	
Absolute difference (minutes)	-5.5	-4.9	-6.8	-10.0	-3.6	+1.7
95% confidence interval (minutes)	[3.3, -14.2]	[7.8, -17.5]	[3.2, -16.8]	[5.5, -25.5]	[12.3, -19.7]	[23.7, -20.3]
t-value	1.247	0.775	1.390	1.337	0.471	-0.160
p-value	0.218	0.442	0.176	0.192	0.642	0.874
Baseline-week 33 (*N*)	(54)		(30)		(24)	
Absolute difference (minutes)	+5.7	+9.3	+7.5	+12.0	+3.5	+6.0
95% confidence interval (minutes)	[13.5, -2.1]	[20.2, -1.5]	[17.8, -2.8]	[24.2, -0.3]	[16.3, -9.2]	[26.0, -14.0]
t-value	-1.471	-1.729	-1.495	-1.992	-0.564	-0.627
p-value	0.147	0.090	0.146	0.056	0.578	0.537
Week 9-week 33 (*N*)	(82)		(45)		(37)	
Absolute difference (minutes)	+10.3	+18.5	+13.8	+27.5	+6.0	+7.7
95% confidence interval (minutes)	[16.2, 4.4]	[29.3, 7.7]	[21.9, 5.8]	[39.8, 15.0]	[15.0, -3.0]	[26.4, -11.0]
t-value	-3.476	-3.404	-3.483	-4.450	-1.363	-0.833
p-value	0.001	0.001	0.001	<0.001	0.181	0.410

Note. +/- signs indicate whether IIV increased (+) or decreased (-) over time.

Differences in effect between treatment groups

Table 5 shows the differences in bedtime and risetime IIV between the two treatment groups at week 9 and week 33. Both bedtime and risetime IIV were approximately the same for the two treatment groups at baseline, with differences of less than 2 minutes. As shown in Table 5, IIV in bedtime at week 9 was 35.4 minutes for F2F CBT-I and 38.4 minutes for dCBT-I. At week 33, IIV in bedtime was 51.0 minutes for F2F CBT-I and 46.8 minutes for dCBT-I. There were no significant differences in IIV in bedtime neither at week 9 nor at week 33 between the two treatment groups (p = .608 for week 9 and p = .454 for week 33). Risetime IIV at week 9 was measured to 46.2 minutes for the F2F CBT-I group, and 59.4 minutes for dCBT-I. At week 33, risetime IIV was 78.6 minutes for F2F CBT-I and 69.0 minutes for dCBT-I. Also in risetime IIV there were no significant differences between the two treatment groups at either measurement points following treatment (p = .160 for week 9 and p = .295 for week 33). In all cases, the effect size was small or trivial with Cohen's d of 0.314 and smaller.

Table 5

Differences in IIV in bedtime and risetime between F2F CBT-I and dCBT-I, following treatment.

	IIV (minutes)		Absolute difference (minutes)	95% confidence interval (minutes)	*t*-value	*p*-value	Cohens *d*
	F2F CBT-I	dCBT-I					
Bedtime							
Week 9	35.4	38.4	3.0	[16.2, -9.5]	-0.515	0.608	0.119
	N=45	*N*=37					
Week 33	51.0	46.8	-4.2	[6.7, -15.]	0.752	0.454	0.151
	N=51	*N*=48					
Risetime							
Week 9	46.2	59.4	13.2	[32.5, -5.5]	-1.414	0.160	0.314
	N=45	*N*=37					
Week 33	78.6	69.0	-9.6	[8.9, -28.2]	1.053	0.295	0.212
	N=51	*N=48*					

Associations between bed-and-risetime IIV and insomnia symptoms and psychological distress

Tables 6 through 9 summarize the associations between changes in bedtime and risetime IIV and changes in insomnia symptoms, measured by ISI scores, and psychological distress, measured by HADS scores. Effects of changes were assessed from baseline to week 9 (Table 6 for ISI and Table 8 for HADS), and from week 9 to week 33 (Table 7 for ISI and Table 9 for HADS).

As shown in Table 6, neither changes in bedtime nor risetime IIV during treatment were significantly associated with lower ISI-scores at treatment termination (N's = 50, p's > .60). However, higher ISI-scores at baseline were significantly associated with higher ISI-scores at week 9 (p's = .003). Neither age nor gender contributed significantly to the explained variances. As, summarized in Table 7, neither changes in bedtime nor risetime IIV during the follow-up period were significantly associated with ISI-scores at week 33 (N's = 79, p's > .05). However ISI-scores at week 9 were significantly associated with ISI-scores at week 33 (p's < .001). Neither age nor gender contributed to the explained variances.

As shown in Table 8, neither changes in bedtime nor risetime IIV during treatment were significantly associated with HADS-scores at week 9 (N's = 50, p's > .20). However, higher HADS-scores at baseline were significantly associated with higher HADS-scores at week 9 (p's < .001). Age and gender did not contribute to the explained variances. Finally, as shown in Table 9, lower IIV in bedtime, but not risetime, during the follow-up period was significantly associated with lower HADS-scores at 33 weeks (N = 78, p = .006 for bedtime and N = 78, p = .318 for risetime). Higher HADS-scores at week 9 were also significantly associated with higher HADS-scores at week 33 (p's < .001). Age and gender did not contribute to the explained variances.

Table 6

Summary of two hierarchical regression analyses on predictors of changes in level of insomnia symptoms, measured in ISI scores at week 9, as an effect of changes in either bedtime or risetime IIV, from baseline to week 9.

Coefficients[a]						
Model (R^2)	Variable	*B*	*SE B*	β	*t*	*p*
1 (.001)	Age	-0.016	0.078	-0.030	-0.210	0.835
2 (.018)	Age	-0.006	0.079	-0.011	-0.076	0.940
	Gender	-2.052	2.199	-0.133	-0.933	0.356
3 (.184)	Age	0.003	0.073	0.005	0.039	0.969
	Gender	-2.249	2.027	-0.146	-1.110	0.273
	ISI baseline	0.787	0.252	0.408	3.123	0.003
4 (.191)	Age	0.020	0.078	0.036	1.257	0.798
	Gender	-2.383	2.050	-0.155	-1.163	0.251
	ISI baseline	0.810	0.256	0.420	3.164	0.003
	Bedtime baseline	0.000	0.001	0.091	0.643	0.523
5 (.191)	Age	0.019	0.079	0.035	0.246	0.806
	Gender	-2.402	2.085	-0.156	-1.152	0.255
	ISI baseline	0.806	0.263	0.418	3.066	0.004
	Bedtime baseline	0.000	0.001	0.095	0.622	0.537
	Bedtime week 9	-4.595E-5	0.001	-0.012	-0.078	0.938
1 (.001)	Age	-0.016	0.078	-0.030	-0.210	0.835
2 (.018)	Age	-0.006	0.079	-0.011	-0.076	0.940
	Gender	-2.052	2.199	-0.133	-0.933	0.356
3 (.184)	Age	0.003	0.073	0.005	0.039	0.969
	Gender	-2.249	2.027	-0.146	-1.110	0.273
	ISI baseline	0.787	0.252	0.408	3.123	0.003
4 (.193)	Age	0.021	0.077	0.039	0.276	0.784
	Gender	-2.169	2.040	-0.141	-1.063	0.293
	ISI baseline	0.786	0.253	0.408	3.107	0.003
	Risetime baseline	0.000	0.000	0.102	0.729	0.470
5 (.196)	Age	0.019	0.078	0.034	0.238	0.813
	Gender	-2.245	2.066	-0.146	-1.086	0.283
	ISI baseline	0.797	0.257	0.413	3.105	0.003
	Risetime baseline	0.000	0.000	0.128	0.827	0.412
	Risetime week 9	0.000	0.000	-0.062	-0.410	0.684

[a]Dependent Variable: ISI week 9

Table 7

Summary of two hierarchical regression analyses on predictors of changes in level of insomnia symptoms, measured in ISI scores at week 33, as an effect of changes in either bedtime or risetime IIV, from week 9 to week 33.

Coefficients[a]						
Model (R^2)	Variable	*B*	*SE B*	β	*t*	*p*
1 (.004)	Age	0.037	0.064	0.036	0.570	0.570
2 (.025)	Age	0.046	0.065	0.080	0.708	0.481
	Gender	-2.330	1.797	-0.147	-1.297	0.199
3 (.460)	Age	0.021	0.048	0.036	0.424	0.673
	Gender	-1.680	1.349	-0.106	-1.246	0.217
	ISI week 9	0.687	0.088	0.662	7.826	<0.001
4 (.460)	Age	0.021	0.049	00.037	0.428	0.670
	Gender	-1.679	1.358	-0.106	-1.237	0.220
	ISI week 9	0.688	0.088	0.662	7.772	<0.001
	Bedtime week 9	2.644E-5	0.000	0.006	0.076	0.940
5 (.470)	Age	0.044	0.053	0.077	0.825	0.412
	Gender	-1.947	1.375	-0.123	-1.417	0.161
	ISI week 9	0.690	0.088	0.664	7.810	<0.001
	Bedtime week 9	0.000	0.000	-0.048	-0.491	0.625
	Bedtime week 33	0.001	0.000	0.122	1.150	0.254
1 (.004)	Age	0.037	0.064	0.064	0.570	0.570
2 (.025)	Age	0.046	0.065	0.080	0.708	0.481
	Gender	-2.330	1.797	-0.147	-1.297	0.199
3 (.460)	Age	0.021	0.048	0.036	0.424	0.673
	Gender	-1.680	1.349	-0.106	-1.246	0.217
	ISI week 9	0.687	0.088	0.662	7.826	<0.001
4 (.469)	Age	0.012	0.049	0.021	0.248	0.804
	Gender	-1.876	1.357	-0.118	-1.382	0.171
	ISI week 9	0.694	0.088	0.669	7.901	<0.001
	Risetime week 9	0.000	0.000	-0.097	-1.129	0.262
5 (.496)	Age	0.069	0.056	0.122	1.237	0.220
	Gender	-2.635	1.386	-0.166	-1.901	0.061
	ISI week 9	0.738	0.089	0.711	8.290	<0.001
	Risetime week 9	0.000	0.000	-0.165	-1.810	0.074
	Risetime week 33	0.001	0.000	0.214	1.975	0.052

[a]Dependent Variable: ISI week 33

Table 8

Summary of two hierarchical regression analyses on predictors of changes in level of psychological distress, measured in HADS scores at week 9, as an effect of changes in either bedtime or risetime IIV, from baseline to week 9.

Coefficients[a]						
Model (R^2)	Variable	*B*	*SE B*	β	*t*	*p*
1 (.067)	Age	-0.159	0.084	-0.258	-1.889	0.065
2 (.126)	Age	-0.138	0.083	-0.223	-1.656	0.104
	Gender	-4.227	2.326	-0.245	-1.818	0.075
3 (.648)	Age	-0.033	0.055	-0.054	-0.606	0.547
	Gender	-2.875	1.499	-0.167	-1.918	0.061
	HADS baseline	0.829	0.098	0.749	8.445	<0.001
4 (.655)	Age	-0.017	0.058	-0.027	-0.292	0.772
	Gender	-3.029	1.510	-0.176	-2.006	0.051
	HADS baseline	0.818	0.099	0.739	8.256	<0.001
	Bedtime baseline	0.000	0.000	0.085	0.930	0.357
5 (.664)	Age	-0.014	0.058	-0.023	-1.052	0.298
	Gender	-2.860	1.514	-0.166	-1.889	0.065
	HADS baseline	0.800	0.100	0.723	7.988	<0.001
	Bedtime baseline	0.000	0.000	0.045	0.458	0.649
	Bedtime week 9	0.000	0.000	0.108	1.122	0.268
1 (.067)	Age	-0.159	0.084	-0.258	-1.889	0.065
2 (.126)	Age	-0.138	0.083	-0.223	-1.656	0.104
	Gender	-4.227	2.326	-0.245	-1.818	0.075
3 (.648)	Age	-0.033	0.055	0-.054	-0.606	0.547
	Gender	-2.875	1.499	-0.167	-1.918	0.061
	HADS baseline	0.829	0.098	0.749	8.445	<0.001
4 (.657)	Age	-0.016	0.057	-0.026	-0.277	0.783
	Gender	-2.827	1.497	-0.164	-1.889	0.065
	HADS baseline	0.804	0.101	0.726	7.962	<0.001
	Risetime baseline	0.000	0.000	0.102	1.086	0.283
5 (.657)	Age	-0.016	0.058	-0.025	-0.270	0.789
	Gender	-2.819	1.516	-0.164	-1.860	0.069
	HADS baseline	0.801	0.106	0.723	7.553	<0.001
	Risetime baseline	0.000	0.000	0.098	0.969	0.338
	Risetime week 9	2.463E-5	0.000	0.009	0.089	0.930

[a]Dependent Variable: HADS week 9

Table 9

Summary of two hierarchical regression analyses on predictors of changes in level of psychological distress, measured in HADS scores at week 33, as an effect of changes in either bedtime or risetime IIV, from week 9 to week 33.

Coefficients[a]						
Model (R^2)	Variable	B	SE B	β	t	p
1 (.031)	Age	-0.123	0.078	-0.177	-1.582	0.118
2 (.032)	Age	-0.123	0.079	-0.176	-1.551	0.125
	Gender	-0.142	2.148	-0.008	-0.066	0.948
3 (.642)	Age	0.021	0.050	0.030	0.411	0.682
	Gender	1.796	1.327	0.095	1.354	0.180
	HADS week 9	0.860	0.076	0.818	11.302	<0.001
4 (.643)	Age	0.023	0.050	0.033	0.458	0.648
	Gender	1.758	1.332	0.095	1.340	0.184
	HADS week 9	0.850	0.078	0.808	10.886	<0.001
	Bedtime week 9	0.000	0.000	0.043	-0.606	0.546
5 (.678)	Age	0.064	0.050	0.093	1.278	0.205
	Gender	1.120	1.296	0.059	0.865	0.390
	HADS week 9	0.809	0.076	0.769	10.633	<0.001
	Bedtime week 9	0.000	0.000	-0.056	-0.724	0.471
	Bedtime week 33	0.001	0.000	0.233	2.812	0.006
1 (.031)	Age	-0.123	0.078	-0.177	-1.582	0.118
2 (.032)	Age	-0.123	0.079	-0.176	-1.551	0.125
	Gender	-0.142	2.148	-0.008	-0.066	0.948
3 (.642)	Age	0.021	0.050	0.030	0.411	0.682
	Gender	1.796	1.327	0.095	1.354	0.180
	HADS week 9	0.860	0.076	0.818	11.302	<0.001
4 (.651)	Age	0.026	0.050	0.038	0.530	0.597
	Gender	2.007	1.326	0.106	1.514	0.134
	HADS week 9	0.838	0.077	0.798	10.892	<0.001
	Risetime week 9	0.000	0.000	0.102	1.422	0.159
5 (.656)	Age	0.056	0.058	0.080	0.965	0.337
	Gender	1.631	1.378	0.086	1.184	0.240
	HADS week 9	0.844	0.077	0.802	10.935	<0.001
	Risetime week 9	0.000	0.000	0.074	0.970	0.335
	Risetime week 33	0.000	0.000	0.087	1.005	0.318

[a]Dependent Variable: HADS week 33

Discussion

Study aims and main findings

One of the presumed key mechanisms of action of CBT-I is stabilizing individual's IIV in bedtime and risetime. While there is substantial research linking high bed-and-risetime IIV to negative health outcomes, there is little research showing whether CBT-I is successful in decreasing IIV in bedtime and risetime. There is also limited research on the effect of dCBT-I on reducing bedtime and risetime IIV. The studies that do exist show mixed findings and limited methodologies, with small sample sizes. Based on the lack of empirical evidence, as presented earlier, this study aimed to assess 1) whether treatment of insomnia is effective in increasing bedtime and risetime stability; 2) whether there is a difference in the effectiveness on increasing bedtime and risetime stability between F2F CBT-I and dCBT-I; and 3) whether changes in bedtime and risetime IIV are associated with changes in insomnia symptoms and psychological distress. In contrast to prior expectations, this study found no significant reductions in IIV following CBT-I, neither at termination of treatment, nor at follow-up. On the contrary, significant increases in IIV were found between termination of treatment and 6 months follow-up. This study found no significant differences between F2F CBT-I and dCBT-I in their effect on changing bedtime and risetime IIV, neither at treatment termination nor at 6 months follow-up. Also in contrast to what was expected, reductions in bedtime and risetime IIV were not significantly associated with lower levels of insomnia severity either at treatment termination or at 6 months follow-up. Moreover, neither reductions in bedtime nor risetime IIV were significantly associated with lower levels of psychological distress at treatment termination. However, reduction in bedtime, but not risetime, IIV was significantly associated with lower levels of psychological distress at 6 months follow-up. The findings of this study are discussed in greater detail, and limitations and implications are considered.

Aim 1: The effect of CBT-I on IIV in bedtime and risetime

This study found no significant decrease in IIV following CBT-I. In fact, there was a significant increase in bedtime and risetime IIV in the follow-up period. These findings are both contrary to prior expectations and surprising for several reasons. Perhaps most importantly are these findings interesting and important as they go against what is generally assumed as best practice. Reducing IIV is, for example, an explicit and central action mechanism of CBT-I. The lack of significant reductions in both bedtime and risetime IIV

both during and following treatment could have important possible implications for CBT-I. These results could indicate a need to revise the present version of CBT-I. Future research should look into other possible mechanisms of action for reducing bedtime and risetime IIV, which could be more effective than those in the present version.

The present findings are partially in accordance with similar studies, such as Suh et al. (2012), who found significant reductions in risetime, but not bedtime, IIV following treatment, and Sánches-Ortuño & Edinger (2012) who found significant decreases in bed-and-risetime IIV from baseline to posttreatment, but not at follow-up. A possible reason for no decrease in IIV could be that the participants had an IIV in both bedtime and risetime prior to treatment, which was within the framework of the treatment model. If so, maintaining a stable bedtime and risetime during treatment would lead to little change in IIV from before to after treatment. One possible explanation for the increase in IIV in the follow-up period could be participants' weariness of having to maintain a routine, and therefore letting completely go of the treatment routines after termination of treatment and adopting an even greater sleep/wake variability than prior to treatment. The results of the current study reject hypothesis one of the study, which proponed that CBT-I would lead to a reduction in bedtime and risetime IIV. Furthermore, as CBT-I was not successful in decreasing bedtime and risetime IIV, its mechanisms of change must rely on other psychological changes. This should be examined closer by future studies.

Aim 2: Differences between F2F CBT-I and dCBT-I in reducing bedtime and risetime IIV

This study found no significant differences in changes in IIV between the two treatment groups. These findings, together with the small effect sizes, suggest that dCBT-I is approximately as effective as F2F CBT-I when it comes to changing IIV in bedtime and risetime. No significant differences between F2F CBT-I and dCBT-I in reducing bedtime and risetime IIV rejects hypothesis two of the current study, which proponed that F2F CBT-I would be more effective than dCBT-I in increasing bedtime and risetime stability. When looking at other outcomes of treatment, however, other studies have found F2F CBTi to be superior to dCBT-I in reducing insomnia severity (Kallestad et al, 2018, submitted). Nevertheless, it should be mentioned that small effect sizes were expected, as the study is comparing two treatment groups based on the same treatment model, rather than a treatment group and a control group. The potential type two errors can thus not be ruled out.

Aim 3: Outcome effects of changes in bedtime and risetime IIV

Lower levels of IIV in either bedtime or risetime were not significantly associated with lower levels of insomnia severity either at treatment termination or at 6 months follow-up. Moreover, lower levels of bedtime and risetime IIV during treatment were not significantly associated with lower levels of general distress. However, lower levels of IIV in bedtime, but not risetime during the follow-up-period, was significantly associated with lower levels of psychological distress at 6 months follow-up. These findings partially support hypothesis three of the current study, which proponed that decreases in bedtime and risetime IIV would predict decreases in insomnia symptoms and psychological distress. The current findings suggest that lower levels of IIV in bedtime and risetime are not significantly associated with less specific insomnia symptoms either in the short -or -longer term. Decrease in IIV is also not associated with rapid improvement in psychological distress during treatment. However, restricting bedtime variability is significantly associated with less psychological distress if it is continued after treatment termination.

Moreover, this study found that levels of insomnia symptoms and psychological distress at baseline, respectively predicted levels of insomnia symptoms and psychological distress at treatment termination. Similarly, levels of insomnia symptoms and psychological distress at week 9, respectively predicted levels of insomnia symptoms and psychological distress at week 33. All these predictions were positive, indicating that the more insomnia symptoms or psychological distress the participants experienced at baseline or termination of treatment the more of these symptoms they also experienced at treatment termination and 6 months follow-up, respectively. Due to the sample size of the current study, it was not possible to compare the two treatment groups for associations between changes in bedtime and risetime IIV and changes in insomnia symptoms and psychological distress.

To the best of our knowledge, this is the first study that has demonstrated a significant association between change in bedtime IIV and change in psychological distress, following CBT-I. This finding is interesting and shows that, although no significant decrease in bedtime IIV was found for the study sample as a whole, the participants who did reduce their bedtime IIV also experienced a decrease in psychological distress. However, the significant association was only found between termination of treatment and 6 months follow-up, but not between baseline and treatment termination. This highlights the importance of following up on this certain behavior after termination of treatment. It could be argued that following up on

these new behaviors after treatment, is even more important than it is during treatment, as the individuals no longer have the emotional support and follow-up of the therapist. This result could also potentially be explained by asserting that the health promoting effects of having a stable bedtime had not developed completely at termination of treatment, but needed more time to activate.

The significant association between changes in bedtime IIV, but not risetime IIV, and changes in psychological distress, was a surprising finding. CBT-I instructs the patients to maintain a constant risetime, but allow for a slightly more variable bedtime. Hence, it would be expected that any association between bedtime IIV and psychological distress, would also be seen between risetime IIV and psychological distress. Similar results have, however, also been found in other studies. Duncan et al. (2016) found higher bedtime IIV, but not risetime IIV, to be associated with poorer health. One possible explanation of the seen results is school and work life expectations and patterns. As most jobs and schools require individuals to wake up at the same time every weekday, setting a constant risetime would lead to little change on workdays, while it might lead to a great change in risetime in the weekends. Meanwhile, most people are more flexible for when they go to bed at night. Maintaining a constant bedtime that ensures enough sleep, especially on workdays, could therefore have a greater effect on daytime functioning, as characterized by psychological distress, than maintaining a set risetime would have. As about a fourth of the participants in the current trial were employed, there is reason to assume the greater part of the participants at baseline had a risetime that was less variable than their bedtime. However, due to a limiting sample size, the current study did not control for possible confounding effects of employment, when assessing the associations between changes in bed-and-risetime IIV and insomnia symptoms and psychological distress. Looking at the effects of whether or not individuals are employed or in school, when studying bedtime and risetime IIV is a topic for future research. Further, studies should examine whether the type of work individuals do impacts the effects of having higher or lower IIV in bedtime and risetime. Answers to these questions could help to further improve and specialize CBT-I.

Another possible explanation for the significant results seen in bedtime and not risetime IIV is variability in sleep duration. If risetime is constant, changes in bedtime could lead to changes in sleep duration. Thus, influencing whether or not an individual has the possibility to get enough sleep at night. Manber et al. (1996) found regularizing sleep timing,

in addition to assuring enough sleep, to have greater and longer lasting improvements in health compared to only assuring enough sleep. However, Phillips et al., (2017), found variability in sleep timing, independently from sleep deprivation, to contribute to poorer health. These findings emphasize the need to look at both IIV in sleep timing, and at sleep duration, separately.

Interestingly, change in bedtime IIV between termination of treatment and follow-up did not predict changes in insomnia symptoms. This was an unexpected finding and could be relevant when designing insomnia treatments. A possible explanation for this finding is that it was not the stabilizing of bedtime IIV in itself that led to a decrease in psychological distress, but that rather the feeling of control of stabilizing sleep timing was the mediating factor leading to alleviation in psychological distress. This is aligned with research showing subjective feelings of being in control to be significant predictors of reduced anxiety and depression symptoms (Keeton et al., 2008). Moreover, Shaffer et al. (2020) found no correlations between increased sleep schedule consistency and insomnia remission. Studies have found CBT-I to lead to reductions in IIV in sleep timing when based on subjective measures, such as sleep diaries, but not on more objective measures, such as actigraphy (Lemola et al., 2013; Sánches-Ortuño and Edinger, 2012). Hence, stabilizing sleep timing might lead to an increased feeling of control, which in turn could leads to an alleviation in psychological distress, without necessarily relieving insomnia symptoms. As it is the subjective feelings of change, rather than actual changes in sleep behavior that seems to be changed by CBT-I, insomnia could be thought of as a "worry disorder", in which sense of control is essential, rather than solely a clear sleep disorder. A measure on sense of control was not included in the current trial, and can thus not be excluded as a possible confounding variable. It would be interesting for future research to include a measure on subjective sense of control when examining associations between sleep schedule consistency, and sleep quality and daytime functioning.

Relevance and utility of stabilizing sleep timing

Despite no significant decreases in bedtime and risetime IIV found in the current study, the main study on this dataset showed significant reductions in both insomnia severity, measured in ISI scores, and levels of psychological distress, measured in HADS scores (Kallestad et al., Submitted). Hence, while not being effective at decreasing bedtime and risetime IIV, CBT-I administered in the current study was still effective in decreasing

insomnia symptoms and psychological distress. Significant reductions in ISI and HADS scores combined with the significant increases in bedtime and risetime IIV in the follow-up period was surprising. Similar findings have, however, also been shown by other studies. Buysse et al. (2010), for example, did not find any clear relationship between bedtime and risetime IIV and clinical measures such as insomnia and depression symptoms, measured pretreatment. Also Irish et al. (2015) found no strong evidence relating consistent bed-and-risetimes with improved sleep. Moreover, Shaffer et al. (2020), who directly studied the relation between CBT-I, bedtime and risetime IIV, and insomnia symptoms, found no effects of bedtime and risetime IIV on insomnia symptoms, either at pre -or -post treatment, or at 6 months follow-up. While they found dCBT-I to increase individual sleep schedule consistency, there were no correlations between sleep schedule consistency and insomnia remission or treatment response (Shaffer et al., 2020).

Based on the present findings it could be argued that in particular risetime, but perhaps also to some extent bedtime IIV, plays a smaller role on insomnia symptoms and psychological distress, than conventionally thought. This indicates that other variables and mechanisms have a greater impact on insomnia symptoms and psychological distress. Some of these variables could be the routines learned in treatment and working through worries and dysfunctional beliefs. Another possible hypothesis based on the current findings is that sleep duration, rather than sleep timing, plays the more important part. Maurer et al. (2020), for example, have found sleep restriction to be an important mediator in reducing insomnia symptoms, over and above sleep regulation. However, as other variables were not examined in this study, no conclusions can be drawn as to what did play the important part in mediating the overall alleviation in symptoms.

One possible proposition based on the results of the current study is that IIV in bedtime and risetime is not necessarily harmful. Findings from Harvey (2000) and Shaffer et al. (2020) showed that stabilizing sleep timing might not be necessary for favorable therapeutic outcomes either at treatment termination or at follow up. These findings are, however, contradictory to the findings of amongst others, Bei, Manber et al. (2017), and Philips et al. (2017) who have shown associations between high bedtime and risetime IIV and negative mood, and Duncan et al. (2016), showing associations between high bedtime IIV and lower sleep quality. Simultaneously, some researchers, such as Bei, Manber et al. (2017) have suggested that keeping a very stable bedtime and risetime IIV can be harmful, as it may either

limit nighttime socialization or lead to a lack of sleep after late night socialization, as well as limit the ability to conduct shift work. Having a strict and stable bedtime and risetime can thus lead to isolation and worsened economy, resulting in worsened daytime functioning and poorer sleep. Indeed, Gooley (2016) found set risetimes combined with late bedtimes, and sleep curtailment to be harmful for both mental and somatic health.

Another possible explanation for the present findings could be that alleviations in insomnia, anxiety and depression symptoms allow the participants to function well with more variable bed-and-risetimes. Participants might have stabilized their bedtime and risetime during treatment, as an element in improving their sleep. As their sleep and daytime functioning improved, they had more energy and motivation for socialization and work, leading to a more variable bedtime and risetime. Thus, high bed-and-risetime IIV may be harmful for sleep and daytime functioning for those struggling with sleep. Simultaneously, it can be a healthy part of work, school and weekend life for those who do not have sleep problems. This is supported by research conducted by Duncan et al. (2016) and Irish et al. (2014), who found no significant associations between IIV in risetime and poorer sleep health or daytime functioning amongst the general population. Meanwhile, research from Shaffer et al. (2020) shows greater bed-and-risetime IIV to be associated with poorer naturalistic insomnia remission among individuals with insomnia disorder.

Several of the findings presented above question the utility of stabilizing bedtime and risetime as a behavioral mechanism in insomnia treatment. However, the present finding of a significant association between bedtime IIV and psychological distress during the follow-up period is also supported by several other studies. Lacks and Rotert (1986) found that although there is no significant difference in the sleep hygiene knowledge between insomniacs and good sleepers, good sleepers do seem to engage in less unhealthy sleep behavior, than insomniacs. The findings of Lacks and Rotert emphasize the importance of complying with the behavioral aspects of CBT-I. This is in line with the findings of amongst other Chan et al. (2017), Harvey et al. (2017) and Shaffer et al. (2020), showing behavioral interventions to be significantly more effective in reducing bedtime and risetime IIV, than merely cognitive interventions.

An important question to be raised is what role, if any, risetime IIV in particular, but also bedtime IIV, play in the treatment of insomnia. The mixed findings presented above question the importance of maintaining fixed sleep schedules in the treatment of insomnia. If

stabilizing bedtime and risetime IIV is not an important element for treatment success, allowing patients a more flexible and natural sleep schedule could make treatment more manageable and acceptable. However, the lack of associations between risetime IIV and insomnia symptoms and psychological distress, and the limited associations between bedtime IIV and insomnia symptoms and psychological distress might be due to the restricted measures of mental health symptoms used in the current study (Suh et al., 2012). Finally, the above presented findings, in conjunction with the findings from the present study, emphasize the importance of examining individual factors that potentially may influence the effect of bedtime and risetime IIV on sleep quality and psychological distress.

Strengths of the current study

Strengths of this study include a large sample size, several points of data collection over a prolonged period of time, controls for possible confounding variables and high external validity as all participants were patients diagnosed with Insomnia Disorder and referred to a public sleep clinic. The high external validity makes the results more generalizable to its population, while the resulting heterogeneity of the sample reduces the internal validity.

Although the sample size of this study is considered large, it could still have benefitted from being even larger. Thereby allowing comparisons between the two treatment groups when examining associations between IIV and treatment outcomes. Having a larger sample size would also allow controlling for more variables in the hierarchical regression analyses. Comparing F2F CBT-I to dCBT-I and controlling for variables such as employment and sense of control when examining the effect of IIV on health outcomes could be an interesting aim for future studies.

The sample size did, however, allow for statistically controlling for the potential confounding effects of both age and gender in the regression analyses. These analyses showed that age and gender did not have a statically significant influence on the results of the regression analyses, which is in contrast to other studies. Suh et al. (2012) have for example found greater bedtime and risetime variability to be associated with younger age. According to Bliwise et al. (2005), bedtime and risetime variability decrease with age. Given that the age range of the participants in the current study was 18 to 65, with a mean age of 40.9, several participants may naturally have established a more stable sleep and wake time, which may reduce the magnitude of the effect of age on the results. The gender distribution in the current

study was approximately 75% of the participants being female and approximately 25% being male. This distribution may represent the tendency of there being more females than males presenting with insomnia (Krishnan & Collop, 2006; Vedaa et al., 2020), and that women have a greater tendency to seek help, than men do (Thompson et al., 2016; Vedaa et al., 2020). The high distribution of females versus males did, however, not have a statistically significant impact on the results.

Another advantage of the study is its design of comparing two modes of treatment administration. Thereby enabling possible evidence on whether one mode of administration is more effective than the other. This study shows no differences effect between F2F CBT-I and dCBT-I, a finding also supported by other studies (Hagatun et al., 2018; Ye et al., 2015). Lastly, an important strength of this study is its specificity. Studying only one element of the treatment methods contributes to specific guidance on the effect of a specific treatment mechanism on specific treatment outcomes. Thereby offering guidance as to how much focus bedtime and risetime IIV should be devoted in future endeavors on improving CBT-I. Lastly, being a Randomized Controlled Trial strengthens the validity and reliability of the found results and minimizes the chances of the results being regressions to the mean.

Limitations of the current study

Validity and generalizability

As the study did not control for other demographic variables than age and gender, or for socioeconomic status, such as family structure, marital status, education, or work variables, amongst others, the findings cannot accurately be generalized to specific demographic or diagnostic groups beyond the study sample. Moreover, as this study solely looked at patients suffering from insomnia disorder, the findings cannot be generalized to the broader population of people, including those who do not suffer from this disorder**.** Irish et al**.** (2015), for example, found that though irregular sleep schedules were associated with poor sleep, assigning regular sleep schedules to nonclinical adults had limited effects on sleep improvement.

Not including other measures of IIV, insomnia symptoms and psychological distress, beyond sleep diaries, ISI and HADS, respectively, limits the content validity of the current study. Having more measures to validate the results from the sleep diaries, ISI and HADS

would have strengthened the validity of the study. Measures and measuring instruments are discussed in further detail below.

Another limitation of the current study is missing data. While the study had an overall large study sample, missing data at different time points, and for different measures led to a much smaller actual sample in several of the analyses. In the regression analyses, for example, the sample size actually included in the analyses ranged between 50 and 80. An *N* of 50 is less than 50% of the participants included in the study. The same tendencies were seen in all analyses conducted in this study. The large amount of missing data reduces the statistical power of the results, can cause bias in the estimation of parameters and limits the representativeness of the found results.

Potential confounding variables

Lack of analysis of third, or confounding variables apart from age and gender, limits the possibility to precisely interpret the results. While the current study found no significant reductions in bedtime and risetime IIV following CBT-I, other studies have found interventions targeting insomnia symptoms to reduce bedtime and risetime IIV (Bei et al., 2016). There is a lack of clarity and significant knowledge gaps concerning what variables mediate which outcomes in the relationship between bedtime and risetime IIV, insomnia and other aspects of health. Neither the current study nor the existing literature has been able to exclude such possible third variables. Nevertheless, several possible explanation models have been suggested.

According to Phillips et al. (2017), an increased bedtime and risetime IIV leads to a change in the light/dark exposure pattern, which subsequently has adverse effects on circadian rhythm and health. This research group found that individuals with higher bedtime and risetime IIV had a delayed onset of melatonin secretion equivalent to travelling 2-3 time zones west, and that light-based interventions have some therapeutic effect on reducing IIV in bedtime and risetime. Recent studies have also found that being exposed to only natural outdoor light decreases IIV in bedtime and risetime (Wright et al., 2013). These studies suggest that it is the change in the light/dark pattern caused by variable sleep-and-waketime which mediates poorer health.

Other studies have shown bed-and-risetime IIV to be associated with hormone secretion. Bei, Seeman et al. (2017) found high IIV in sleep timing to be associated with flatter diurnal cortisol trajectories, while Okun et al. (2011) have found irregularity in sleep timing to be associated with higher levels of circulating cytokines, and other inflammatory markers. Flatter cortisol trajectories and higher inflammatory hormones are linked with poor health outcomes and higher mortality rates (Bei, Seeman et al., 2017; Okun et al., 2011). Merklinger-Gruchala et al. (2008) have found IIV in bedtime and risetime to be associated with estradiol levels in fertile women. In their study, they found higher sleep timing irregularity to be associated with increased estradiol levels, which is linked with higher risks of breast cancer. These studies suggest that it is the alterations in hormone secretions caused by higher IIV that mediates poorer health.

Another third variable that could be a possible mediator between bedtime and risetime IIV and health is eating patterns. Having a more variable sleep timing could lead to an increase in food intake during adverse circadian phases, when the body is not preconditioned to process food. Research has shown later bedtime and sleep curtailment to be associated with increased caloric intake in the late evening. Late and irregular food intake have in turn been shown to be associated with weight gain and metabolic problems (Gooley, 2016; Spaeth et al., 2013; Spiegel et al., 2004). Changes in the exposures in the light/dark pattern, hormone secretion, and irregular food intake are just a few of the possible confounding variables that may link IIV in bedtime and risetime with health outcomes.

Comorbidities

While having a diverse and heterogeneous group adds to the natural validity of the study, not controlling for comorbidities is also a limitation to the interpretation of the data. This study did not differentiate patients only suffering from insomnia from patients with comorbidities. It is therefore not possible to know whether the changes in insomnia symptoms and psychological distress, and their relations to bedtime and risetime IIV, are actually functions of confounding comorbidities. Sánches-Ortuño and Edinger (2012), for example, found poorer sleep quality to be associated with higher IIV in several sleep measures among participants with primary insomnia, but not among those with comorbid insomnia. Interestingly, although both groups in their study had reductions in IIV following CBT-I, only the comorbid insomnia group also had paralleled improvements in subjective sleep quality (Sánches-Ortuño & Edinger, 2012). Furthermore, bedtime and risetime IIV seems to be

greater among people with comorbid insomnia than people with primary insomnia (Suh et al., 2012). Suh et al. (2012) also found that patients with elevated depressive symptoms had greater reductions in IIV, than those with initial lower levels of depressive symptoms. Moreover, different types of comorbidities could potentially have different effects in the associations between CBT-I, bedtime and risetime IIV and treatment outcomes. Controlling for comorbidities when examining the relations between bedtime and risetime IIV and treatment outcomes could be an important element in the quest for further developing and tailoring treatments of insomnia.

Finally, for those with comorbid insomnia, the insomnia symptoms often persist after successful treatment of the comorbid disorder (Harvey, 2001; Sánches-Ortuño & Edinger, 2012). These findings are similar to the findings of the present study, where reduction in bedtime IIV predicted lower levels of psychological distress, but not of insomnia symptoms. This emphasizes the importance of finding interventions that focus on and target the insomnia symptoms directly, rather than trying to treat all symptoms with one intervention. Studies where comorbidities are controlled for are needed for the development and testing of such interventions.

Workdays versus days off

An important limitation of the current study is that it did not control for differences in variability between workdays and days off. In the society of which the study was conducted, it is common to have different sleep schedules between workdays and days off, which may lead to a high observed bedtime and risetime IIV, even if an individual has stable, but different bedtimes and risetimes between workdays and days off. This effect would be of special interest when looking at bedtime and risetime IIV at different points separately, as a descriptive variable. For example, investigating the relationship between having more or less bedtime and risetime IIV between workdays and days off and insomnia and other mental health symptoms.

Sleepiness is timed according to an individual's circadian rhythm, which does not change based on work or school days, and days off (Czeisler et al., 1980). Evidence is linking psychological distress and deficits in performance with sleep outside one's natural sleep time (Åkerstedt, 2003). Some studies have found that among adolescents and young adults, bedtime and risetime IIV above 2 hours between weekdays and weekends predicted adverse

outcomes such as daytime sleepiness, depressive symptoms (Hidalgo et al., 2009; Lund et al., 2010; Spruyt et al., 2011; Wolfson & Carskadon, 1998), and increased cardiovascular disease (Blunden et al., 2019). Furthermore, the magnitude of bedtime and risetime IIV between days off, and workdays has been found to be associated with somatic problems, such as increased fat mass, and insulin resistance (Gooley, 2016). The current study chose not to include this variable as it was the change in bedtime and risetime IIV over time, rather than IIV at specific time points, which was of interest. Additionally, the particular interventions administered in the current study are focused on a stable bedtime and risetime throughout the complete treatment period, without separating workdays from days off.

Chronotype

Another variable the current study did not control for, and that would be of interest to investigate, is the effect of chronotype on bedtime and risetime IIV, and sleep quality and daytime functioning. Chronotype refers to circadian phase preferences, and is usually classified as either morningness or eveningness chronotypes (Wong et al., 2015). Suh et al. (2012) have found that those with an eveningness chronotype and elevated depression symptoms have a higher IIV in bedtime and risetime. Furthermore, Hagatun et al. (2018) found that patients with an eveningness chronotype, as well as those with higher bedtime and risetime IIV showed greater reductions in bedtime and risetime IIV and insomnia, anxiety and depression symptoms following CBT-I, than did those with a morningness chronotype, or lower initial bedtime and risetime IIV.

There is evidence that individuals with higher morningness chronotype adapt better to regular school and work day schedules both emotionally and behaviorally (Blunden et al., 2019). This suggests that the society of the study sample is likely to be better fitted for morning types, which in turn would lead to natural better functioning and wellbeing for morning types than for evening types. Simultaneously, evening types will have to adapt to a greater behavioral change, when undergoing CBT-I, than will morning types. If this behavioral change is successful, evening types would be likely to also experience both a greater decrease in bedtime and risetime IIV and in insomnia symptoms and psychological distress. This is supported by evidence showing that evening types present with worse wellbeing and performance, as well as more emotional problems (Blunden et al., 2019). Such effects could be possible confounding variables in the interpretation of the results of the

current study. Unfortunately, there is a lack of research on the mechanisms linking variables, such as bedtime and risetime IIV, chronotype and daytime symptoms together.

Measures and measuring instruments

Two of the most common and least invasive methods for measuring sleep are sleep diaries and actigraphy. In the current study, only sleep diaries were used. A disadvantage of sleep diaries is that they are subjective measures, and are subject to distorting factors of the participants, such as mood and cognitive biases. The use of actigraphy can give a more objective perspective on the data. Disadvantages of actigraphy are that they may overestimate sleep in participants remaining still while awake, and underestimate sleep in those moving a lot in their sleep (Mullin et al., 2011). Sánches-Ortuño and Edinger (2012), for example, found IIV in time spent in bed to decrease throughout treatment, in the subjective measures, but not in the actigraphy measures. This raises a question as to whether the found changes in bedtime and risetime IIV, are linked to reporting bias, rather than actual differences in bedtime and risetime IIV. However, several studies indicate that the associations between mood and bedtime and risetime IIV are mediated by perceived sleep quality, as shown by a meta-analysis conducted by Bei, Manber et al. (2017). This finding supports the use of sleep diaries when examining the associations between bed-and-risetime IIV, and insomnia symptoms and psychological distress.

The current study chose to focus on sleep diaries, solely, as it was interested in the relationship between perceived behavior, sleep quality and daytime functioning, in relation to treatment. Moreover, sleep diaries, in conjunction with ISI, are recommended as key outcome measures for clinical trials and studies concerning insomnia (Buysse et al., 2006). However, bedtime and risetime IIV do not specify the amount of time the participant spent in bed, neither sleeping nor awake. The current study would thus not be able to rule out whether constant bedtimes and risetimes or other confounding variables such as sleep duration, nighttime awakenings or light exposure, as suggested by Phillips et al. (2017), had the greater impact on sleep quality and psychological distress.

Clinical cutoff point for bedtime and risetime IIV

A final, yet important limitation of the current study is the lack of a clinical cut-off point for IIV in bedtime and risetime. As no data could be found on what amount of bedtime

and risetime IIV should be considered clinically significant, the current study did not have sufficient information to set cutoff scores for bedtime and risetime IIVs. According to the statistical analysis carried out, a 14-minute difference in risetime IIV was defined as statistically significant, while a 13-minutes difference was not. On an individual level, most would agree that a 14-minutes difference in bedtime or risetime is not more significant than a 13-minutes difference. Duncan et al. (2016) have classified higher levels of bed-and-risetime variations with a 30-minutes criteria. Others, like Kline et al. (2014) and Manber et al. (1996) suggest that a variation of 1 hour should be the cutoff point. Yet others, like Taylor et al. (2016), defined a high IIV in sleep timing as more than one standard deviation outside of the person's mean sleep timing. On a population level however, it is less clear how clinically significant these differences are. Although studies have found reduced bedtime and risetime IIV following CBT-I (Edinger et al., 1992; Edinger & Means, 2005; Vallières et al., 2005), none of the reviewed studies tested for clinical significance. In order to be able to obtain more certain data on the effect of treatment on bed-and-risetime IIV, and of the effect of bedtime and risetime IIV on sleep quality and mental health, more research specifically designed to investigate the clinical significance of different amounts of variability in bedtime and risetime is needed. Research is needed both in clinical and nonclinical populations.

Conclusions

Sleep problems, with insomnia at the forefront, are an increasing worldwide problem. About one in every three people experience insomnia symptoms. This raises a demand for easily available and effective interventions. While CBT-I is considered the number one treatment of insomnia, and digital versions of CBT-I have been shown to be as effective as F2F CBT-I, the mechanisms through which CBT-I achieves its action are poorly studied. One action mechanism, which is a core component of CBT-I is maintaining a regular sleep schedule, or consistent bedtimes and risetimes. There is, however, a lack of empirical evidence on the effects of CBT-I on bedtime and risetime IIV, and on the relation between IIV in bed-and-risetime and sleep quality and daytime functioning. Existing research on this topic is sparse, with mixed findings that often contradict one another. Based on this knowledge gap, the current thesis aimed to: assess changes in IIV in bedtime and risetime following CBT-I; compare F2F CBT-I with dCBT-I in their effect on reducing bed-and-risetime IIV; and examine associations between changes bedtime and risetime IIV and

changes in treatment outcomes, measured in insomnia symptoms and psychological distress. The study did not find any significant decreases in either bedtime or risetime IIV following CBT-I, nor any differences between F2F CBT-I and dCBT-I in their effect on changing bed-and-risetime IIV. The study did, however, find reductions in bedtime IIV to significantly predict lower levels of psychological distress, measured from termination of treatment to 6 months follow-up. All other associations between changes in both bedtime and risetime IIV and changes in both insomnia symptoms and psychological distress were not significant.

While there were no significant reductions in bedtime and risetime IIV at any point following CBT-I, significant increases in both bedtime and risetime IIV from termination of treatment to 6 months follow-up were found. These findings indicate that in the current trial CBT-I was not successful in reducing IIV in bedtime and risetime, but that it on the contrary, over time, promoted increased bedtime and risetime IIV. If bedtime and risetime IIV, are indeed key mechanism affecting sleep quality and daytime functioning, this finding could indicate that the treatment models of CBT-I need to be revisited.

The fact that there were no significant differences between F2F CBT-I and dCBT-I in their effect on reducing bedtime and risetime IIV implies that none of the treatment models, as used in the current trial, were more effective than the other on their goal of inducing a stable sleep schedule. Evidence showing dCBT-I not to be inferior of F2F CBT-I is necessary for the development and support of use of dCBT-I programs. dCBT-I, in turn, has the potential of lowering the costs and increasing the availability of treatment for patients suffering from insomnia or insomnia symptoms.

In light of the relation between change in bedtime IIV and change in psychological distress following treatment, there are some points that should be taken into consideration in future research when assessing associations between CBT-I, IIV and treatment outcomes. Traditionally, in CBT-I, risetime has been the important focus in treatment, with bedtime being a secondary variable of change. However, the results of this study could indicate that the importance of bedtime IIV is underestimated in the treatment of insomnia. Perhaps having a greater focus on bedtime, in CBT-I, would lead to better treatment outcomes. Furthermore, controlling bedtime, when risetime is controlled by factors outside treatment, could have an effect on the variation in sleep duration, as well as on sleep timing. Moreover, this study found that decreasing bedtime IIV only had an effect on psychological distress when maintained over time after treatment termination. This emphasizes the importance of making

sure patients understand the significance of maintaining a low bedtime IIV especially after termination of treatment. Finally yet importantly, the finding of change in bedtime IIV only being a predictor of change in psychological distress, but not in insomnia symptoms could point to sense of control as a possible mediator between bedtime and risetime IIV and health. Based on these points, future research should examine both the short- and longer-term effects of bedtime IIV on health, taking into consideration possible confounding variables, such as sense of control, sleep duration and employment amongst others.

The lack of statistically significant associations between risetime IIV, and insomnia symptoms and psychological distress, questions the strong emphasis CBT-I has on maintaining a set risetime. If maintaining a constant risetime is actually not necessary for positive treatment effects, excluding this mechanism from CBT-I could make the intervention less demanding and easier to follow for those receiving it. While the participants who succeeded in reducing their bedtime IIV after treatment termination, also experienced a reduction in psychological distress, CBT-I administered in the current treatment trial was not successful in reducing bedtime and risetime IIV for the study sample as a whole. Meanwhile, the study sample as a whole did experience a significant decrease in both insomnia symptoms and psychological distress, both at treatment termination and at 6 months follow-up. These findings raise a question about whether decreasing IIV in bedtime and risetime is actually beneficial to sleep quality and other mental health problems for the general population. An important topic for further research is to explore both the possible benefits and harms of reducing bedtime and risetime IIV. If high IIV in either bedtime or risetime is indeed found to be harmful, another question is what amount of change in bedtime and risetime IIV should be considered clinically significant, and what amount of IIV should be considered as clinically harmful.

Another consideration for further research is what role poor sleep hygiene, comorbidities and different insomnia subtypes, chronotype, daily schedules, and demographics play in the relationship between CBT-I, bedtime and risetime IIV, and sleep and daytime functioning and other treatment outcomes. Empirical knowledge on these questions is a necessity for professionals to give educated advice to patients about decreasing their IIV in bedtime and risetime, and for the standards of CBT-I. Having more specific evidence on the action mechanism of CBT-I, and thereby more specific guidelines, could also make the education about CBT-I in the health care sector easier.

Since bedtime and risetime IIV, on one hand, is not found to play a significant role in insomnia remission, its relevance as a key feature in CBT-I should be reconsidered. On the other hand, a longer-term change in bedtime IIV was found to play a significant role on the secondary outcome, of psychological distress. Based on this finding, it should be examined whether there should be more focus on bedtime in CBT-I, together with emphasis on the importance of longer-term behavioral adaptations, also after termination of treatment. Finally, as the availability of F2F CBT-I is far behind its demands, more empirical evidence is needed on dCBT-I. Specifically, research is needed to assess the specific modes of action of CBT-I and dCBT-I and their effect on sleep and daytime functioning. It should be assessed as to whether either bedtime or risetime IIV should be given more or less focus in CBT-I, and if necessary, on how to increase the effect CBT-I has on bedtime and risetime IIV. If either bedtime or risetime IIV are not important for treatment success, more research is needed to find what mechanisms of action are important to achieve the best possible treatment effects. This is necessary to make treatment as efficient, specific and widely available as possible for the great percentage of our population in need of it, at as low a cost as possible for both individuals and societies.

Bibliography

Åkerstedt, T. (2003). Shift work and disturbed sleep/wakefulness. *Occupational medicine, 53*(2), 89-94.

American Academy of Sleep, M. (2005). *The international classification of sleep disorders : diagnostic & coding manual*. American Academy of Sleep Medicine.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Batterham, P. J., Christensen, H., Mackinnon, A. J., Gosling, J. A., Thorndike, F. P., Ritterband, L. M., Glozier, N., & Griffiths, K. M. (2017). Trajectories of change and long-term outcomes in a randomised controlled trial of internet-based insomnia treatment to prevent depression. *BJPsych open, 3*(5), 228-235. https://doi.org/10.1192/bjpo.bp.117.005231

Bei, B., Byrne, M. L., Ivens, C., Waloszek, J., Woods, M. J., Dudgeon, P., Murray, G., Nicholas, C. L., Trinder, J., & Allen, N. B. (2013, May). Pilot study of a mindfulness-based, multi-component, in-school group sleep intervention in adolescent girls. *Early Interv Psychiatry, 7*(2), 213-220. https://doi.org/10.1111/j.1751-7893.2012.00382.x

Bei, B., Manber, R., Allen, N. B., Trinder, J., & Wiley, J. F. (2017, Feb 1). Too Long, Too Short, or Too Variable? Sleep Intraindividual Variability and Its Associations With Perceived Sleep Quality and Mood in Adolescents During Naturalistically Unconstrained Sleep. *Sleep, 40*(2). https://doi.org/10.1093/sleep/zsw067

Bei, B., Seeman, T. E., Carroll, J. E., & Wiley, J. F. (2017). Sleep and Physiological Dysregulation: A Closer Look at Sleep Intraindividual Variability. *Sleep, 40*(9), zsx109. https://doi.org/10.1093/sleep/zsx109

Bei, B., Wiley, J. F., Trinder, J., & Manber, R. (2016, Aug 1). Beyond the mean: A systematic review on the correlates of daily intraindividual variability of sleep/wake patterns. *Sleep Medicine Reviews, 28*, 108-124. https://doi.org/https://doi.org/10.1016/j.smrv.2015.06.003

Bliwise, D. L., Ansari, F. P., Straight, L.-B., & Parker, K. P. (2005). Age changes in timing and 24-hour distribution of self-reported sleep. *The American journal of geriatric psychiatry*, *13*(12), 1077-1082.

Blunden, S., Magee, C., Clarkson, L., Searle, A., Banks, S., & Olds, T. (2019, Dec 1). Interindividual and intraindividual variability in adolescent sleep patterns across an entire school term: A pilot study. *Sleep Health*, *5*(6), 546-554. https://doi.org/https://doi.org/10.1016/j.sleh.2019.08.002

Breslau, N., Roth, T., Rosenthal, L., & Andreski, P. (1996, Mar 15). Sleep disturbance and psychiatric disorders: a longitudinal epidemiological study of young adults. *Biol Psychiatry*, *39*(6), 411-418.

Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Lichstein, K. L., & Morin, C. M. (2006). Recommendations for a standard research assessment of insomnia. *Sleep*, *29*(9), 1155-1173.

Buysse, D. J., Cheng, Y., Germain, A., Moul, D. E., Franzen, P. L., Fletcher, M., & Monk, T. H. (2010, Jan 1). Night-to-night sleep variability in older adults with and without chronic insomnia. *Sleep Medicine*, *11*(1), 56-64. https://doi.org/https://doi.org/10.1016/j.sleep.2009.02.010

Carney, C. E., Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Krystal, A. D., Lichstein, K. L., & Morin, C. M. (2012). The consensus sleep diary: standardizing prospective sleep self-monitoring. *Sleep*, *35*(2), 287-302. https://doi.org/10.5665/sleep.1642

Carney, R. M., Freedland, K. E., & Jaffe, A. S. (1990, Nov-Dec). Insomnia and depression prior to myocardial infarction. *Psychosom Med*, *52*(6), 603-609.

Chan, W. S., Williams, J., Dautovich, N. D., McNamara, J. P., Stripling, A., Dzierzewski, J. M., Berry, R. B., McCoy, K. J., & McCrae, C. S. (2017). Night-to-night sleep variability in older adults with chronic insomnia: mediators and moderators in a randomized controlled trial of brief behavioral therapy (BBT-I). *Journal of Clinical Sleep Medicine*, *13*(11), 1243-1254.

Christensen, H., Batterham, P. J., Gosling, J. A., Ritterband, L. M., Griffiths, K. M., Thorndike, F. P., Glozier, N., O'Dea, B., Hickie, I. B., & Mackinnon, A. J. (2016). Effectiveness of an online insomnia program (SHUTi) for prevention of depressive episodes (the GoodNight Study): a randomised controlled trial. *The Lancet Psychiatry, 3*(4), 333-341.

Czeisler, C. A., Weitzman, E., Moore-Ede, M. C., Zimmerman, J. C., & Knauer, R. S. (1980). Human sleep: its duration and organization depend on its circadian phase. *Science, 210*(4475), 1264-1267.

Davidson, A. J., Sellix, M. T., Daniel, J., Yamazaki, S., Menaker, M., & Block, G. D. (2006). Chronic jet-lag increases mortality in aged mice. *Current Biology, 16*(21), R914-R916. https://doi.org/10.1016/j.cub.2006.09.058

Duffy, J. F., & Czeisler, C. A. (2009). Effect of light on human circadian physiology. *Sleep medicine clinics, 4*(2), 165-177.

Duffy, J. F., & Wright Jr, K. P. (2005). Entrainment of the human circadian system by light. *Journal of biological rhythms, 20*(4), 326-338.

Duncan, M. J., Kline, C. E., Rebar, A. L., Vandelanotte, C., & Short, C. E. (2016, Feb 1). Greater bed- and wake-time variability is associated with less healthy lifestyle behaviors: a cross-sectional study. *Journal of Public Health, 24*(1), 31-40. https://doi.org/10.1007/s10389-015-0693-4

Edinger, J. D., Hoelscher, T. J., Marsh, G. R., Lipper, S., & Ionescu-Pioggia, M. (1992). A cognitive-behavioral therapy for sleep-maintenance insomnia in older adults. *Psychology and Aging, 7*(2), 282.

Edinger, J. D., Marsh, G. R., McCall, W. V., Erwin, C. W., & Lininger, A. W. (1991). Sleep variability across consecutive nights of home monitoring in older mixed DIMS patients. *Sleep, 14*(1), 5-12.

Edinger, J. D., & Means, M. K. (2005, Jul). Cognitive-behavioral therapy for primary insomnia. *Clin Psychol Rev, 25*(5), 539-558. https://doi.org/10.1016/j.cpr.2005.04.003

Eysenbach, G. (2005, Mar 31). The Law of Attrition. *J Med Internet Res*, *7*(1), e11. https://doi.org/10.2196/jmir.7.1.e11

Filipski, E., Delaunay, F., King, V. M., Wu, M.-W., Claustrat, B., Gréchez-Cassiau, A., Guettier, C., Hastings, M. H., & Francis, L. (2004). Effects of Chronic Jet Lag on Tumor Progression in Mice. *Cancer Research*, *64*(21), 7879. https://doi.org/10.1158/0008-5472.CAN-04-0674

Flynn-Evans, E. E., Shekleton, J. A., Miller, B., Epstein, L. J., Kirsch, D., Brogna, L. A., Burke, L. M., Bremer, E., Murray, J. M., Gehrman, P., Rajaratnam, S. M. W., & Lockley, S. W. (2017). Circadian Phase and Phase Angle Disorders in Primary Insomnia. *Sleep*, *40*(12). https://doi.org/10.1093/sleep/zsx163

Freeman, D., Sheaves, B., Goodwin, G. M., Yu, L.-M., Nickless, A., Harrison, P. J., Emsley, R., Luik, A. I., Foster, R. G., Wadekar, V., Hinds, C., Gumley, A., Jones, R., Lightman, S., Jones, S., Bentall, R., Kinderman, P., Rowse, G., Brugha, T., Blagrove, M., Gregory, A. M., Fleming, L., Walklet, E., Glazebrook, C., Davies, E. B., Hollis, C., Haddock, G., John, B., Coulson, M., Fowler, D., Pugh, K., Cape, J., Moseley, P., Brown, G., Hughes, C., Obonsawin, M., Coker, S., Watkins, E., Schwannauer, M., MacMahon, K., Siriwardena, A. N., & Espie, C. A. (2017). The effects of improving sleep on mental health (OASIS): a randomised controlled trial with mediation analysis. *The lancet. Psychiatry*, *4*(10), 749-758. https://doi.org/10.1016/S2215-0366(17)30328-0

Gabe, J., Coveney, C. M., & Williams, S. J. (2016). Prescriptions and proscriptions: moralising sleep medicines. *Sociology of Health & Illness*, *38*(4), 627-644. https://doi.org/10.1111/1467-9566.12383

Germain, A., Shear, M. K., Hall, M., & Buysse, D. J. (2007, Mar). Effects of a brief behavioral treatment for PTSD-related sleep disturbances: a pilot study. *Behav Res Ther*, *45*(3), 627-632. https://doi.org/10.1016/j.brat.2006.04.009

Gooley, J. J. (2016). How Much Day-To-Day Variability in Sleep Timing Is Unhealthy? *Sleep*, *39*(2), 269-270. https://doi.org/10.5665/sleep.5424

Hagatun, S., Vedaa, Ø., Harvey, A. G., Nordgreen, T., Smith, O. R. F., Pallesen, S., Havik, O. E., Thorndike, F. P., Ritterband, L. M., & Sivertsen, B. (2018, Jun 1). Internet-delivered cognitive-behavioral therapy for insomnia and comorbid symptoms. *Internet Interventions, 12*, 11-15. https://doi.org/10.1016/j.invent.2018.02.003

Harvey, A. G. (2000, Jan). Sleep hygiene and sleep-onset insomnia. *J Nerv Ment Dis, 188*(1), 53-55. https://doi.org/10.1097/00005053-200001000-00011

Harvey, A. G. (2001). Insomnia: symptom or diagnosis? *Clin Psychol Rev, 21*(7), 1037-1059.

Harvey, A. G., Dong, L., Bélanger, L., & Morin, C. M. (2017). Mediators and treatment matching in behavior therapy, cognitive therapy and cognitive behavior therapy for chronic insomnia. *Journal of Consulting and Clinical Psychology, 85*(10), 975.

Hidalgo, M. P., Caumo, W., Posser, M., Coccaro, S. B., Camozzato, A. L., & Chaves, M. L. F. (2009). Relationship between depressive mood and chronotype in healthy subjects. *Psychiatry and clinical neurosciences, 63*(3), 283-290.

Irish, L. A., Kline, C. E., Gunn, H. E., Buysse, D. J., & Hall, M. H. (2015). The role of sleep hygiene in promoting public health: A review of empirical evidence. *Sleep Medicine Reviews, 22*, 23-36.

Irish, L. A., Kline, C. E., Rothenberger, S. D., Krafty, R. T., Buysse, D. J., Kravitz, H. M., Bromberger, J. T., Zheng, H., & Hall, M. H. (2014). A 24-hour approach to the study of health behaviors: Temporal relationships between waking health behaviors and sleep. *Annals of Behavioral Medicine, 47*(2), 189-197.

Irwin, M. R., Olmstead, R., & Carroll, J. E. (2016, Jul 1). Sleep Disturbance, Sleep Duration, and Inflammation: A Systematic Review and Meta-Analysis of Cohort Studies and Experimental Sleep Deprivation. *Biol Psychiatry, 80*(1), 40-52. https://doi.org/10.1016/j.biopsych.2015.05.014

Kales, J. D., Kales, A., Bixler, E. O., Soldatos, C. R., Cadieux, R. J., Kashurba, G. J., & Vela-Bueno, A. (1984, Nov). Biopsychobehavioral correlates of insomnia, V: Clinical characteristics and behavioral correlates. *Am J Psychiatry, 141*(11), 1371-1376. https://doi.org/10.1176/ajp.141.11.1371

Kallestad, H., Langsrud, K., Vedaa, Ø., Stiles, T., Vethe, D., Lydersen, S., Ritterband, L., Morken, G., & Sivertsen, B. (2018). 0371 A Randomized Noninferiority Trial Comparing Cognitive Behavior Therapy For Insomnia (cbt-i) Delivered By A Therapist Or Via A Fully Automated Online Treatment Program. *Sleep, 41*(suppl_1), A142-A142. https://doi.org/10.1093/sleep/zsy061.370

Kallestad, H., Scott, J., Vedaa, Ø., Vethe, D., Morken, G., Lydersen, S., Thorndike, F. P., Ritterband, L. M., Stiles, T. C., Sivertsen, B., & Langsrud, K. (Submitted). Cognitive Behaviour Therapy for Insomnia Delivered through a digital programme or face-to-face by a therapist: A randomized controlled non-inferiority trial. *Sleep*.

Kessler, R. C., Berglund, P. A., Coulouvrat, C., Hajak, G., Roth, T., Shahly, V., Shillington, A. C., Stephenson, J. J., & Walsh, J. K. (2011, Sep 1). Insomnia and the performance of US workers: results from the America insomnia survey. *Sleep, 34*(9), 1161-1171. https://doi.org/10.5665/sleep.1230

Keeton, C. P., Perry-Jenkins, M., & Sayer, A. G. (2008). Sense of control predicts depressive and anxious symptoms across the transition to parenthood. *Journal of family psychology : JFP : journal of the Division of Family Psychology of the American Psychological Association (Division 43), 22*(2), 212–221. https://doi.org/10.1037/0893-3200.22.2.212

Kline, C. E., Irish, L. A., Buysse, D. J., Kravitz, H. M., Okun, M. L., Owens, J. F., & Hall, M. H. (2014). Sleep hygiene behaviors among midlife women with insomnia or sleep-disordered breathing: the SWAN sleep study. *Journal of Women's Health, 23*(11), 894-903.

Krakow, B., Johnston, L., Melendrez, D., Hollifield, M., Warner, T. D., Chavez-Kennedy, D., & Herlan, M. J. (2001, Dec). An open-label trial of evidence-based cognitive behavior therapy for nightmares and insomnia in crime victims with PTSD. *Am J Psychiatry, 158*(12), 2043-2047. https://doi.org/10.1176/appi.ajp.158.12.2043

Krishnan, V., & Collop, N. A. (2006). Gender differences in sleep disorders. *Current Opinion in Pulmonary Medicine, 12*(6). https://journals.lww.com/co-pulmonarymedicine/Fulltext/2006/11000/Gender_differences_in_sleep_disorders.3.aspx

Lacks, P., & Rotert, M. (1986). Knowledge and practice of sleep hygiene techniques in insomniacs and good sleepers. *Behav Res Ther, 24*(3), 365-368. https://doi.org/10.1016/0005-7967(86)90197-x

Leiknes, K. A., Dalsbø, T. K., & Siqveland, J. (2016). *Måleegenskaper ved den norske versjonen av Hospital Anxiety and Depression Scale (HADS). [Psychometric assessment of the Norwegian version of the Hospital Anxiety and Depression Scale (HADS).]* [Report](9516, Issue. a. f. k. i. K. Folkehelseinstituttet.

Lemola, S., Ledermann, T., & Friedman, E. M. (2013). Variability of Sleep Duration Is Related to Subjective Sleep Quality and Subjective Well-Being: An Actigraphy Study. *PLOS ONE, 8*(8), e71292. https://doi.org/10.1371/journal.pone.0071292

Lie, S. S., Karlsen, B., Oord, E. R., Graue, M., & Oftedal, B. (2017, May 30). Dropout From an eHealth Intervention for Adults With Type 2 Diabetes: A Qualitative Study. *J Med Internet Res, 19*(5), e187. https://doi.org/10.2196/jmir.7479

Luik, A. I., Kyle, S. D., & Espie, C. A. (2017). Digital Cognitive Behavioral Therapy (dCBT) for Insomnia: a State-of-the-Science Review. *Current sleep medicine reports, 3*(2), 48-56. https://doi.org/10.1007/s40675-017-0065-4

Lund, H. G., Reider, B. D., Whiting, A. B., & Prichard, J. R. (2010). Sleep patterns and predictors of disturbed sleep in a large population of college students. *Journal of adolescent health, 46*(2), 124-132.

Manber, R., Bootzin, R. R., Acebo, C., & Carskadon, M. A. (1996). The effects of regularizing sleep-wake schedules on daytime sleepiness. *Sleep, 19*(5), 432-441.

Manber, R., Edinger, J. D., Gress, J. L., San Pedro-Salcedo, M. G., Kuo, T. F., & Kalista, T. (2008, Apr). Cognitive behavioral therapy for insomnia enhances depression outcome in patients with comorbid major depressive disorder and insomnia. *Sleep, 31*(4), 489-495.

Markwald, R. R., Iftikhar, I., & Youngstedt, S. D. (2018, Mar-Apr). Behavioral Strategies, Including Exercise, for Addressing Insomnia. *ACSM's health & fitness journal, 22*(2), 23-29. https://doi.org/10.1249/FIT.0000000000000375

Maurer, L. F., Espie, C. A., Omlin, X., Reid, M. J., Sharman, R., Gavriloff, D., Emsley, R., & Kyle, S. D. (2020, May 18). Isolating the role of time in bed restriction in the treatment of insomnia [Article]. *a randomised, controlled, dismantling trial comparing sleep restriction therapy with time in bed regularisation*. https://doi.org/10.1093/sleep/zsaa096

McLeod, S. A. (2019, July 10). What does effect size tell you? Simply psychology: https://www.simplypsychology.org/effect-size.html

Merklinger-Gruchala, A., Ellison, P. T., Lipson, S. F., Thune, I., & Jasienska, G. (2008). Low estradiol levels in women of reproductive age having low sleep variation. *European Journal of Cancer Prevention, 17*(5). https://journals.lww.com/eurjcancerprev/Fulltext/2008/10000/Low_estradiol_levels_in_women_of_reproductive_age.14.aspx

Mitchell, M. D., Gehrman, P., Perlis, M., & Umscheid, C. A. (2012). Comparative effectiveness of cognitive behavioral therapy for insomnia: a systematic review. *BMC Family Practice, 13*, 40-40. https://doi.org/10.1186/1471-2296-13-40

Morin, C. M. (1993). *Insomnia : psychological assessment and management*. Guilford Press.

Morin, C. M. (2004). Cognitive-behavioral approaches to the treatment of insomnia. *J Clin Psychiatry, 65 Suppl 16*, 33-40.

Morin, C. M., Belleville, G., Bélanger, L., & Ivers, H. (2011, May 1). The Insomnia Severity Index: psychometric indicators to detect insomnia cases and evaluate treatment response. *Sleep, 34*(5), 601-608. https://doi.org/10.1093/sleep/34.5.601

Morin, C. M., & Benca, R. (2012, Mar 24). Chronic insomnia. *Lancet, 379*(9821), 1129-1141. https://doi.org/10.1016/s0140-6736(11)60750-2

Morin, C. M., Bootzin, R. R., Buysse, D. J., Edinger, J. D., Espie, C. A., & Lichstein, K. L. (2006, Nov). Psychological and behavioral treatment of insomnia:update of the recent evidence (1998-2004). *Sleep, 29*(11), 1398-1414.

Morin, C. M., Drake, C. L., Harvey, A. G., Krystal, A. D., Manber, R., Riemann, D., & Spiegelhalder, K. (2015, Sep 3, online). Insomnia disorder [Primer]. *Nature Reviews Disease Primers, 1*, 15026. https://doi.org/10.1038/nrdp.2015.26

Mullin, B. C., Harvey, A. G., & Hinshaw, S. P. (2011, Jun). A preliminary study of sleep in adolescents with bipolar disorder, ADHD, and non-patient controls. *Bipolar Disord, 13*(4), 425-432. https://doi.org/10.1111/j.1399-5618.2011.00933.x

Myers, E., Startup, H., & Freeman, D. (2011, Sep). Cognitive behavioural treatment of insomnia in individuals with persistent persecutory delusions: a pilot trial. *J Behav Ther Exp Psychiatry, 42*(3), 330-336. https://doi.org/10.1016/j.jbtep.2011.02.004

Ohayon, M. M., & Reynolds, C. F., 3rd. (2009, Oct). Epidemiological and clinical relevance of insomnia diagnosis algorithms according to the DSM-IV and the International Classification of Sleep Disorders (ICSD). *Sleep Med, 10*(9), 952-960. https://doi.org/10.1016/j.sleep.2009.07.008

Okun, M. L., Reynolds, C. F., 3rd, Buysse, D. J., Monk, T. H., Mazumdar, S., Begley, A., & Hall, M. (2011, Feb-Mar). Sleep variability, health-related practices, and inflammatory markers in a community dwelling sample of older adults. *Psychosom Med, 73*(2), 142-150. https://doi.org/10.1097/PSY.0b013e3182020d08

Phillips, A. J. K., Clerx, W. M., O'Brien, C. S., Sano, A., Barger, L. K., Picard, R. W., Lockley, S. W., Klerman, E. B., & Czeisler, C. A. (2017, Jun 12). Irregular sleep/wake patterns are associated with poorer academic performance and delayed circadian and sleep/wake timing. *Sci Rep, 7*(1), 3216. https://doi.org/10.1038/s41598-017-03171-4

Ritterband, L. M., Thorndike, F. P., Gonder-Frederick, L. A., Magee, J. C., Bailey, E. T., Saylor, D. K., & Morin, C. M. (2009). Efficacy of an Internet-based behavioral intervention for adults with insomnia. *Archives of general psychiatry, 66*(7), 692-698. https://doi.org/10.1001/archgenpsychiatry.2009.66

Rosen, R. C., Rosekind, M., Rosevear, C., Cole, W. E., & Dement, W. C. (1993, Apr). Physician education in sleep and sleep disorders: a national survey of U.S. medical schools. *Sleep, 16*(3), 249-254.

Roth, T. (2007). Insomnia: definition, prevalence, etiology, and consequences. *Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine, 3*(5 Suppl), S7-S10. https://pubmed.ncbi.nlm.nih.gov/17824495

Roth, T., Coulouvrat, C., Hajak, G., Lakoma, M. D., Sampson, N. A., Shahly, V., Shillington, A. C., Stephenson, J. J., Walsh, J. K., & Kessler, R. C. (2011, Mar 15). Prevalence and perceived health associated with insomnia based on DSM-IV-TR; International Statistical Classification of Diseases and Related Health Problems, Tenth Revision; and Research Diagnostic Criteria/International Classification of Sleep Disorders, Second Edition criteria: results from the America Insomnia Survey. *Biol Psychiatry, 69*(6), 592-600. https://doi.org/10.1016/j.biopsych.2010.10.023

Sánches-Ortuño, M. M., & Edinger, J. D. (2012). Internight sleep variability: its clinical significance and responsiveness to treatment in primary and comorbid insomnia. *Journal of Sleep Research, 21*(5), 527-534. https://doi.org/10.1111/j.1365-2869.2012.01010.x

Schernhammer, E. S., Laden, F., Speizer, F. E., Willett, W. C., Hunter, D. J., Kawachi, I., & Colditz, G. A. (2001). Rotating Night Shifts and Risk of Breast Cancer in Women Participating in the Nurses' Health Study. *JNCI: Journal of the National Cancer Institute, 93*(20), 1563-1568. https://doi.org/10.1093/jnci/93.20.1563

Schutte-Rodin, S., Broch, L., Buysse, D., Dorsey, C., & Sateia, M. (2008). Clinical guideline for the evaluation and management of chronic insomnia in adults. *Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine, 4*(5), 487-504. https://pubmed.ncbi.nlm.nih.gov/18853708

Shaffer, K. M., Hedeker, D., Morin, C. M., Ingersoll, K., Thorndike, F., & Ritterband, L. M. (2020). Intraindividual variability in sleep schedule: effects of an internet-based cognitive-behavioral therapy for insomnia program and its relation with symptom remission. *Sleep*. https://doi.org/10.1093/sleep/zsaa115

Simon, G. E., & VonKorff, M. (1997, Oct). Prevalence, burden, and treatment of insomnia in primary care. *Am J Psychiatry, 154*(10), 1417-1423. https://doi.org/10.1176/ajp.154.10.1417

Sivertsen, B., Krokstad, S., Overland, S., & Mykletun, A. (2009, Aug). The epidemiology of insomnia: associations with physical and mental health. The HUNT-2 study. *J Psychosom Res, 67*(2), 109-116. https://doi.org/10.1016/j.jpsychores.2009.05.001

Sousa, I. C., Souza, J. C., Louzada, F. M., & Azevedo, C. V. M. (2013, July 01). Changes in sleep habits and knowledge after an educational sleep program in 12th grade students [journal article]. *Sleep and Biological Rhythms, 11*(3), 144-153. https://doi.org/10.1111/sbr.12016

Spaeth, A. M., Dinges, D. F., & Goel, N. (2013). Effects of Experimental Sleep Restriction on Weight Gain, Caloric Intake, and Meal Timing in Healthy Adults. *Sleep, 36*(7), 981-990. https://doi.org/10.5665/sleep.2792

Spiegel, K., Tasali, E., Penev, P., & Van Cauter, E. (2004, Dec 7). Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Ann Intern Med, 141*(11), 846-850. https://doi.org/10.7326/0003-4819-141-11-200412070-00008

Spielman, A. J., Saskin, P., & Thorpy, M. J. (1987, Feb). Treatment of chronic insomnia by restriction of time in bed. *Sleep, 10*(1), 45-56.

Spruyt, K., Molfese, D. L., & Gozal, D. (2011). Sleep duration, sleep regularity, body weight, and metabolic homeostasis in school-aged children. *Pediatrics, 127*(2), e345-e352.

Stoller, M. K. (1994, Sep-Oct). Economic effects of insomnia. *Clin Ther, 16*(5), 873-897; discussion 854.

Stoller, M. K. (1997, Jan 1). The socio-economics of insomnia: the materials and the methods. *European Psychiatry, 12*, 41-48. https://doi.org/https://doi.org/10.1016/S0924-9338(97)80019-3

Strine, T. W., & Chapman, D. P. (2005). Associations of frequent sleep insufficiency with health-related quality of life and health behaviors. *Sleep Medicine, 6*(1), 23-27.

Suh, S., Nowakowski, S., Bernert, R. A., Ong, J. C., Siebern, A. T., Dowdle, C. L., & Manber, R. (2012, May 1). Clinical significance of night-to-night sleep variability in insomnia. *Sleep Medicine, 13*(5), 469-475. https://doi.org/https://doi.org/10.1016/j.sleep.2011.10.034

Talbot, L. S., Maguen, S., Metzler, T. J., Schmitz, M., McCaslin, S. E., Richards, A., Perlis, M. L., Posner, D. A., Weiss, B., Ruoff, L., Varbel, J., & Neylan, T. C. (2014, Feb 1). Cognitive behavioral therapy for insomnia in posttraumatic stress disorder: a randomized controlled trial. *Sleep, 37*(2), 327-341. https://doi.org/10.5665/sleep.3408

Taylor B.J., Matthews K.A., Hasler B.P., Roecklein K.A., Kline C.E., and Buysse D.J. (2016). Bedtime variability and metabolic health in midlife women: The SWAN sleep study. *Sleep*, 39(2), 457–465.

Thomas, J. C., June, M. G., Joel, D. K., Marchini, E., Hamilton, S., & Carl, E. T. (1981). First night effects in good sleepers and sleep-maintenance insomniacs when recorded at home. *Sleep, 4*(3), 293-298.

Thompson, A. E., Anisimowicz, Y., Miedema, B., Hogg, W., Wodchis, W. P., & Aubrey-Bassler, K. (2016, Mar 31). The influence of gender and other patient characteristics on health care-seeking behaviour: a QUALICOPC study. *BMC Family Practice, 17*(1), 38. https://doi.org/10.1186/s12875-016-0440-0

Thorndike, F. P., Saylor, D. K., Bailey, E. T., Gonder-Frederick, L., Morin, C. M., & Ritterband, L. M. (2008). Development and Perceived Utility and Impact of an Internet Intervention for Insomnia. *E-journal of applied psychology : clinical and social issues, 4*(2), 32-42. https://doi.org/10.7790/ejap.v4i2.133

Tibbitts, G. M. (2008, Dec 1). Sleep Disorders: Causes, Effects, and Solutions. *Primary Care: Clinics in Office Practice, 35*(4), 817-837. https://doi.org/https://doi.org/10.1016/j.pop.2008.07.006

Vallières, A., Morin, C. M., & Guay, B. (2005). Sequential combinations of drug and cognitive behavioral therapy for chronic insomnia: an exploratory study. *Behav Res Ther, 43*(12), 1611-1630.

Vedaa, Ø., Kallestad, H., Scott, J., Smith, O. R. F., Pallesen, S., Morken, G., Langsrud, K., Gehrman, P., Thorndike, F. P., Ritterband, L. M., Harvey, A. G., Stiles, T., & Sivertsen, B. (2020, Aug 1). Effects of digital cognitive behavioural therapy for insomnia on insomnia severity: a large-scale randomised controlled trial. *The Lancet Digital Health, 2*(8), e397-e406. https://doi.org/https://doi.org/10.1016/S2589-7500(20)30135-7

Vetter, C., Devore, E. E., Wegrzyn, L. R., Massa, J., Speizer, F. E., Kawachi, I., Rosner, B., Stampfer, M. J., & Schernhammer, E. S. (2016). Association Between Rotating Night Shift Work and Risk of Coronary Heart Disease Among WomenRotating Night Shift Work and Risk of CHD Among WomenRotating Night Shift Work and Risk of CHD Among Women. *JAMA, 315*(16), 1726-1734. https://doi.org/10.1001/jama.2016.4454

Wilson, S. J., Nutt, D. J., Alford, C., Argyropoulos, S. V., Baldwin, D. S., Bateson, A. N., Britton, T. C., Crowe, C., Dijk, D. J., Espie, C. A., Gringras, P., Hajak, G., Idzikowski, C., Krystal, A. D., Nash, J. R., Selsick, H., Sharpley, A. L., & Wade, A. G. (2010, Nov). British Association for Psychopharmacology consensus statement on evidence-based treatment of insomnia, parasomnias and circadian rhythm disorders. *J Psychopharmacol, 24*(11), 1577-1601. https://doi.org/10.1177/0269881110379307

Wittmann, M., Dinich, J., Merrow, M., & Roenneberg, T. (2006). Social Jetlag: Misalignment of Biological and Social Time. *Chronobiology International, 23*, 497 - 509.

Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. *Child development, 69*(4), 875-887.

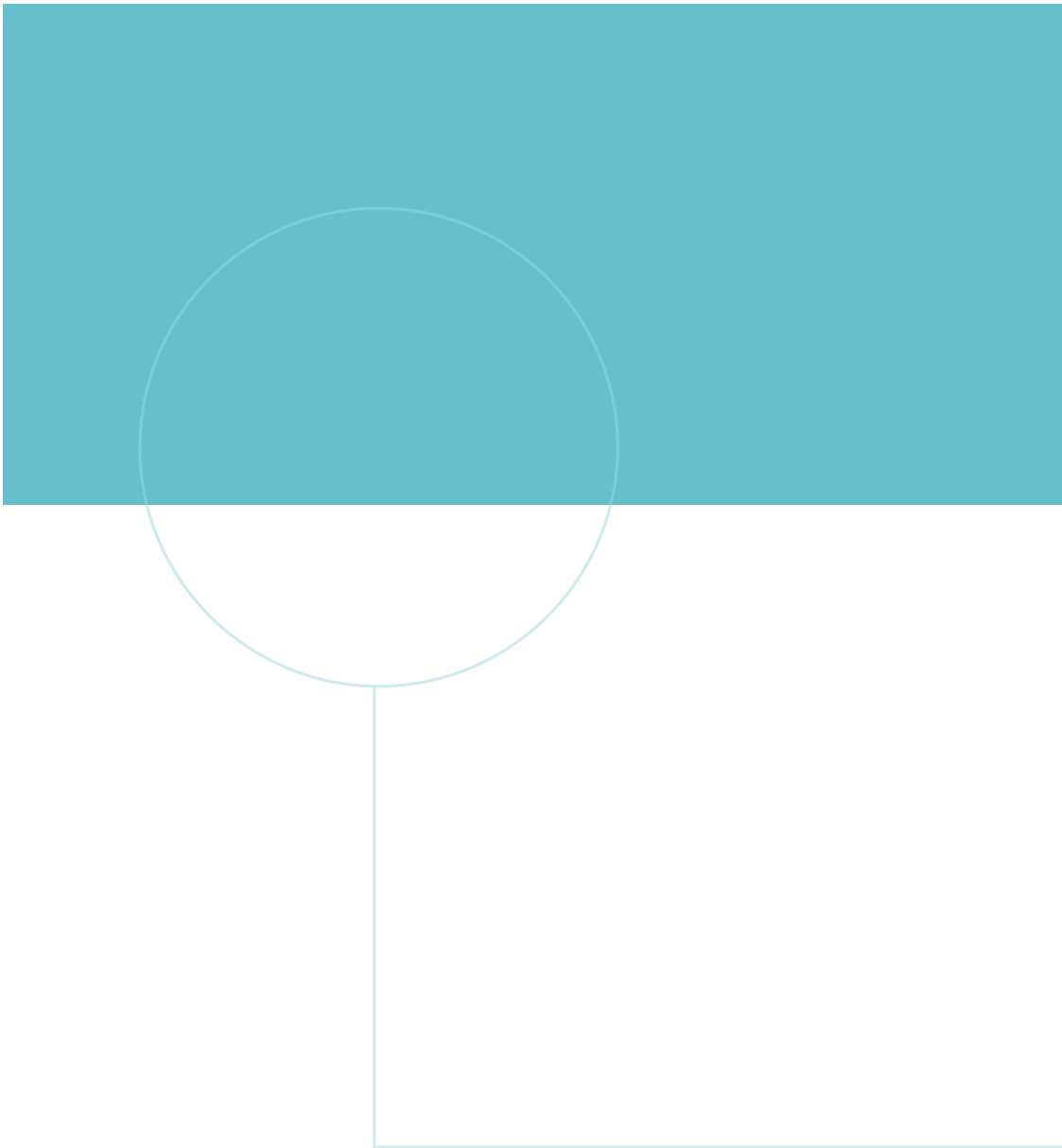
Wong, P. M., Hasler, B. P., Kamarck, T. W., Muldoon, M. F., & Manuck, S. B. (2015). Social Jetlag, Chronotype, and Cardiometabolic Risk. *The Journal of clinical endocrinology and metabolism*, *100*(12), 4612–4620. https://doi.org/10.1210/jc.2015-2923

Wright, K. P., Jr., Drake, A. L., Frey, D. J., Fleshner, M., Desouza, C. A., Gronfier, C., & Czeisler, C. A. (2015, Jul). Influence of sleep deprivation and circadian misalignment on cortisol, inflammatory markers, and cytokine balance. *Brain Behav Immun*, *47*, 24-34. https://doi.org/10.1016/j.bbi.2015.01.004

Wright, Kenneth P., Jr., McHill, Andrew W., Birks, Brian R., Griffin, Brandon R., Rusterholz, T., & Chinoy, Evan D. (2013). Entrainment of the Human Circadian Clock to the Natural Light-Dark Cycle. *Current Biology*, *23*(16), 1554-1558. https://doi.org/10.1016/j.cub.2013.06.039

Ye, Y.-Y., Zhang, Y.-F., Chen, J., Liu, J., Li, X.-J., Liu, Y.-Z., Lang, Y., Lin, L., Yang, X.-J., & Jiang, X.-J. (2015). Internet-Based Cognitive Behavioral Therapy for Insomnia (ICBT-i) Improves Comorbid Anxiety and Depression-A Meta-Analysis of Randomized Controlled Trials. *PLOS ONE*, *10*(11), e0142258-e0142258. https://doi.org/10.1371/journal.pone.0142258

Zigmond, A. S., & Snaith, R. P. (1983, Jun). The hospital anxiety and depression scale. *Acta Psychiatr Scand*, *67*(6), 361-370. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x



NTNU

Norwegian University of
Science and Technology