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Who benefits from adolescent sleep interventions? Moderators of treatment efficacy in a randomized controlled trial of a cognitive-behavioral and mindfulness-based group sleep intervention for at-risk adolescents

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Background: The aim of this study was to test moderators of therapeutic improvement in an adolescent cognitive-behavioral and mindfulness-based group sleep intervention. Specifically, we examined whether the effects of the program on postintervention sleep outcomes were dependent on participant gender and/or measures of sleep duration, anxiety, depression, and self-efficacy prior to the interventions. **Method:** Secondary analysis of a randomized controlled trial conducted with 123 adolescent participants (female = 59.34%; mean age = 14.48 years, range 12.04–16.31 years) who had elevated levels of sleep problems and anxiety symptoms. Participants were randomized into either a group sleep improvement intervention (n = 63) or group active control 'study skills' intervention (n = 60). The sleep intervention ('Sleep SENSE') was cognitive behavioral in approach, incorporating sleep education, sleep hygiene, stimulus control, and cognitive restructuring, but also had added anxiety-reducing, mindfulness, and motivational interviewing elements. Components of the active control intervention ('Study SENSE') included personal organization, persuasive writing, critical reading, referencing, memorization, and note taking. Participants completed the Pittsburgh Sleep Quality Index (PSQI), Spence Children's Anxiety Scale (SCAS), Center for Epidemiologic Studies Depression Scale (CES-D), and General Self-Efficacy Scale (GSE) and wore an actigraph and completed a sleep diary for five school nights prior to the interventions. Sleep assessments were repeated at postintervention. The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN12612001177842; http://www.anzctr.org.au/TrialSearch.aspx?searchTxt=ACTRN12612001177842&isBasic=True). **Results:** The results showed that compared with the active control intervention, the effect of the sleep intervention on self-reported sleep quality (PSQI global score) at postintervention was statistically significant among adolescents with relatively moderate to high SCAS, CES-D, and GSE prior to the intervention, but not among adolescents with relatively low SCAS, CES-D, and GSE prior to the intervention. The results were consistent across genders. However, the effects of the sleep intervention on actigraphy-measured sleep onset latency and sleep diary-measured sleep efficiency at postintervention were not dependent on actigraphy-measured total sleep time, SCAS, CES-D, or GSE prior to the intervention. **Conclusions:** This study provides evidence that some sleep benefits of adolescent cognitive-behavioral sleep interventions are greatest among those with higher levels of anxiety and depressive symptoms, suggesting that this may be an especially propitious group to whom intervention efforts could be targeted. Furthermore, adolescents with lower levels of self-efficacy may need further targeted support (e.g. additional motivational interviewing) to help them reach treatment goals. **Keywords:** Sleep; anxiety; depression; adolescence; intervention.

Introduction

Adolescence can be defined as the stage in human growth between the onset of puberty and the adoption of adult roles and responsibilities. It usually corresponds to the period of development between the ages of 10 and 19 years (World Health Organization, 2015). Adolescence is characterized by substantial increases in negative emotionality, greater reward seeking, heightened reactivity to peer-related social interactions, and increased engagement with long-term goals (Allen & Sheeber, 2008). These changes encourage the skills necessary for greater independence from the family, and the establishment of developmentally important peer and romantic relationships, but also create susceptibility to emotional and behavioral dysregulation (Spear, 2000; Steinberg, 2005). The presence of such plasticity offers a unique opportunity for the study of a

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range of risk and vulnerability processes, including those associated with sleep and mental health.

Adolescents are thought to optimally require approximately 9 hours of sleep per night (Fuligni, Arruda, Krull, & Gonzales, 2017). However, a recent meta-analysis found that 53% obtain <8 hr of sleep on school nights and 36% report difficulty falling asleep (Gradisar, Gardner, & Dohnt, 2011). Physiological maturation processes (Colrain & Baker, 2011) and social/cultural factors (Bartel, Gradisar, & Williamson, 2015) interact in adolescence so that reduced sleep propensity in the late evening becomes permissive of continued waking activities and delayed bedtimes (BT). As school starts early in the morning, this delay in sleep onset often results in sleep restriction. Further, sleep can have reduced restorative value, because recovery sleep tends to occur at an inappropriate circadian phase (Carskadon, 2011).

There is emerging evidence that adolescent sleep disturbance may precipitate and maintain many emotional and behavioral problems (Dahl & Harvey, 2007). Indeed, recent evidence suggests that sleep problems, particularly wakefulness in bed [e.g. prolonged sleep onset latency (SOL) and poor sleep efficiency (SE)], precede the development of anxiety and depression in adolescence more than the reverse (Lovato & Gradisar, 2014; McMakin & Alfano, 2015), suggesting that early treatment programs for adolescent sleep problems may reduce the risk for developing internalizing disorders.

Cognitive-behavioral therapy for insomnia (CBT-I) is recommended as a first-line treatment for adult insomnia (Qaseem, Kansagara, Forciea, Cooke, & Denberg, 2016), based on evidence from multiple systematic reviews and meta-analyses that the intervention improves sleep and mental health in adults, usually with medium-large effect sizes (Ballesio et al., 2017; Taylor & Pruiksma, 2014; Trauer, Qian, Doyle, Rajaratnam, & Cunnington, 2015; Van Straten et al., 2017). CBT-I involves behavioral techniques such as sleep education, sleep hygiene instruction, stimulus control, sleep restriction, and relaxation training, but also addresses unhelpful beliefs and attitudes about sleep (for a review, see Edinger & Means, 2005). There is also emerging evidence that sleep problems can be treated successfully using protocols that include a mindfulness component (for a meta-analytic review, see Gong et al., 2016). Mindfulness can be defined as 'the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience' (Kabat-Zinn, 2003, p. 145). Mindfulness meditation is especially indicated for sleep-related problems, because it aims to reduce the hyperarousal and negative emotional states (e.g. anxiety and worry) that are frequently reported by individuals experiencing sleep problems (Harvey, 2002; Riemann et al., 2010).

Despite that CBT-I is a first-line treatment for insomnia in adults, and mindfulness-based sleep interventions are showing promise of efficacy, research on adolescent cognitive-behavioral and mindfulness-based sleep interventions is not as developed as the adult literature. A recent systematic review and meta-analysis found that only nine trials (n = 357) have examined the efficacy of cognitive-behavioral sleep interventions among adolescents with self-identified sleep problems or a diagnosis of a sleep disorder (mean age = 14.97 years, range 11–20 years; Blake, Sheeber, Youssef, Raniti, & Allen, 2017). Two of the studies evaluated 'manualized' CBT-I, whereas the other interventions included added treatment components (e.g., mindfulness, anxiety/depression specific modules). The results showed that the sleep interventions produced marked and statistically significant improvements in objective and self-reported indices of sleep, daytime sleepiness, anxiety, and depression at postintervention time points. Moreover, gains were generally maintained over time. However, the trials included in the meta-analysis were limited in several ways, including small sample sizes, lack of control groups, wait-list control groups, high attrition rates, low generalizability, lack of follow-ups, short follow-ups, failure to differentiate between weekday and weekend sleep, and/or reliance of self-reported measures of sleep. Furthermore, there was evidence of notable variability in adolescent responses to the programs, and a key unanswered question is: which individual differences predict who is most likely to benefit from adolescent cognitive-behavioral sleep interventions?

The SENSE Study is an RCT investigating whether a 7-week, cognitive-behavioral and mindfulness-based group sleep intervention can prevent the emergence of major depressive disorder (MDD) at 2-year follow-up among a group of adolescents (aged 12–17) who were experiencing high levels of sleep problems and anxiety symptoms (Waloszek et al., 2015). Strengths of the SENSE study are the large sample size; the well-defined manual-driven treatment consisting of components demonstrated to improve sleep in prior research; the time- and format-equated active control 'study skills' condition; and the use of both self-report and objective measures of sleep duration and quality. We have previously reported the postintervention effects of the intervention on sleep and internalizing symptoms (Blake et al., 2016; Blake, Schwartz, et al., 2017). The results showed that the sleep intervention condition ('Sleep SENSE') was associated with significantly greater improvements in objective SOL, self-reported SE, perceived sleep quality, and anxiety, compared with the active control 'study skills' condition ('Study SENSE'; Blake et al., 2016). Improvements in perceived sleep quality and anxiety were specifically mediated by improvements in presleep arousal, but not sleep hygiene awareness

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(Blake, Schwartz, et al., 2017). The aim of this study was to further extend these findings by examining moderators of these therapeutic improvements.

A number of trials have examined moderators of treatment outcomes in adult CBT-I. Bathgate, Edinger, and Krystal (2017) found that adult patients with primary sleep maintenance insomnia and objective short sleep duration (<6 hr) were significantly less responsive to CBT-I compared with those with normal sleep duration (>6 hr), suggesting that treatment outcomes may differ as a function of insomnia phenotype (i.e. short vs. normal sleep duration; Vgontzas, Fernandez-Mendoza, Liao, & Bixler, 2013). However, this study was limited by a small sample size, lack of a control condition, and high attrition at follow-up. Other studies have found that CBT-I works equally well among adults with high versus low internalizing symptoms (Hamoen, Redlich, & de Weerd, 2014; Lancee, Van Den Bout, Van Straten, & Spoormaker, 2013; Manber et al., 2011). In the largest of these studies, Manber et al. (2011) found that adult patients with insomnia complaints and high versus low depressive symptoms at baseline were equally responsive to CBT-I, suggesting that depression is not a contraindication for CBT-I. However, this study was limited by a lack of control condition and exclusive reliance on self-reported measures of sleep. Furthermore, treatment noncompleters were excluded from the analyses, and depression symptoms increase risk of early termination from CBT-I (Ong, Kuo, & Manber, 2008). Similarly, Hamoen et al. (2014) found that CBT-I improved self-reported sleep regardless of depression symptom severity and worrying, but this study was also uncontrolled and did not include objective measures of sleep. Finally, there is emerging evidence that perceived self-efficacy may influence responsiveness to CBT-I (Schwartz & Carney, 2012). The intervention requires a considerable investment in time and effort from patients, and successful treatment outcomes may depend on the ability to comply with clinical recommendations; patients with low self-efficacy may have little confidence in their capacity to begin and/or maintain the prescribed behavior change. Indeed, low self-efficacy has been shown to predict poor treatment adherence to CBT-I in adults (Bouchard, Bastien, & Morin, 2003).

The aim of this study was to examine whether findings from the adult literature would generalize to a younger sample. On the basis of the adult literature, we hypothesized that compared with the control Study SENSE intervention, the effect of the Sleep SENSE intervention on objective and self-reported indices of sleep would be moderated by participants' level of objective sleep duration prior to the interventions. Specifically, we predicted that adolescents with normal sleep duration would show greater responsiveness to the intervention. Moreover, we also hypothesized that those with high levels of anxiety, depression, and/or self-efficacy would show increased responsiveness to the intervention. While it is possible that high levels of internalizing symptoms may interfere with responsiveness to 'manualized' CBT-I (e.g. fatigue and amotivation may reduce adherence to sleep hygiene recommendations, and worrying may increase presleep arousal), we postulated that adolescents with higher internalizing symptoms would benefit more from the Sleep SENSE intervention because it has added anxiety-specific modules (e.g. worry management and mindfulness). We also examined gender differences given that female adolescents consistently report higher internalizing symptoms compared with male adolescents (Hyde, Mezulis, & Abramson, 2008; Spence, Barrett, & Turner, 2003). While the gender analyses were exploratory, a recent meta-analysis found that female adolescents may benefit more from depression prevention programs compared with male adolescents (Stice, Shaw, Bohon, Marti, & Rohde, 2009). Therefore, we predicted that female adolescents would benefit more from the Sleep SENSE intervention compared with male adolescents.

Methods

The full methods of the SENSE Study were reported in Waloszek et al. (2015), Blake et al. (2016) and Blake, Schwartz, et al. (2017). Here, we focus on the methods relevant to the present analyses.

Design

The study used a parallel RCT design that followed all CONSORT RCT requirements for nonpharmacological trials (see Appendix S1) in order to ensure the quality, accuracy, and integrity of the trial (Moher et al., 2012). The study utilized appropriate statistical power, randomization sequence generation and allocation concealment, attempted to minimize interventional contamination and operator bias, provided blinded assessment of study endpoints, and included a detailed record of participant flow (see Figure 1). The experimental group took part in a cognitive-behavioral and mindfulness-based sleep intervention (Sleep SENSE) and the active control group took part in a study skills educational program (Study SENSE). The control intervention was chosen to have strong face validity as an intervention that addresses salient issues for adolescents, and to entail similar delivery format, levels of effort, and engagement with facilitators, as did the sleep intervention.

Ethical considerations

Participants were recruited from secondary schools in metropolitan Melbourne, Australia. Pre- and postintervention data collection was conducted in the Melbourne School of Psychological Sciences at the University of Melbourne, Australia. Interventions were held after school at the University, except for one group that was held at the participants' school. The study and all procedures were approved by the University of Melbourne Human Research Ethics Committee (HREC#1237312), the Department of Education and Early Childhood Development (DEECD; 2012_001659), and the Catholic Education Office Melbourne (CEOM; GE12/000091819), and complied with the Australian National Health

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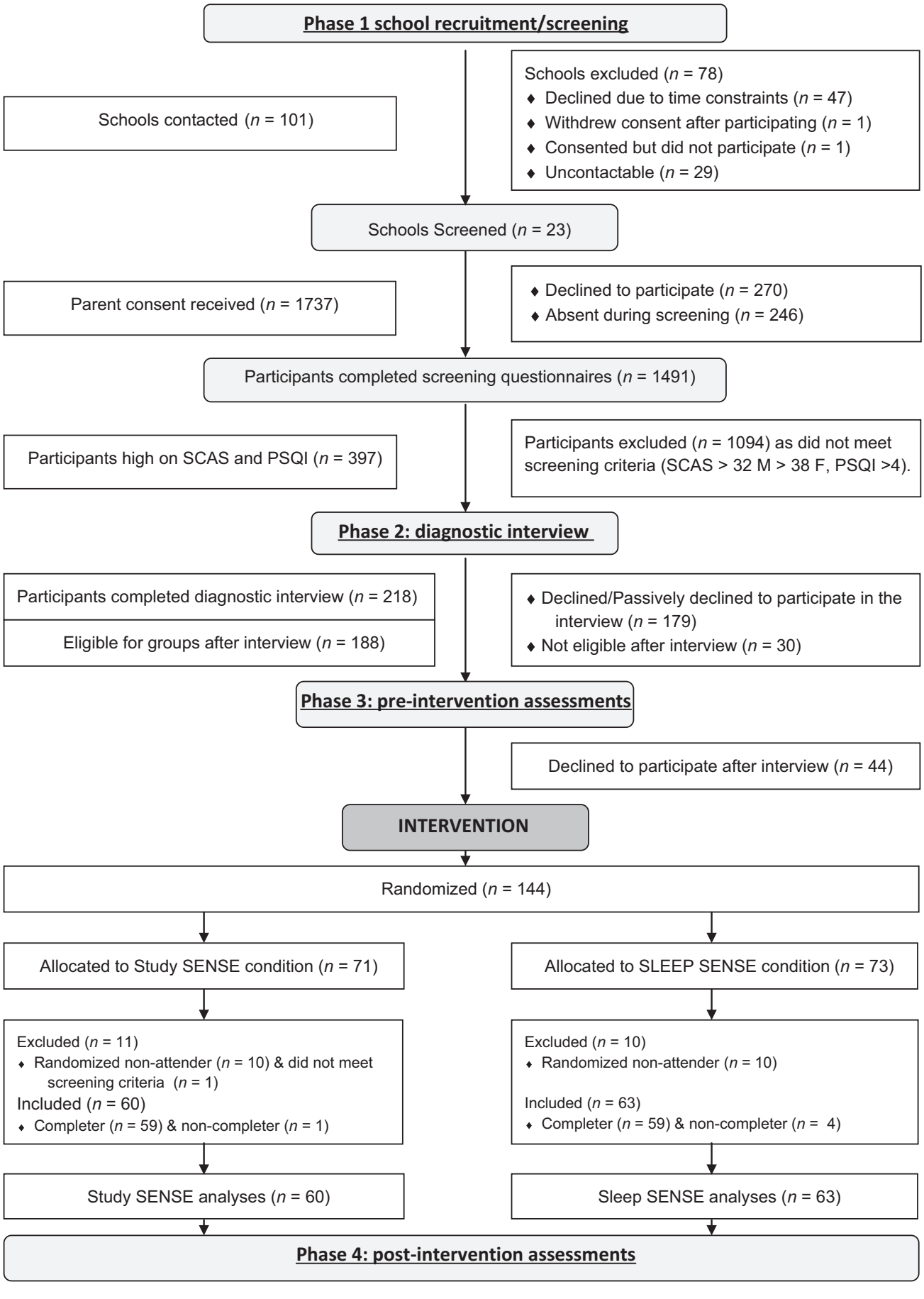

Figure 1 Flowchart of participants through the SENSE Study (Phases 1–4)

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and Medical Research Council guidelines. All participants and their guardians gave written informed consent before participating in the study. The trial is registered with the Australian New Zealand Clinical Trials Registry (ACTRN126 12001177842; http://www.anzctr.org.au/TrialSearch.aspx?searchTxt=ACTRN12612001177842&isBasic=True).

Procedure

The overall study had five data collection phases (Waloszek et al., 2015). The present paper reports on the first four phases (school recruitment/screening, diagnostic interview, preintervention assessments, and postintervention assessments), which were completed in 2013–2014. Phase 5 (2-year follow-up) will be completed by 2017. Details of Phases 1–4, the recruitment process, and participant numbers can be found in Figure 1. Participants were reimbursed for their time and travel expenses with a department store voucher for each assessment phase.

Participant recruitment

Participants were recruited using a two-stage procedure, consisting of an in-school screening followed by a diagnostic interview for those meeting screening criteria, to identify students with high levels of anxiety and sleeping difficulties but without a history of MDD (Figure 1). One hundred one schools were contacted via letter or email describing the study. Schools who did not wish to participate in the study ($n = 78$, 77.23%) indicated that they did not have enough time due to a full curriculum, were already participating in other research studies (i.e. decline, $n = 47$, 46.53%), or the school coordinator was not contactable (i.e. passive decline, $n = 29$, 28.71%). One school (0.99%) consented but did not participate and another school withdrew consent after participating. All students in Years 7 through 10 were invited to participate in the study. One thousand seven hundred thirty-seven students provided written parental consent to participate in the screening and were asked to attend the screening assessment session. One thousand four hundred ninety-one students (85.84%) completed the screening questionnaire. Two hundred seventy participants (15.54%) declined to participate after their parents had provided consent, and 246 participants (14.16%) were absent from school during the screening.

Inclusion and exclusion criteria

Participants whose ratings on the screening questionnaire (i.e. phase 1) indicated high anxiety [Spence Children's Anxiety Scale (SCAS) total score >32 and >38 for males and females, respectively; (84th percentile or above, based on population norms described at www.scaswebsite.com); Spence, 1998], as well as the likely presence of sleep problems [Pittsburgh Sleep Quality Index (PSQI) global score >4; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989], were invited to take part in a face-to-face diagnostic interview (i.e. phase 2) based on DSM-IV-TR criteria [the *Kiddie Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version* (K-SADS-PL); Axelson, Birmaher, Zelazny, Kaufman, & Kay Gill, 2009] with trained interviewers. Three hundred ninety-seven participants (26.63%) met criteria after the school screening and were invited to participate in the interview; 218 (14.62%) consented to participate. Participants who scored above the cut-off in the SCAS and PSQI in the screening assessment, indicating high levels of anxiety symptoms and sleep problems, but not necessarily an anxiety or sleep disorder, and who had never met criteria for MDD ($n = 188$), as assessed using the K-SADS-PL, were invited to participate in the intervention stage of the study. Those with a history of MDD ($n = 30$, 13.76%) were excluded because the study's ultimate goal was to prevent first incidence of MDD at 2-year follow-up (Blake et al., 2016; Waloszek et al., 2015). It is worth noting that although participants did not meet DSM-IV-TR criteria for MDD during the screening phase of the study (i.e. at phase 2), some of them scored highly on the self-report measure of depression [Center for Epidemiologic Studies Depression Scale (CES-D)] prior to the commencement of interventions (i.e. at phase 3), as can be seen in Tables 1 and 3. This could be attributable to a number of factors: (1) differences between clinician-rated and self-report measures of depression; (2) participants under-reporting depression symptoms during the clinical interview and/or over-reporting depression symptoms on the self-report questionnaire; (3) participants developing depression symptoms between the screening and preintervention phases of the study; and (4) the strong relationship between anxiety and depression symptoms and sleep problems in adolescence. Other exclusion criteria were current or past diagnoses of bipolar or psychotic disorder, and inadequate comprehension of written and spoken English; however, no participants were excluded for these reasons.

Data collection

One hundred eighty-eight participants met inclusion criteria after the diagnostic interview. Participants who met inclusion criteria after the diagnostic interview and who consented to participate in the intervention stage of the trial ($n = 144$) were asked to complete a number of assessments. Participants completed sleep and mental health questionnaires and wore an actigraph and completed a sleep diary for five school nights (i.e. Sunday night to Thursday night) prior to the interventions. Sleep assessments were repeated at postintervention. We analyzed school night sleep because of the well-established discrepancy between weekday and weekend/vacation sleep habits in adolescents and because sleep problems are more likely to occur on school nights. In particular, adolescents tend to show shorter total sleep time, higher rates of daytime sleepiness, and more presleep arousal on school nights (Gradisar et al., 2011; Hiller, Lovato, Gradisar, Oliver, & Slater, 2014).

Randomization and blinding

Eligible participants who consented to participate in the intervention stage of the trial were randomly allocated to receive either the sleep intervention (Sleep SENSE, $n = 71$) or the study intervention (Study SENSE, $n = 73$). A blinded statistician randomized the eligible participants stratified by gender, age, and presence/absence of current anxiety disorder using a minimization procedure available in the MINIM program (Evans, McGee, & Williams, 1990). Participants and their guardians were not told the status of the condition to which participants were assigned (i.e. sleep vs. control) or the expected outcome of the study. Twenty participants (10 randomized to Sleep SENSE, 10 to Study SENSE) declined participation prior to the start of the interventions and were counted as 'randomized nonattenders'. Five participants did not complete at least four of the seven intervention sessions (Sleep SENSE = 4, Study SENSE = 1) and were classified as 'noncompleters'. Reasons provided were illness, travel distance, transportation issues, homework, and extracurricular activities. Outcome assessors were blinded to the treatment condition (i.e. sleep vs. control).

Intervention group sessions

The Sleep SENSE intervention is cognitive-behavioral in approach, incorporating sleep education, sleep hygiene, stimulus control, and cognitive restructuring, but also has

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added anxiety-reducing and mindfulness components. The intervention is tailored to the unique developmental challenges and opportunities of adolescence, including the social, cultural, and maturational factors known to affect sleep patterns in adolescence, and has a specific focus on tracking behavioral change and identifying and overcoming barriers to change via incorporation of motivational interviewing techniques. Motivational interviewing techniques included in Sleep SENSE were guided discovery to elicit change talk, rolling with resistance, expressing empathy, supporting self-efficacy (e.g. goal setting, problem-solving, managing uncertainty and stress), planning behavioral experiments, and developing discrepancies through the use of decisional balance matrices and scaling questions. Motivational interviewing was typically delivered in contexts where the adolescent was resistant to adopting healthy sleep practices, such as disengaging from electronic media close to bedtime. Behavioral change was monitored via homework worksheets (e.g. sleep diaries, thought monitoring, mindfulness monitoring) and weekly reviews of progress (e.g. sleep goals). The intervention involves seven weekly 90-min group sessions supported by a range of psycho-educational materials. Clinical psychologists or graduate clinical psychologists in training delivered the intervention sessions, along with a co-facilitator.

A trained teacher and a co-facilitator administered the Study SENSE interventions, at the same time, for the same duration, and in the same format, as the Sleep SENSE interventions. Components of the Study SENSE intervention included personal organization, persuasive writing, critical reading, referencing, memorization, and note taking. The content of the Sleep SENSE and Study SENSE intervention sessions and program acceptability results were previously described in Waloszek et al. (2015), Blake et al. (2016) and Blake, Schwartz, et al. (2017). Nine separate Sleep and Study SENSE intervention groups were conducted (i.e. 18 groups in total); Sleep SENSE groups ranged from six to nine participants per group (mean = 6.7) and Study SENSE groups from four to nine participants per group (mean = 7). Completion rate was high (Sleep SENSE = 93.65%, Study SENSE = 98.33%) and participants attended 76.88% of sessions on average (Sleep SENSE = 74.86%, Study SENSE = 79.00%). Participants rated both programs as useful (Sleep SENSE = 4.3/5, Study SENSE = 3.87/5), interesting (Sleep SENSE = 3.9/5, Study SENSE = 3.7/5), and of good quality overall (Sleep SENSE = 4/5, Study SENSE = 3.81/5).

Chi-square test for independence and independent samples *t*-test indicated that the differences in gender [χ^2 (1, n = 123) = .77, p = .38], age [t = (121) = .01, p = .99], year level [χ^2 (1, n = 123) = .81, p = .85], completion rate [χ^2 (1, n = 123) = 1.78, p = .19], and average number of sessions attended [t = (121) = −1.33, p = .19] between the conditions were not statistically significant. Furthermore, while participants rated the Sleep SENSE program as more useful than the Study SENSE program [t = (94) = 2.89, p = .01], there were no other differences between the conditions in program acceptability. Participants did not rate the Sleep SENSE program as more interesting [t = (94) = 1.13, p = .26] or of better quality overall [t = (94) = 1.02, p = .31] compared with the Study SENSE program.

Treatment integrity

The following quality assurance processes maintained treatment fidelity: (1) piloting of the interventions to refine treatment protocols and assess program acceptability; (2) detailed facilitator training; (3) comprehensive facilitator manuals; (4) weekly supervision sessions; and (5) facilitator logbooks. The group sessions were audio-recorded and 20% of sessions were randomly selected and rated by two independent researchers for integrity. Checklists for each session (ranging from 8 to 19 elements) were rated by using a 3-point scale (2 = *fully addressed*, 1 = *partially addressed*, 0 = *not addressed).* Mean integrity was 94.61% for the Sleep SENSE condition and 84.84% for the Study SENSE condition, indicating very good integrity. Interrater reliability was assessed using two-way mixed intraclass correlations (ICCs) under the assumption of absolute agreement (McGraw & Wong, 1996). The ICCs were 0.91 for Sleep SENSE and 0.97 for Study SENSE.

Measures

Objective sleep. At the pre- and postintervention phases, participants were provided with a wristwatch actigraphy monitor (either an Actiwatch L/64 or Actiwatch 2, which generate comparable sleep statistics) with instructions to wear it on their nondominant wrist for five school nights. Wrist actigraphy is widely used in adolescent populations to assess sleep-wake patterns when participants are in their normal environments over extended periods of time (Sadeh, 2011).

Self-reported sleep.

(a) Participants were also asked to complete a paper sleep diary for five school nights during the period they were wearing the actigraph; each morning, participants were asked to record bedtime (BT), sleep onset time, number of nocturnal awakenings, wake time, and rise time (RT). Sleep diaries are considered the gold standard of self-reported sleep assessment (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006).
(b) At the screening, preintervention, and postintervention phases, participants also completed the PSQI (Buysse et al., 1989). The PSQI is a self-report inventory designed to assess sleep quality and disturbances and the impact of poor sleep on daytime functioning. It is the most commonly used generic measure of self-reported sleep in clinical and research settings in adults (Mollayeva et al., 2016). Emerging evidence suggests that it demonstrates adequate reliability and validity in adolescent populations (Ji & Liu, 2016; de la Vega et al., 2015). Internal consistency statistics for the school night global score in the current sample were acceptable [preintervention Cronbach's alpha (α) = .76; postintervention α = .78].

Anxiety. At the screening and preintervention phases, participants also completed the SCAS (Spence, 1998). The SCAS is a 44-item self-report measure designed to measure the frequency with which children and adolescents experience anxiety symptoms. It has been shown to have good internal consistency (α = .92) and 3-month temporal stability (r = .63) among 12–15 year olds (Muris, Schmidt, & Merckelbach, 2000; Spence et al., 2003), as well as strong convergent validity with other measures of anxiety and good divergent validity with measures of depression (Spence et al., 2003). It has normative data in the relevant age range (Spence, 2017). Internal consistency of the total score in the current sample was excellent (α = .89).

Depression. At the preintervention phase, participants also completed the CES-D (Radloff, 1977). The CES-D is a 20-item self-report inventory designed to measure current levels of depressive symptomatology in the general population (Radloff, 1977). A validation study found that it had good internal consistency, validity, and acceptability when completed by high school students (Radloff, 1991; Roberts, Lewinsohn, & Seeley, 1991), and a recent meta-analysis found

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that it demonstrates good internal reliability (α = .88), sensitivity (.76), and specificity (.71) among clinical and nonclinical samples of adolescents (Stockings et al., 2015). Internal consistency of the total score in the current sample was excellent (α = .89).

Self-efficacy. At the preintervention phase, participants also completed the General Self-Efficacy Scale (GSE; Schwarzer & Jerusalem, 1995). The GSE is a 10-item self-report inventory designed to assess optimistic self-beliefs about one's ability to cope with new and difficult tasks and to reach goals. The GSE is widely used and has been shown to have good reliability, stability, and construct validity among adult and adolescent samples (Luszczynska, Gutiérrez-Doña, & Schwarzer, 2005; Scholz, Doña, Sud, & Schwarzer, 2002). It has norms in the relevant age range (Schwarzer, 2014). Internal consistency of the total score in the current sample was excellent (α = .88).

Affective and psychotic disorders. Following the screening phase (i.e. phase 1), participants were also administered the K-SADS-PL (Axelson et al., 2009), a semistructured diagnostic interview designed to identify past or present psychopathology in children and adolescents. The K-SADS-PL has been shown to be a reliable and valid measure of *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition (DSM–IV) Axis I disorders among children and adolescents (Kaufman et al., 1997). Graduate clinical psychology students and research assistants administered the interviews. A clinical psychologist provided regular clinical supervision to all interviewers. Approximately 20% of interviews were double-scored by another interviewer who listened to a deidentified audio recording of the interview. Interrater reliability was assessed using Byrt, Bishop, and Carlin's (1993) prevalence-adjusted and bias adjusted kappa (PABAK) statistic. Analyses were conducted at the item level, which included symptoms and diagnoses. PABAK kappa was calculated at .98 for this study.

Data processing

Actigraphy variables. Bedtimes and RT were determined by visually screening the actograms using the collective information of the Actiware algorithm/movement, light (when available), event markers (when available) and sleep diary (when available). A recent study suggests that this procedure ('human scoring') has a good correlation with polysomnography and a superior correlation to automated actigraphy algorithms in determining BT and RT among adolescent samples (Boyne, Sherry, Gallagher, Olsen, & Brooks, 2013). Several studies have confirmed the poor ability of actigraphy algorithms to detect wakefulness in bed (Cellini, Buman, McDevitt, Ricker, & Mednick, 2013; Sadeh, 2011). Given that actigraphy algorithms define sleep based on lack of movement, lying in bed awake but motionless (e.g. watching television) will likely be coded as sleep (Martin & Hakim, 2011). This highlights the importance of cross-validating algorithm/movement data with collateral information. The Actiware algorithm was used as the primary method of determining BT and RT, but was adjusted if necessary using sleep diary, event marker, and/or light information. The sleep interval was defined as the time between sleep onset and sleep termination and was automatically determined by the Actiware. The start of the sleep interval was set at the first minute of the first 10 consecutive epochs scored as immobile, and the end of the sleep interval was set as the last minute of the last 10 consecutive epochs scored as immobile ('10-min immobility', the default setting in Actiware 6). The following school night actigraphy sleep variables were calculated using the Actiware software: total sleep time [TST (minutes)], sleep onset latency [SOL (minutes)], sleep efficiency [SE (percent)], wake after sleep onset [WASO (minutes)], and BT (hh:mm).

Self-reported variables. The following school night sleep diary variables were calculated: TST (minutes), SOL (minutes), SE (percent), WASO (minutes), and BT (hh:mm). The total scores for the PSQI, SCAS, CES-D, and GSE were calculated using the standard methods recommended by the authors of the scales (Buysse et al., 1989; Radloff, 1991; Schwarzer & Jerusalem, 1995; Spence, 1998).

Variable names

Preintervention scores (i.e. phase 3) use the suffix '1' (e.g. $SCAS_1$) and postintervention scores (i.e. phase 4) use the suffix '2' (e.g. $PSQI_2$). Additionally, actigraphy variables use the suffix 'obj' (e.g. TST_{obj1}) and sleep diary variables use the suffix 'subj' (e.g. SE_{subj2}).

Statistical analyses

A 'modified intention-to-treat' approach was taken; intervention completers ($n = 118$) and noncompleters ($n = 5$) were included in analyses, but randomized nonattenders ($n = 20$; defined above) were excluded. Missing data were imputed using the multiple imputation procedure with five imputation data sets in IBM SPSS Statistics for Macintosh, version 24.0 (IBM Corp., Armonk, NY). Missing data occurred when participants did not complete all or part of the sleep diary and/or questionnaire battery, when participants did not wear the Actiwatch, or when the Actiwatch equipment malfunctioned. There was a low incidence of missing data for the questionnaire (2.60% average) and actigraphy (6.10% average) variables. On average, participants wore the actigraph on 4.5 of the five school nights at pre- and postintervention. There was a higher incidence of missing data for the sleep diary variables (14.60%). On average, participants completed the sleep diaries on 3.75 of the five school nights at pre- and postintervention. However, it is generally recognized that sleep diaries are vulnerable to poor compliance, including missing data and entry errors (Blake, Schwartz et al., 2017; Blake, Sheeber et al., 2017; Buysse et al., 2006).

A series of additive moderation analyses were conducted using the statistical program PROCESS (Model 2; Hayes, 2013) to examine whether the effects of the two treatment conditions (*X*: 1 = Sleep SENSE, 2 = Study SENSE) on the postintervention sleep outcomes (*Y*'s) were dependent on participant gender (moderator 1, or *M*1) and/or level of objective sleep duration, anxiety, depression, and self-efficacy prior to the interventions (*M*2's: TST_{obj1}, $SCAS_1$, $CES\text{-}D_1$, or GSE_1). Sleep variables that did not show statistically significant treatment effects (i.e. one-way between groups ANCOVAs that were not statistically significant, as reported in Blake et al. 2016 and Blake, Schwartz, et al., 2017) were not included as dependent variables in the analyses. Therefore, the dependent variables were SOL_{obj2}, SE_{subj2}, and $PSQI_2$. Preintervention scores for the dependent variables were included as covariates in the respective models to control for individual differences. All analyses used ordinary least squares regression. Figure 2 shows a conceptual and statistical diagram of the models. Simple slope analysis was used to probe significant interactions. This procedure provides conditional effects of *X* (i.e. treatment conditions) on *Y* (e.g. $PSQI_2$) when *M*'s (e.g. $SCAS_1$ for males and females) are set to one standard deviation (*SD*) below the mean (i.e. relatively low scores), the mean (i.e. relatively moderate scores), and one *SD* above the mean (i.e. relatively high scores).

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Results

Demographic and descriptive statistics

One hundred twenty-three participants began the interventions (female = 59.34%; mean age = 14.48, *SD* = 0.95, range 12.04–16.31 years), with 60 in the Sleep SENSE condition and 63 in the Study SENSE condition. Full demographic statistics were previously reported in Blake et al. (2016) and Blake, Schwartz, et al. (2017). Descriptive statistics for the sleep, anxiety, depression, and self-efficacy variables used in this study are provided in Table 1. Consistent with the inclusion criteria, the intervention sample was characterized by short sleep duration, wakefulness in bed, and poor sleep quality prior to the interventions. Average TST_{obj1} was 6:47 hr, SOL_{obj1} 29.78 min, SE_{obj1} 79.25%, $WASO_{obj1}$ 59.42 min, and $PSQI_1$ 6.3. Although no specific quantitative parameters define insomnia disorder, TST <6:30 hr, SOL >30 min, and SE <85% are common manifestations of insomnia (Lichstein, Durrence, Taylor, Bush, & Riedel, 2003) and PSQI global >5 indicates sleeping problems in adults (Buysse et al., 1989). The intervention sample was also characterized by internalizing symptoms prior to the interventions. Average $SCAS_1$ was 28.5 for males and 36.17 for females (scores >32 for males and 38 for females are indicative of subclinical anxiety; Spence, 1998) and average $CESD_1$ was 15.77 (scores >15 are indicative of subclinical depression; Radloff,

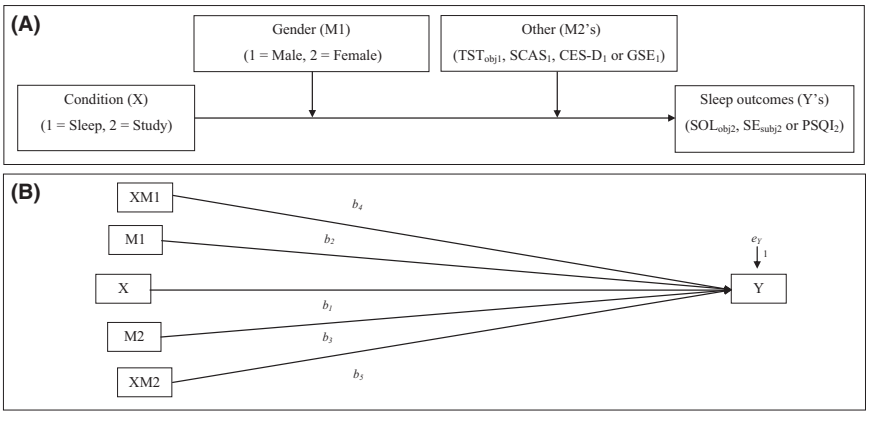

Figure 2 The additive moderation models as depicted as a conceptual (A) and statistical diagram (B). *b*, regression co-efficient; $CES\text{-}D_1$, Center for Epidemiologic Studies Depression Scale (preintervention); e_Y, residual; GSE_1, General Self-Efficacy Scale (preintervention); *M*, moderating variable; $PSQI_2$, Pittsburgh Sleep Quality Index (postintervention); $SCAS_1$, Spence Children's Anxiety Scale (preintervention); SE_{subj2}, sleep diary-measured sleep efficiency (postintervention); SOL_{obj2}, actigraphy-measured sleep onset latency (postintervention); TST_{obj1}, actigraphy-measured total sleep time (preintervention); *X*, independent variable; *XM*, interaction between independent and moderating variables; *Y*, outcome variable

Table 1 Descriptive statistics for the intervention sample at pre- and postintervention

		Intervention sample $n = 123$		Sleep SENSE condition $n = 63$				Study SENSE condition $n = 60$			
		Preintervention		Preintervention		Postintervention		Preintervention		Postintervention	
Domain	Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Sleep diaries (school nights)	TST	468.00	58.80	467.40	57	486.60	55.02	469.20	61.50	470.40	61.20
	SOL	33.60	20.40	33.48	19.80	27.28	18.60	34.80	21.00	31.20	20.22
	SE	88.98	6.05	88.05	6.85	91.04	5.32	89.92	4.99	89.48	5.48
	WASO	7.80	12.00	11.04	15.48	4.18	7.20	4.20	6.00	4.80	9.00
	BT	10.32 pm	64.01	10.25 pm	57.04	10.24 pm	54.41	10.38 pm	70.34	10.36 pm	64.76
Actigraphy (school nights)	TST	407.46	43.86	417.20	38.89	415.17	39.22	397.23	46.70	402.75	46.18
	SOL	29.78	23.62	29.09	20.64	23.30	16.11	30.48	26.56	33.68	25.36
	SE	79.25	6.62	79.66	5.56	79.63	5.47	78.86	7.60	78.08	7.42
	WASO	59.42	21.85	59.19	20.54	63.20	21.42	59.66	23.31	59.55	22.94
	BT	10.57 pm	56.33	10.49 pm	46.79	11.00 pm	44.68	11.04 pm	64.38	11.13 pm	58.58
Questionnaires	PSQI	6.31	2.66	6.23	2.51	4.79	1.97	6.39	2.83	5.93	2.32
	SCAS	33.07	12.86	35.37	13.73	–	–	30.66	11.49	–	–
	CES-D	15.77	9.22	16.19	9.80	–	–	15.32	8.62	–	–
	GSE	27.45	5.20	28.47	4.84	–	–	26.37	5.40	–	–

BT, bedtime (hh:mm); CES-D, Center for Epidemiologic Studies Depression Scale; GSE, General Self-Efficacy Scale; *M*, mean; PSQI, Pittsburg Sleep Quality Index; SCAS, Spence Children's Anxiety Scale; *SD*, standard deviation; SE, sleep efficiency (%); SOL, sleep onset latency (minutes); TST, total sleep time (minutes); WASO, wake after sleep onset (minutes).

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1991). Finally, participants reported approximately normal self-efficacy prior to the interventions – average GSE_1 (27.45) was higher than 32% of adolescents in a representative sample of high school students (Schwarzer, 2014). Of note, the intervention sample was not characterized by late BTs prior to the interventions. Average BT_{obj1} was 10.57 pm – BTs later than 11.30 pm are typically associated with lower school performance, lower motivation, and increased risk for depressive symptoms in adolescence (Merikanto, Lahti, Puusniekka, & Partonen, 2013). Independent samples *t*-tests showed that there were no statistically significant differences between the treatment conditions on the dependent (SOL_{obj}, SE_{subj}, PSQI) and moderating (TST_{obj}, SCAS, CES-D, GSE) variables prior to the interventions (see Appendix S2).

Moderators of therapeutic improvement

A summary of the results from the additive moderation models is provided in Table 2. The results showed that compared with the Study SENSE intervention, the effect of the Sleep SENSE intervention on $PSQI_2$ depended on participants' $SCAS_1$, $CESD_1$, and GSE_1 but not their gender. However, the effect of the treatment conditions on SOL_{obj2} and SE_{subj2} did not depend on participants' gender or TST_{obj1}, $SCAS_1$, $CESD_1$, or GSE_1.

A summary of the results from the simple slopes analyses is provided in Table 3. The results showed that compared with the Study SENSE intervention, the effect of the Sleep SENSE intervention on $PSQI_2$ was statistically significant among participants with 'relatively moderate' or 'relatively high' $SCAS_1$, $CESD_1$, and GSE_1, but not among participants with 'relatively low' $SCAS_1$, $CESD_1$, and GSE_1, as defined using the distribution of $SCAS_1$, $CESD_1$, and GSE_1 scores in the sample. The clinical ranges (using cut-off scores) and/or population norm percentiles for these relatively low, moderate, and high scores are provided in Table 3, for descriptive purposes and to give an indication of the severity of the mean and +/−1 *SD* scores in the sample (Radloff, 1991; Schwarzer, 2014; Spence, 2017). The Sleep SENSE intervention was most effective for adolescents with subclinical and clinical $SCAS_1$ and $CESD_1$ and moderate to high GSE_1. The intervention was less effective for adolescents with normal $SCAS_1$ and $CESD_1$ and low GSE_1. The results were consistent across genders, but effect sizes were larger for males.

Discussion

The Sleep SENSE intervention was especially likely to improve perceived sleep quality in adolescents who were experiencing subclinical and clinical levels of anxiety symptoms, depression symptoms, and/or moderate to high levels of self-efficacy prior to the interventions. By contrast, gender was not a

Table 2 Summary of the results from the additive moderation models

Variables				Beta co-efficient (*b*) and confidence interval				
Y	*M1*	*M2*	R^2	*X* (b_1)	*M1* (b_2)	*M2* (b_3)	XM1 (b_4)	XM2 (b_5)
$PSQI_2$	Gender	TST_{obj1}	.41*	2.03 (−4.73, 8.80)	1.07 (−0.94, 3.07)	0.00 (−0.02, 0.02)	−0.35 (−1.65, 0.95)	−0.00 (−0.01, 0.01)
		$SCAS_1$	.44*	0.65 (−1.66, 2.97)	1.59 (−0.42, 3.62)	−0.06 (−0.13, 0.02)	−0.81 (−2.12, 0.49)	−0.05 (0.02, 0.11)*
		CES-D_1	.45*	0.98 (−1.13, 3.09)	1.32 (−0.68, 3.34)	−0.06 (−0.16, 0.04)	−0.62 (−1.90, 0.65)	−0.07 (0.00, 0.13)*
		GSE_1	.43*	−1.45 (−5.25, 2.35)	1.35 (−0.62, 3.39)	−0.18 (−0.38, 0.02)	−0.52 (−1.79, 0.74)	0.12 (0.00, 0.24)*
SOL_{obj2}	Gender	TST_{obj1}	.26*	−35.94 (−110.82, 38.94)	1.66 (−20.31, 23.62)	−0.10 (−0.37, 0.17)	−0.95 (−15.28, 13.38)	0.12 (−.04, 0.28)
		$SCAS_1$	.23*	20.46 (−6.11, 47.05)	5.41 (−17.89, 28.72)	0.06 (−0.82, 0.94)	−3.93 (−18.96, 11.08)	−0.15 (−0.75, 0.44)
		CES-D_1	.22*	19.62 (−5.07, 44.32)	5.62 (−17.89, 29.14)	0.10 (−1.12, 1.33)	−4.64 (−19.57, 10.29)	−0.15 (−0.95, 0.65)
		GSE_1	.24*	37.83 (−4.93, 80.60)	5.19 (−17.31, 27.70)	0.86 (−1.40, 3.13)	−4.68 (−19.05, 9.68)	−0.76 (−2.15, 0.62)
SE_{subj2}	Gender	TST_{obj1}	.39*	0.09 (−0.08, 0.25)	−0.01 (−0.06, 0.04)	0.00 (−0.00, 0.00)	0.01 (−0.02, 0.04)	−0.00 (−0.00, 0.00)
		$SCAS_1$	.37*	−0.03 (−0.09, 0.02)	−0.02 (−0.06, 0.03)	0.00 (−0.00, 0.00)	0.01 (−0.02, 0.04)	−0.00 (−0.00, 0.00)
		CES-D_1	.38*	−0.03 (−0.09, 0.02)	−0.02 (−0.07, 0.03)	0.00 (−0.00, 0.00)	0.01 (−0.02, 0.04)	−0.00 (−0.00, 0.00)
		GSE_1	.38*	−0.02 (−0.11, 0.08)	−0.01 (−0.06, 0.03)	0.00 (−0.00, 0.00)	0.01 (−0.02, 0.04)	−0.00 (−0.00, 0.00)

$CES\text{-}D_1$, Center for Epidemiologic Studies Depression Scale (preintervention); GSE_1, General Self-Efficacy Scale (preintervention); *M*, moderating variable; $PSQI_2$, Pittsburgh Sleep Quality Index (postintervention); $SCAS_1$, Spence Children's Anxiety Scale (preintervention); SE_{subj2}, sleep diary-measured sleep efficiency (postintervention); SOL_{obj2}, actigraphy-measured sleep onset latency (postintervention); TST_{obj1}, actigraphy-measured total sleep time (preintervention); *X*, independent variable (treatment condition); *XM*, interaction between independent and moderating variables; *Y*, outcome variable.
*Evidence of an effect (confidence interval did not include zero or $p < .05$).

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Table 3 Summary of the results from the simple slopes analyses

Variables					Clinical range and percentile norm (%)	Conditional effect of Y at the values of the moderators (M1 and M2)					
Y	*M*1	*M*2	*M*2 value			Effect	*SE*	*t*	*p*	LLCI	ULCI
$PSQI_2$	Male	$SCAS_1$	−1*SD*	20.21	Normal (55^{th})	0.94	0.52	1.77	.08	−0.10	1.98
			Mean	33.06	Subclinical (84^{th})	1.63*	0.51	3.21	.00	0.62	2.64
			+1*SD*	45.92	Clinical (95^{th})	2.33*	0.68	3.42	.00	0.98	3.68
	Female	$SCAS_1$	−1*SD*	20.21	Normal (32^{rd})	0.12	0.57	0.21	.83	−1.01	1.26
			Mean	33.06	Normal (67^{th})	0.82*	0.41	1.99	.04	0.01	1.64
			+1*SD*	45.92	Subclinical (91^{st})	1.52*	0.48	3.13	.00	0.56	2.48
$PSQI_2$	Male	$CES\text{-}D_1$	−1*SD*	6.55	Normal[a]	0.82	0.52	1.55	.12	−0.22	1.85
			Mean	15.76	Subclinical[a]	1.45*	0.49	2.98	.00	0.49	2.42
			+1*SD*	24.98	Clinical[a]	2.11*	0.64	3.28	.00	0.83	3.38
	Female	$CES\text{-}D_1$	−1*SD*	6.55	Normal[a]	0.19	0.56	0.33	.73	−0.91	1.28
			Mean	15.76	Subclinical[a]	0.83*	0.40	2.07	.04	0.03	1.62
			+1*SD*	24.98	Clinical[a]	1.48*	0.46	3.17	.00	0.55	2.41
$PSQI_2$	Male	GSE_1	−1*SD*	22.24	(3^{rd})[b]	0.71	0.57	1.24	.22	−0.42	1.83
			Mean	27.45	(28^{th})[b]	1.33*	0.49	2.72	.01	0.36	2.30
			+1*SD*	32.65	(73^{rd})[b]	1.96*	0.61	3.21	.00	0.75	3.16
	Female	GSE_1	−1*SD*	22.24	(3^{rd})[b]	0.18	0.55	0.32	.74	−0.91	1.27
			Mean	27.45	(28^{th})[b]	0.81*	0.41	1.96	.04	0.00	1.62
			+1*SD*	32.65	(73^{rd})[b]	1.43*	0.50	2.86	.00	0.45	2.42

−1*SD*, a standard deviation below the mean; +1*SD*, a standard deviation above the mean; $CES\text{-}D_1$, Center for Epidemiologic Studies Depression Scale (preintervention); GSE_1, General Self-Efficacy Scale (preintervention); LLCI, lower limit of confidence interval; *M*, moderating variable; $PSQI_2$, Pittsburgh Sleep Quality Index (postintervention); $SCAS_1$, Spence Children's Anxiety Scale (preintervention); *SE*, standard error; ULCI, upper limit of confidence interval; *Y*, outcome variable.
[a]We are not aware of percentile norms for the CES-D.
[b]There are no clinical cut-offs for the GSE.
*Evidence of an effect (confidence interval did not include zero and $p < .05$).

significant moderator of outcomes. Initial levels of sleep duration, anxiety, depression, and self-efficacy also did not moderate improvements in actigraphy-measured SOL or sleep diary-measured SE.

These results are not consistent with previous studies showing that CBT-I works equally well among adults with high versus low internalizing symptoms (Hamoen et al., 2014; Lancee et al., 2013; Manber et al., 2011). However, the adult studies evaluated 'manualized' CBT-I whereas the Sleep SENSE intervention incorporates both sleep- and anxiety-specific modules. Nonetheless, the results suggest that sleep interventions should be targeted toward adolescents who are experiencing early signs of sleep and internalizing disorders rather than unselected groups such as whole school classes. As we have previously described, 20% of unselected adolescents in the population from which these participants were drawn (i.e. the screening sample) reported subclinical levels of both sleep and internalizing disorders, whereas 50% reported no subclinical symptoms (Blake et al., 2016). The lack of change in sleep and mental health outcomes following many school-based sleep interventions (Blunden, Chapman, & Rigney, 2012; Gruber, 2016) may be due to the universal intervention approach taken. Specifically, the relatively low prevalence of sleep and mental health problems in the general student population may result in many adolescents being exposed to interventions from which they are unlikely to benefit. In contrast, sleep interventions targeting 'at-risk' adolescents may be more effective because the adolescents are more likely to be motivated, ready for change, and to identify with the content (Wensing, Bosch, & Grol, 2010).

The results also suggest that adolescents with low levels of self-efficacy may need further targeted support (e.g. additional motivational interviewing) to help them reach treatment goals. For example, adolescents with low levels of self-efficacy may believe that sleep intervention strategies are unachievable or ineffectual. Higher doses of motivational interviewing may be effective because the approach is patient-centered, instructive, and aims to resolve treatment ambivalence, shape intrinsic motivation, foster personal agency, and develop autonomy (Harvey, 2016). The latter is a key developmental task in adolescence. Supplemental motivational interviewing strategies could include asking the adolescent for permission before offering advice about sleep; asking what the adolescent already knows about sleep before offering sleep education; offering recommendations in a nonconfrontational way that supports and respects the adolescents autonomy; selecting and contracting sleep goals that are specific, measurable, attainable, realistic and timely; using decisional balance matrices to identify advantages and disadvantages of change; identifying solvable versus unsolvable problems; and building hope that change is possible. Conducting additional behavioral experiments could also be beneficial, as they may bring about disconfirmation of unhelpful

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and pessimistic self-beliefs; provide experiential learning that new beliefs, thoughts, and behaviors can improve sleep and mental health; and inspire adolescents to become scientists 'who make judgments in their lives based on data they collect, rather than based solely on their subjective beliefs and feelings' (Harvey, 2016, p. 345). However, future studies are needed to explore these possibilities. Motivational interviewing has been used to promote behavior change in an increasing number of adolescent health-related domains (Cushing, Jensen, Miller, & Leffingwell, 2014).

Finally, the results suggest that initial sleep duration does not moderate treatment response to adolescent cognitive-behavioral sleep interventions. This result is discordant with a recent study by Bathgate et al. (2017) that showed that middle-aged and older adults with primary sleep maintenance insomnia and short objective sleep duration had blunted response to CBT-I. There are several possible explanations for this discrepancy: (1) findings from the adult insomnia literature do not generalize to younger samples with predominantly sleep onset complaints and concomitant psychiatric symptoms; (2) insomnia phenotypes of short versus normal sleep duration are not apparent in adolescents; (3) the study by Bathgate et al. (2017) lacked a control condition, whereas this study included an active control condition, which is likely to result in smaller effect sizes; and (4) the defining feature of CBT-I, the sleep restriction protocol, was not included in the Sleep SENSE intervention, as the sample was not specifically selected for insomnia symptoms, so the interventions effect on sleep duration may differ. Future studies are needed to explore these possibilities.

Of course, this study was not without its limitations. First, common method variance may have accounted for some of the relationship between the questionnaire variables (i.e. $SCAS_1$, $CESD_1$, GSE_1, and $PSQI_2$). Second, although the study investigated a number of treatment moderators drawn from the theoretical insomnia literature, other variables may also moderate treatment response to adolescent cognitive-behavioral sleep interventions, including attitude to treatment, treatment expectancy, satisfaction with treatment, and homework compliance (Matthews, Arnedt, McCarthy, Cuddihy, & Aloia, 2013). Finally, the exclusion of participants with previous episodes of MDD may restrict the generalizability of the study.

This study provides evidence that cognitive-behavioral sleep interventions may be most effective when they are directed toward adolescents who are experiencing subclinical and clinical levels of anxiety and depression. Adolescents with low levels of self-efficacy may need further targeted support (e.g. additional motivational interviewing) to help them reach treatment goals.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. CONSORT checklist.

Appendix S2. Results of independent sample *t*-tests comparing preintervention differences between the treatment conditions.

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Key points

- Many adolescents obtain insufficient and/or poor-quality sleep. However, few RCTs have evaluated the efficacy of adolescent sleep interventions.
- This was the first study to examine moderators of therapeutic efficacy in an adolescent cognitive-behavioral sleep intervention.
- We found that adolescents with lower levels of anxiety and depression symptoms but not short objective sleep duration showed blunted response to the intervention, contrary to findings from the adult literature. Furthermore, adolescents with higher levels of self-efficacy showed increased responsiveness to the intervention.
- These findings suggest that sleep interventions may be most effective when they are directed toward adolescents who are experiencing subclinical and clinical levels of anxiety and depressive symptoms. Furthermore, adolescents with low self-efficacy may need further targeted support (e.g. additional motivational interviewing) to help them reach treatment goals.

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