THE ACCEPTABILITY AND IMPACT OF SLEEP EXTENSION ON EXECUTIVE FUNCTIONING IN YOUTH WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER: A PILOT RANDOMIZED CONTROL STUDY

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Cori Manning

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As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Cori Manning, titled *The Acceptability and Impact of Sleep Extension on Executive Functioning in Youth with Attention-Deficit/Hyperactivity Disorder: A Pilot Randomized Control Study* and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Michelle M Perfect
box SIGN 4Q5J7224-4PR63YXK
Date: Aug 6, 2025
Michelle Perfect, PhD

Lauren Meyer, PhD
box SIGN 463W6J81-4PR63YXK
Date: Aug 7, 2025
Lauren Meyer, PhD

David A. Sbarra, Ph.D.
box SIGN 18K9WZVJ-4PR63YXK
Date: Aug 7, 2025
David Sbarra, PhD

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Michelle M Perfect
box SIGN 4Q5J7224-4PR63YXK
Date: Aug 6, 2025
Michelle Perfect, PhD
Dissertation Committee Chair
Department of Disability and Psychoeducational Studies

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Abstract

Background and Objective: Adolescents with attention-deficit/hyperactivity disorder (ADHD) frequently experience impairments in executive functioning (EF), including difficulties with working memory, inhibitory control, and cognitive flexibility. Sleep problems are also highly prevalent in this population and may further exacerbate EF-related challenges. Emerging research suggests that improving sleep, particularly through increasing total sleep time (TST), may support better EF outcomes. However, few studies have directly tested sleep extension as an intervention for EF deficits in adolescents with ADHD. The present pilot study examined the acceptability and preliminary efficacy of a brief behavioral sleep extension intervention for adolescents with ADHD and comorbid sleep difficulties, with a focus on improving sleep outcomes and EF skills.

Methods: Thirteen adolescents aged 11 to 17 years (M = 13.62, SD = 1.80) with a diagnosis of ADHD and comorbid sleep difficulties participated in a pilot randomized controlled trial. Participants were randomized into either a behavioral sleep extension intervention group (n = 9) or a routines-based control group (n = 4) following a two-week baseline period. The intervention included a brief, collaborative consultation focused on increasing total time in bed and improving sleep habits over a two-week period, supported by two follow-up phone calls. Sleep was measured using actigraphy, daily sleep diaries, and both self- and parent-report questionnaires (CRSP, CSHQ). EF was assessed pre- and post-intervention using the BRIEF (self- and parent-report) and performance-based tasks targeting working memory, inhibitory control, and cognitive flexibility (WJ-IV subtests, Digit Span Backward, Stop Signal Task, and Trail Making Test). Acceptability was assessed through post-intervention surveys with participants and caregivers.

Results: The intervention group demonstrated longer TST, longer TIB, and reduced variability in sleep duration, relative to the control group, as measured by actigraphy. Although these changes were not statistically significant, medium to large effect sizes were observed for increased TST (Hedges' $g = 0.92$), increased TIB ($g = 0.82$) and reduced coefficient of variability in sleep duration ($g = -1.11$). Improvements in executive functioning were also noted in the intervention group across multiple measures, with small to medium effect sizes favoring the intervention on self-reported working memory ($g = -0.31$) and global executive functioning ($g = -0.38$), and on performance-based inhibitory control ($g = 0.61$). Acceptability ratings were high among both adolescents and caregivers, who reported that the intervention was easy to follow and helped improve sleep.

Conclusions: This pilot study provides preliminary evidence that a brief, individualized behavioral sleep extension intervention is both acceptable and potentially effective for adolescents with ADHD. While the small sample size limited statistical power, consistent medium-to-large effect sizes across objective sleep outcomes suggest the intervention may improve sleep duration, consistency, and select areas of executive functioning. Adolescents and caregivers reported high acceptability and engagement, and performance-based tasks indicated modest improvements in working memory and inhibitory control. These findings highlight the feasibility of delivering personalized, at-home sleep interventions for adolescents with ADHD and underscore the importance of further research with larger samples and longer follow-up to evaluate sustained effects and real-world implementation.

Chapter 1: Introduction

This chapter provides an overview of research exploring the connections between attention-deficit/hyperactivity disorder (ADHD), sleep difficulties, and executive function (EF). It will provide an overview of the neurobiological functioning related to ADHD and sleep insufficiency, and the impact of brain functioning on symptom presentation. This chapter will also address current gaps in the literature, specifically related to sleep interventions for populations of adolescents with ADHD. The purpose of the study was to investigate the acceptability and preliminary efficacy of a behavioral sleep extension intervention emphasizing sleep extension to improve EF skills in a population of children and adolescents with ADHD and comorbid sleep difficulties.

ADHD

ADHD is a neurodevelopmental disorder that causes clinically significant impairments in EF (Doernberg & Hollander, 2016). EF is a broad term that describes several higher-order cognitive processes and is paramount to cognitive and behavioral functioning in daily life (Doebel, 2020). Although there has been much debate about models of EF, there appears to be the most support for EF containing three core domains: working memory, inhibitory control, and set shifting (Miyake et al., 2000; Miyake & Friedman, 2012; St. Clair-Thompson & Gathercole 2006; Van der Sluis et al., 2007). An estimated 7.2% of children and adolescents have ADHD, making it one of the most prevalent disorders diagnosed among this age group (American Psychiatric Association, 2022; Thomas et al., 2015). ADHD is characterized by greater levels of persistent inattention and/or hyperactivity/impulsivity than are observed in typically developing individuals (Austerman, 2015). Parents often notice hyperactivity during the time the child is in preschool and begin to notice more inattention as it becomes more impairing as the child goes through elementary school (APA, 2022). Although hyperactivity, manifested in behaviors such as running around excessively, is typically a prominent symptom of ADHD during preschool years, as children age, hyperactivity symptoms can begin to manifest as fidgeting, restlessness, or inner feelings of jitteriness (APA, 2022). All individuals with ADHD experience impairments in EF; however, the symptom expression and severity may vary.

Some children and adolescents with ADHD do not require support in order to succeed in the school setting, whereas others require additional support to succeed in the school setting. Many students with ADHD receive accommodations through a 504-plan, which often include accommodations such as extra time for assignments, taking tests in distraction-free environments, additional reminders, or having items read aloud (Lovett & Nelson, 2021). Students who experience negative impacts on their academic, behavioral, or social functioning in the school setting as a result of ADHD often qualify for special education services under the category of Other Health Impairment (OHI) and are able to receive specially designed instruction through an Individualized Education Plan (IEP; Lovett & Nelson, 2021). DuPaul et al. (2018) examined school services within a national sample of students, ages 4 to 17 years, with ADHD. Results from this study found that the majority of students with ADHD in the US were being served by one or more school services, with most services directed at educational support and behavior management. This study also found that 42.9% of students with ADHD were served by an IEP, 13.6% of students were served by a 504-Plan, and at least one out of five students with ADHD did not receive any school services despite experiencing significant academic, social, or behavioral impairment (DuPaul et al., 2018).

The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition - Text Revision (DSM-5-TR; APA, 2022) categorizes the symptom presentation of individuals with ADHD into three distinct categories: combined presentation, predominantly inattentive presentation, and predominantly hyperactive/impulsive presentation. For a child or adolescent to meet diagnostic criteria for ADHD-combined presentation, they must present with at least six out of nine symptoms of inattention and at least six out of nine symptoms of hyperactivity/impulsivity. To meet criteria for ADHD-predominantly inattentive presentation or ADHD-predominantly hyperactive/impulsive presentation, they must present with six or more symptoms in the respective area, but present with less than six symptoms in the non-predominant area. Since ADHD is a neurodevelopmental disorder, individuals must show presentation of inattentive and/or hyperactive/impulsive symptoms prior to the age of 12 across multiple settings (i.e., home and school; APA, 2022). Along with symptoms of inattention and hyperactivity/impulsiveness, those with ADHD commonly report experiencing sleep difficulties (Lunsford-Avery et al., 2016). Sleep problems are not only prevalent among individuals with ADHD, but they may also exacerbate core symptoms and contribute to additional challenges with EF. In fact, research suggests that sleep disturbances can mimic or intensify ADHD symptoms—including impairments in attention, hyperactivity, impulsivity, and EF—making it difficult to disentangle the effects of each condition. Given that EF encompasses essential cognitive processes responsible for managing behavior, organizing tasks, and regulating emotions, disruptions in sleep may further compromise these abilities in individuals with ADHD (Welsch et al., 2021). This relationship highlights the possibility that improving sleep—especially by increasing sleep duration, consistency, and quality—could be a promising pathway to enhance EF, and consequently, daily functioning for adolescents with ADHD.

EF

EF is one of the most clinically relevant symptoms of ADHD, resulting from the neurological differences of individuals with ADHD compared to typically developing peers (Mehta et al., 2019). Research has shown that children with ADHD experience hypoactivation of the basal ganglia and supplementary motor area during inhibition tasks (Hart et al., 2013). Additionally, functional connectivity between the ventrolateral prefrontal cortex, anterior cingulum, cerebellum, and superior parietal cortex is reduced in the brains of children with ADHD when using working memory (Wolf et al., 2009). Brain dysfunction while completing tasks requiring EF supports a neurobiological basis for those with ADHD struggling with EF.

When individuals, such as those with ADHD, experience executive dysfunction, it may negatively impact daily functioning (Brown, 2009). Children and adolescents with ADHD often struggle with working memory, attentional and emotional regulation, organization, task initiation, planning and prioritizing, self-monitoring, impulse control, and flexible thinking as a result of impairments in EF (Martel et al., 2007). Difficulties such as these can make it more difficult for children and adolescents with ADHD to learn, work, and generally manage the tasks of everyday life.

Skogli et al. (2013) investigated the relationship between the two subtypes of ADHD and EF impairments. This study used a sample of 36 adolescents with ADHD-combined presentation, 44 with ADHD-predominantly inattentive type, and 50 neurotypical adolescents for the control group. Findings from this study suggest that there is not a statistically significant difference between the two ADHD groups in EF measures, meaning that both experience symptoms of executive dysfunction to a relatively similar degree (Skogli et al., 2013). One possible mechanism that differentiates those with ADHD, who have greater EF challenges and those who do not, is sleep. Research has shown that sleep insufficiency impacts neurological functioning, resulting in impairments in cognitive functioning, specifically EF.

Sleep

Sleep plays a vital role in the healthy, biopsychosocial development of all children and adolescents (Becker et al., 2015). Several studies have identified a higher prevalence of sleep disorders among individuals with ADHD. Moreover, some research has implicated sleep problems in the exacerbation or potential overlap of symptoms, potentially leading to a diagnosis of ADHD when in fact the behavioral manifestations are due to sleep deficiency (Gloger & Suhr, 2020). In healthy individuals, insufficient sleep is related to decreased cognitive functioning in areas such as attention, processing speed, and working memory (Molfese et al., 2013; Van Dongen et al., 2023). As a result of these research findings, increasing sleep quality, consistency, and duration has frequently been an aim of previous research (Larsson et al., 2023; Malkani et al., 2022). Sleep quality typically is used to refer to the efficiency of sleep as well as the perception or feeling of waking up restored or well rested (Ohayon et al., 2017). Sleep duration, or Total Sleep Time (TST) refers to the total time that an individual is asleep (Osamu et al., 2017). The American Academy of Sleep Medicine (AASM) currently recommends TST of 9 to 12 hours per night for children ages 6 to 12, and 8 to 10 hours per night for adolescents ages 13 to 18 (Paruthi et al., 2016).

Despite these recommendations, more than half of all children and adolescents report getting less than the recommended amount of sleep each night (Wheaton et al., 2018). Even youth who only sleep one hour less than recommended are likely to be impacted negatively (Gillen O'Neel et al., 2013; Sadeh et al., 2003). In fact, research has shown that when children and adolescents (ages 10 - 17) are given the opportunity to sleep in controlled conditions, they naturally sleep 9.25 hours as a result of their internal clock or circadian rhythm (Carskadon, 1982; Crowley et al., 2018). Children and adolescents who do not routinely get an adequate amount of sleep are put at a higher risk for a multitude of negative cognitive, physical, and psychological health outcomes, such as behavior and attention difficulties, poor academic performance, obesity, injuries, and diabetes (Cook et al., 2021; Wheaton et al., 2018). There has been a significant amount of research conducted on sleep duration, and more recently research has found sleep consistency to be a key factor in overall sleep health (Becker et al., 2017; Bei et al., 2016).

Although sleep is important for all adolescents, it is especially crucial for adolescents with ADHD, as they frequently report experiencing sleep difficulties, which can present as an obstacle to obtaining healthy sleep (Lunsford-Avery et al., 2016). It is estimated that up to 70% of children and adolescents with ADHD experience mild to severe sleep problems, making it one of the most common comorbidities with ADHD (Cortese et al., 2013). Sleep problems in this context refer to sleep-related complaints or difficulties (e.g., delayed sleep onset) that may be caused by exacerbating conditions such as insomnia, circadian rhythm sleep disorder, night wakings, or restless leg syndrome (Cortese et al., 2013). Comorbid sleep problems with ADHD may exacerbate the already present impairments in EF, though the directionality of this relationship is currently unclear (Hvolby, 2015). When a typically developing student experiences sleep disorders or difficulties resulting in inadequate amounts of sleep, they often present with symptoms that “mimic” ADHD (Beebe, 2006; Gruber, 2009). Research has shown that sleep deprivation in typically developing individuals results in hypoactivation of the frontal lobe, which is also something that is observed in the brains of individuals with ADHD (Kasparek et al., 2013). Such findings suggest that a person with ADHD with a comorbid sleep problem may experience even less activation of the frontal lobes than typical for them.

Much research on sleep interventions for youth with ADHD has focused on improved sleep as the primary outcome variable, but less research has investigated symptom presentation as a result of sleep intervention. For example, Peppers et al. (2016) found that an intervention of sleep hygiene education in a sample of children and adolescents with ADHD increased sleep quality and decreased ADHD symptom presentation. A recent systematic review and meta-analysis of behavioral sleep interventions for children with ADHD revealed that there are currently only a handful (n = 7) published randomized control trials looking at behavioral sleep interventions, with most focusing on parent education or sleep hygiene as the intervention. Of those studies, one conducted by Keshavarzi et al. in 2014 included a sleep extension component of a larger sleep training program treatment condition. Results from this study found that adolescents in the treatment condition showed improvements in sleep continuation (increased sleep duration, reduced sleep onset latency, and decreased nighttime awakenings), general sleep patterns (sleeping alone, falling asleep, waking up feeling restored, and waking up at the same time), mood, emotions, and relationships with others. However, this study examined a multicomponent sleep program and did not isolate whether sleep extension was the contributory factor in the observed changes on behavioral and emotional functioning. One limitation of this study was that EF was not directly measured as an outcome variable. It is possible that this intervention may have helped improve EF skills such as emotional and behavioral regulation, although direct data would be needed to support this. Cremone-Caira et al. (2019) specifically investigated the impact of sleep extension on inhibitory control, which is a domain of EF, in a population of youth with ADHD. Results suggested that sleep extension may positively impact inhibitory control. More research is needed to investigate the impact of sleep on EF skills, as EF is crucial for academic, social, and occupational functioning.

Purpose and Introduction to Methods

Children and adolescents with ADHD continually struggle with EF skills necessary to function successfully at school, work, and home. These individuals face daily struggles with organization, time management, attention regulation, planning, prioritizing, emotional and attentional control, and starting new tasks. In the school setting, these individuals often misplace necessary items for school (i.e., pencils, paper, calculators, homework), forget about important deadlines, struggle to regulate attention in the class setting and while working on assignments at home, and experience peer difficulties due to poor emotional regulation and poor impulse control. In fact, students with ADHD typically earn lower grades than their typically developing peers (Frazier et al., 2007). ADHD is also associated with adverse health outcomes such as elevated risk of mortality and morbidity, obesity, and accidental injury (Nigg, 2013).

Overall, ADHD negatively impacts the daily functioning of these children and adolescents and is only made worse with the presence of a comorbid sleep disorder, which occurs in the majority of individuals with ADHD. Therefore, by experimentally manipulating TST, it is possible to determine if increasing sleep in individuals with ADHD may causally improve EF skills in this population. Most importantly, the proposed research may provide preliminary evidence of efficacy of a feasible behavioral sleep intervention that can be used to maximize the benefits that school-aged children obtain from all other supports already in place, such as accommodations and individualized learning plans in the school setting.

The purpose of this study was to examine if adolescents with ADHD who increase their sleep show improvements in EF, specifically working memory, cognitive flexibility, and inhibitory control. This was a pilot study including a total of 13 adolescents between the ages of 11 and 17 years old, with a diagnosis of ADHD (combined presentation or predominantly inattentive presentation). Participants were stratified by gender and randomly assigned to one of two conditions with a 2:1 allocation ratio: 1) sleep extension condition or 2) routines (control) condition. The intervention was ready to be implemented and adapted for an ADHD population. In this regard, Perfect et al. (2016; 2023) designed an intervention for which the primary intervention target was sleep extension. Though the intervention itself was not focused on sleep hygiene, the team incorporated strategies to increase the likelihood of extending sleep duration, such as reviewing actigraphy and sleep diary data with the participant, collaboration between the participant, caregiver, and interventionist (i.e., researcher) to address obstacles to obtaining sleep in the recommended range, and instructing the participant to obtain a specific amount of sleep. The first study demonstrated that sleep extension in youth with type 1 diabetes was feasible, whereas the ongoing study has demonstrated that overall youth increase TST over a 3-month period (Perfect et al., 2023). This latter study has a booster session approximately one month after the initial consultation. Thus, this study was one month with two weeks of baseline to establish sleep patterns (Leproult et al., 2015; Mah et al., 2011) and the intervention portion was two weeks to monitor whether the youth increased their sleep and ascertain an effect size of intervention impact. The consultative nature and brevity of the intervention as well as the support of the provider to the individual and at least one caregiver make it conducive to a school setting and optimal for home-school collaboration.

Research Questions

Children and adolescents with ADHD experience significant impairment in EF resulting in symptoms of inattention, hyperactivity, and impulsivity that impact daily functioning. The majority of children and adolescents are also impacted by comorbid sleep disorders which may exacerbate the already present symptoms of ADHD, making daily functioning in school, home, and community settings even more difficult. Although there is much research about the impact of ADHD and sleep disturbances, there appears to be a gap in the literature about specific sleep interventions to decrease executive dysfunction within an adolescent ADHD population. Therefore, there is a need to investigate how different sleep interventions, such as sleep extension, may impact areas of EF, specifically working memory, inhibitory control, and cognitive flexibility in a population of ADHD adolescents. This study aims to answer the following research questions:

Research Question 1: Is the behavioral sleep extension intervention acceptable within a population of adolescents with ADHD?

Acceptability will be determined through open-ended questions for the participants and caregivers following completion of the intervention.

Research Question 2**:** Do the data support that sleep for adolescents with ADHD improves following participation in a behavioral sleep extension intervention?

Hypothesis: Adolescents in the sleep intervention condition will increase their average sleep duration.

Hypothesis: Adolescents in the sleep intervention condition will reduce the variability of their bedtimes and/or sleep duration across nights

Research Question 3: Does a behavioral sleep extension intervention for adolescents with ADHD positively impact one or more areas of EF (working memory, inhibitory control, or cognitive flexibility)?

Hypothesis: Adolescents in the sleep intervention condition will report improved functioning in one or more areas of EF (working memory, inhibitory control, or cognitive flexibility) as evidenced by greater increases in scores relative to the control group

Since this is a pilot phase study, effect sizes will be reported to determine magnitude of change in addition to statistical significance testing.

Definition of Terms

This paper uses a variety of terms relevant to the proposed research. Definitions of important terms are provided below.

Acceptability - how well an intervention is received by a specific population, and the extent to which it meets the needs of the specific population

Actigraph - small, watch-like device, typically worn on the wrist, that senses movement and light in order to measure amount and quality of a person's sleep

Bedtime Fading/Faded Bedtime - gradually making a child's bedtime earlier

Circadian Rhythm - mental, physical, and behavioral changes within a 24-hour cycle which respond to light exposure

Coefficient of Variation (CV) - the ratio of the standard deviation to the mean

Cognitive Flexibility/Set Shifting - a core domain of EF that refers to the ability to efficiently and quickly shift between mental sets

Effect Size - the magnitude of difference between groups

Efficacy - the ability of an intervention to produce an effect in ideal circumstances

Feasibility - used to determine if an intervention is able to be conducted, and if it is appropriate for future research

Inhibitory Control - a core domain of EF that refers to being able to control attention, behavior, thoughts, and emotions to override a strong internal predisposition in order to do what is more necessary or appropriate

Intelligence Quotient (IQ) - a standardized measure of cognitive abilities compared to a population of same age peers

Intra-Individual Variability (IIV) - night-to-night fluctuations in sleep within an individual

Positive Reinforcement - the process of rewarding a desired behavior to increase the chance of it being repeated in the future

Working Memory - a core domain of EF that refers to the ability to process, remember, and use information on a daily basis

Sleep Hygiene - healthy habits, behaviors and environmental factors that can aid in obtaining healthy sleep

Sleep Latency/Sleep Onset Latency - the amount of time it takes for a person to fall asleep once in bed with lights off.

Chapter 2: Literature Review

This chapter will delve further into the relevant literature regarding the relationships between sleep, ADHD, EF, and behavioral sleep medicine interventions.

ADHD

ADHD is one of the most commonly diagnosed disorders and impacts approximately 7.2% of children and adolescents worldwide (APA, 2022; Thomas et al., 2015). Mental health professionals such as psychologists or psychiatrists, or primary care providers are able to diagnose ADHD. The current concept of ADHD is characterized by persistent levels of inattention and/or hyperactivity/impulsivity that are greater than those observed in typically developing individuals (Austerman, 2015).

History of the Diagnosis

ADHD was first added to the Diagnostic and Statistical Manual of Mental Disorders, Third Edition - Revised (DSM-III-R) in 1987 (APA, 1987). Although ADHD did not appear as a diagnosis until the late 1980's, individuals who presented with excessive hyperactivity, inattention, and impulsivity, had previously been recorded and categorized under a variety of different diagnoses throughout history.

In fact, the first known record of a disorder resembling ADHD occurred over 200 years ago, in Scottish Physician Sir Alexander Crichton's, *An Inquiry into the Nature and Origin of Mental Derangement* (Crichton, 1798). The second chapter of his book regarding attention, details a mental disorder characterized by the "incapacity of attending with a necessary degree of constancy to any one object" (Crichton, 1798/2008). In addition to discussing the abnormal inattention levels observed within this disorder, Crichton also noted that individuals may express these symptoms from birth or that they can occur as the result of an accident or disease (Crichton, 1798). He cited examples of patients' behaviors, which characterized restlessness, overstimulation from sensory stimuli, and some emotional dysregulation (Crichton, 1798). Though this description of an attention-based disorder was brief, it does resemble the characteristics of what is currently known as ADHD.

The next possible example of ADHD comes from German physician, Heinrich Hoffmann, who created a number of children's stories that were thought to be used as learning tools or educational warning stories for children at the time (Lange et al., 2010). In 1844, Hoffman created a story titled "Fidgety Phil," which depicts fidgety behaviors of a child at dinner that led to family conflict (Lange et al., 2010). Hoffmann's short story was not meant to be documentation of a mental disorder, but it does illustrate behaviors that can be commonly observed in children today with ADHD, such as restlessness and fidgeting.

In 1902, British pediatrician Sir George Fredereic Still, lectured at the Royal College of Physicians of London, which was a three-lecture series known as the Goulstonian Lectures (Still, 1902). During these lectures, Still spoke about the "abnormal defect of moral control in children" and described that it can occur in children without accompanying intellectual impairments or physical diseases (Still, 1902). Still noted that this "defect of moral control" disproportionately affects males, symptoms typically begin before the age of 7, and that these children typically struggle with delaying gratification and sustaining attention (Lange et al., 2010; Still, 1902).

From 1917 to 1928, approximately 20 million people were affected by the encephalitis lethargica epidemic (Lange et al., 2010; Rafalovich, 2001). Many children who survived encephalitis were observed displaying abnormal behaviors described as distractible, hyperactive, antisocial, unruly, destructive, impulsive, and unmanageable (Lange et al., 2010). This shift in behavior and personality displayed in children who had survived encephalitis was referred to as "postencephalitis behavior disorder" (Lange et al., 2010). Although there are some overlapping symptoms between postencephalitis behavior disorder and ADHD, the majority of those afflicted with postencephalitis behavior disorder would not meet present criteria for ADHD (Lange et al., 2010). However, this disorder is relevant as it highlighted the causal connection between brain damage and symptoms commonly associated with ADHD, such as hyperactivity and inattention (Lange et al., 2010; Rafalovich, 2001).

Shortly after the epidemic, in 1932, German physicians Franz Kramer and Hans Pollnow introduced the term "hyperkinetic disease," which was characterized primarily by hyperactivity and inattention (Lange et al., 2010). In addition to describing symptoms of the disease, Kramer and Pollnow discussed the functional impairments that these children face in school as a result of frequently disrupting the classroom, struggling to play with peers, and being unpopular (Lange et al., 2010). This is the first documented disorder that encapsulated the three core characteristics of the current diagnosis of ADHD: inattention, hyperactivity, and impulsivity. In the 1950's, the ideas of "minimal brain damage" and "minimal brain dysfunction" were introduced as possible causes of the hyperactive behavior observed in some children, building on the idea from Still that hyperactivity may have a neurological cause.

Historical Progression of ADHD in the DSM

In the second edition of the DSM (DSM-II), the diagnostic label of "Hyperkinetic Reaction of Childhood" was introduced (APA, 1968). This diagnosis included two sentences describing a disorder characterized by distractibility, restlessness, and overactivity, that typically impacts children and resolves in adolescence (APA, 1968). In the third edition of the DSM (DSM-III), the longstanding focus on symptoms of hyperactivity shifted to focusing on symptoms of attention deficits (Lange et al., 2010). To reflect the shift, the disorder previously called Hyperkinetic Reaction of Childhood, was renamed to "Attention Deficit Disorder (ADD) (with or without hyperactivity)" (APA, 1980; Barkley, 2006; Lange et al., 2010). This was a significant change to the diagnosis, as it highlighted that symptoms of inattention and impulsivity can occur with or without symptoms of hyperactivity.

The revision of the DSM-III (DSM-III-R) was the first version of the DSM to include the diagnostic label of "Attention deficit-hyperactivity disorder (ADHD)" (APA, 1987). In this revision, the two subtypes of ADD (with and without hyperactivity) were removed and replaced by ADHD, categorized by inattention, hyperactivity, and impulsivity. As a result of the ADD without hyperactivity subtype being removed, a residual category called "undifferentiated ADD" took its place.

Between the release of the DSM-III-R and the DSM-IV, researchers found that children with and without hyperactivity differed from each other, thus laying the foundation for the new diagnosis of ADHD to contain three separate subtypes: predominantly hyperactive-impulsive type, predominantly inattentive type, and combined type (APA, 1994; Barkley, 2006). During this time period, structural abnormalities of the brain in children with ADHD, were observed through neuroimaging, and it was discovered that ADHD could persist throughout adulthood (Barkley, 2006; Lange et al., 2010). In 2009, the DSM-IV was revised (DSM-IV-TR) but no changes were made to diagnostic criteria for ADHD (APA, 2009).

In 2013, the DSM-5 was released and the diagnostic criteria for ADHD was modified (APA, 2013). Previously, an individual needed to present with a minimum of six symptoms of inattention and/or hyperactivity/impulsivity, but this was reduced to a minimum of five symptoms (Epstein & Loren, 2013). The age of symptom onset changed from before 7 years to before 12 years of age, and the functional impairment changed from needing to be clinically significant to needing to reduce the quality of functioning (Epstein & Loren, 2013). This revision also removed autism spectrum disorder (ASD) as an exclusionary diagnosis (APA, 2013).

DSM-V-TR Diagnostic Criteria for ADHD

The most recent version of the Diagnostic and Statistical Manual of Mental Disorders, the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition-Text Revised (DSM-V-TR), includes three presentations of ADHD: predominantly inattentive presentation, predominantly hyperactive/impulsive presentation, and combined presentation (APA, 2022). The DSM-V-TR categorizes ADHD as a neurodevelopmental disorder, meaning that onset of the disorder and symptom presentation must occur during the developmental period. Specifically for ADHD, symptoms must be present prior to 12 years old (APA, 2022). Additionally, neurodevelopmental disorders, such as ADHD, stem from developmental differences in the brain that lead to impairments in academic, personal, social, or occupational functioning (APA, 2022). Thus, to receive a diagnosis of a neurodevelopmental disorder such as ADHD, an individual must present with not only symptoms but also functional impairment (Thaper et al., 2017). In addition to experiencing ADHD symptoms listed in the DSM-V-TR, individuals with ADHD frequently report sleep difficulties (Lunsford-Avery et al., 2016).

For an individual age 16 or younger to obtain a diagnosis of ADHD-predominantly inattentive presentation (ADHD-I), they must present with a minimum of six out of nine total listed symptoms of inattention. If an older adolescent or adult (age 17 years or older) is being assessed for ADHD-I, they must present with at least five symptoms. DSM-V-TR symptoms of inattention include difficulties with attention to detail, trouble sustaining attention, trouble listening when spoken to, poor follow-through with tasks, difficulty with organization, trouble engaging in non-preferred tasks, losing important objects, being easily distracted, and being forgetful in daily activities.

Similarly, for an individual to obtain a diagnosis of ADHD-predominantly hyperactive/impulsive presentation (ADHD-H), they must present with a minimum of six out of nine listed symptoms of hyperactivity and impulsivity (APA, 2022). If an older adolescent or adult (age 17 years or older) is being assessed for ADHD-H, they must present with at least five symptoms. DSM-V-TR symptoms of hyperactivity and impulsivity include frequent fidgeting, difficulty staying seated, running at inappropriate times or feeling restless, difficulty engaging in activities quietly, often being “on the go,” excessive talking, frequent blurting out, trouble waiting one's turn, and frequent interrupting of others (APA, 2022). Lastly, for an individual to receive a diagnosis of ADHD - combined presentation (ADHD-C), they must meet diagnostic criteria for ADHD-I and ADHD-H.

Prevalence and Diagnostic Considerations

Although population surveys suggest that ADHD affects about 7.2% of children worldwide, prevalence rates vary considerably across different populations (APA, 2022; Thomas et al., 2015). Most notably, ADHD is currently diagnosed more frequently in males than females, with a ratio of 2:1 in youth (Polancyzk et al., 2007). Although males are diagnosed more frequently, females are more likely than males to present with predominantly inattentive symptoms (Arnett et al., 2015). While there is not one specific gene or a biological marker tied to ADHD, it is still a very heritable disorder, with heritability estimated at approximately 74% (Faraone & Larsson, 2019).

Prevalence rates may vary considerably due to cultural beliefs and expectations surrounding the behaviors of children and adolescents, mental health, and treatment. In the US, white children are more frequently diagnosed and treated with medication than their black and Latinx peers (Coker et al., 2016). In fact, results from Coker et al. (2016) suggest that underdiagnosis and undertreatment of black and Latinx children is more likely a cause of the disproportionate rates of ADHD diagnoses than is the overdiagnosis and overtreatment of white children. Underdiagnosis may result from implicit bias from clinicians, as youth from marginalized backgrounds with ADHD are often over diagnosed with disruptive behavior disorders (Fadus et al., 2020). Additionally, ADHD is also diagnosed more frequently within populations of foster youth and in correctional settings (APA, 2022; Ford et al., 2007; Lehmann et al., 2013, Moore et al., 2016).

Symptom Presentation

Although all individuals with ADHD experience functional impairment due to developmental differences or deficits, the extent to which symptoms present may vary from person to person. Oftentimes, parents are the first ones to notice these differences within their own children. For many, hyperactivity is the first symptom that is noticed, and this usually occurs around the time that a child is in preschool (APA, 2022). During the preschool years, hyperactivity may initially present as running around excessively and having great difficulty sitting still. However, as children get older, hyperactivity may shift its presentation into less obvious forms such as excessive feelings of restlessness, jitteriness, or fidgeting (APA, 2022). As children grow, symptoms of inattention typically become more prevalent, normally around the time that children go through elementary school, which is more structured and demanding than preschool (APA, 2022).

Youth with ADHD are at a higher risk for suicidal ideation and behaviors, accidental injury, and suffering a trauma than their typically developing peers (Biederman et al., 2013; Impey & Heun, 2012; Nigg, 2013). ADHD is also associated with poorer academic attainment and school performance (Zendarski et al., 2017). Throughout the lifespan, those with ADHD tend to obtain less schooling, have lower vocational achievement, more interpersonal conflict, and higher rates of unemployment compared to peers (APA, 2022; Kessler et al., 2006).

Individuals with ADHD tend to have lower self-esteem than their typically developing peers, and often experience peer rejection, teasing, and peer neglect, making it difficult to foster relationships (Harpin et al., 2013). Those with ADHD are also at a higher risk for developing a substance use disorder and being incarcerated (Mohr-Jensen et al., 2019).

Overall, ADHD can range in symptom presentation from person to person, but does impose significant functional impairments in social, academic, and occupational areas of life. Many of the symptoms of ADHD can be attributed to deficits in EF.

ADHD and School

School-aged children with ADHD present with varying levels of symptom presentation and functional impairment in academic settings. Some children and adolescents with ADHD do not require any additional or special support to succeed in academic settings. However, this is the exception, not the rule, as only one out of five school-aged children with ADHD do not receive extra school-based support (DuPaul et al., 2018). The majority of school-aged children and adolescents with ADHD do in fact require more support than typically provided in general education. Results from a national study by DuPaul et al. (2018) found that the majority of school-aged children with ADHD in the United States received one or more school-based services, with most services pertaining to behavior management and educational support.

504-Plans

One way that school-aged children with ADHD receive extra support in school is through Section 504 of the Rehabilitation Act of 1973 created by the United States Department of Education's Office for Civil Rights (OCR). Section 504 is a federal law set in place to protect the rights of students with disabilities in the educational setting. Section 504 has led to the development of 504-Plans in schools, which aim to uphold a Free and Appropriate Education (FAPE) for students with disabilities by providing equitable accommodations in the school setting. Roughly 13.6% of students with ADHD are serviced through a 504-Plan (DuPaul et al., 2018). 504-Plans for students with ADHD frequently include accommodations such as allowing the student to take tests in a distraction free environment, allowing the student extra time to finish tasks and assignments, having read aloud services, and having teachers provide additional reminders about assignments (Lovett & Nelson, 2021).

Individualized Education Programs (IEPs)

Approximately 42.9% of school-aged children with ADHD receive extra support and services through an Individualized Education Program (IEP), making it the most common way students with ADHD receive additional support in schools (DuPaul et al., 2018). IEPs exist because of the United States Department of Education's Individuals with Disabilities Education Act (IDEA) which mandates FAPE for students with disabilities and provides special education services. In the school setting, school psychologists can identify a student with ADHD during a psychoeducational assessment, even if the student does not have a pre-existing diagnosis of ADHD from an outside provider like a pediatrician or private psychologist (NASP, 2018). School-aged children with ADHD often experience negative impacts in their social, academic, and/or behavioral functioning as a result of their ADHD symptoms, which allows them to qualify for specially designed instruction and special education services through an IEP (Lovett & Nelson, 2021). Students with ADHD often qualify for special education services under the IDEA categories of Other Health Impairment (OHI) and Emotional Disability (ED) (Lovett & Nelson).

EF

EF refers to several cognitive and behavioral skills and elements, which play a significant role in daily functioning, learning, and academic achievement (Baggetta & Alexander, 2016; Doebel, 2020). Although there has been much research on EF, there is not one clear and agreed upon definition of what constitutes EF. Due to the complex nature of EF, there continues to be much debate about current models and domains of EF. Amongst all of the controversy and argument surrounding EF, research has agreed and supported that working memory, inhibitory control, and set shifting can be thought of as three domains of EF. (Miyake et al., 2000; Miyake and Friedman, 2012; St. Clair-Thompson & Gathercole 2006; Van der Sluis et al., 2007). Baggetta and Alexander (2016) attempted to conceptualize and operationally define EF by conducting a systematic review of 106 empirical studies. Studies included in the systematic review investigated how EF impacts performance in general and in educational settings for typically developing populations, as well as studies of psychometric properties for EF measures. Results from this systematic review indicated that inhibitory control or response inhibition, working memory, and set shifting or cognitive flexibility were the three most commonly included components of EF across models of EF (Baggetta & Alexander, 2016). Throughout the remainder of this paper, inhibitory control or response inhibition, will be referred to as inhibitory control, and set shifting or cognitive flexibility will be referred to as cognitive flexibility. Results of the systematic review allowed the researchers to define inhibitory control as “the ability to deliberately control or inhibit dominant or automatic, behaviors, responses, or thoughts”; working memory as “the ability to maintain a task or idea in mind while rapidly adding relevant information in response to task demands;” and cognitive flexibility as “the ability to move backward and forward between tasks, mental sets, or goals” (Baggetta & Alexander, 2016, p. 14-15).

Development of EF

It is thought that EF develops and becomes more complex with age. Inhibitory control is considered a core domain of EF that begins to be displayed in early childhood in behaviors such as delaying eating a preferred food or treat (Best & Miller, 2010). With age, inhibitory control develops and is used in conjunction with working memory as a child delays one response and produces an alternative (Best & Miller, 2010). Similar to inhibitory control, working memory may occur in a simple manner or more complex one, depending on the difficulty of a presented task (Best & Miller, 2010). Research has found that working memory is developed sufficiently by the age of 6 years, with a steady increase in development between the ages of 4 and 14 years, and a leveling of development around the ages of 14 and 15 years (Best & Miller, 2010; Gathercole et al., 2004). The third core domain of EF, cognitive flexibility, appears to require substantial inhibitory control and working memory in order to function (Best & Miller, 2010). Similar to inhibitory control and working memory, cognitive flexibility also appears to develop with age. By the age of 3 or 4 years old, children are typically able to shift between two response sets where rules are placed using a story for context (Best & Miller, 2010; Hughes, 1998). The ability to set-shift appears to increase until leveling out around the age of 15 (Best & Miller, 2010; Huizinga et al., 2006).

Executive Dysfunction

EF skills are a crucial part of daily cognitive and behavioral functioning. Individuals with neurodevelopmental disorders, such as ADHD, are more likely than their typically developing peers to experience difficulties or deficits in EF skills, also referred to as executive dysfunction (Lambek et al., 2010). Many symptoms of ADHD are rooted in executive dysfunction, making it one of the most clinically relevant symptoms of ADHD (Mehta et al., 2019). Since EF is crucial to many areas of daily functioning, those who experience executive dysfunction may be negatively affected in several areas of daily functioning (Brown, 2009). Individuals with ADHD commonly experience difficulties with areas of EF such as organization, task initiation, planning, working memory, emotional regulation, attention, flexible thinking, impulse control, and self-monitoring (Martel et al., 2007). These daily difficulties with EF can make it challenging for children and adolescents with ADHD to manage everyday tasks, work, or learn. Although there are three subtypes or presentations of ADHD, research has shown that there does not appear to be a significant difference in EF between different subtypes (Winther Skogli et al., 2013).

Sleep

Sleep is one of the most crucial factors in ensuring the healthy biological, psychological, and social, also known as biopsychosocial, development of children (Becker et al., 2015). Due to the importance of sleep, it is vital that children of all ages get enough sleep for their developmental stage. Current guidelines from the American Academy of Sleep Medicine recommend that children ages 6 to 12 years routinely sleep between 9 and 12 hours per night and adolescents ages 13 to 18 years routinely sleep between 8 and 10 hours per night in order for optimal functioning (Paruthi et al., 2016). Although these recommendations are supported by research and healthcare professionals, the majority of children and adolescents in the United States still report not regularly obtaining the recommended amount of sleep for their age group (Wheaton et al., 2018). Even children and adolescents who average one hour of sleep less than the recommended amount (average of 8 hours per night for children; average of 7 hours per night for adolescents) increase their risk for a number of negative physical, cognitive, and psychological health outcomes, such as obesity, injuries, diabetes, behavior difficulties, attention difficulties, and poor academic performance (Cook et al., 2021; Gillen O'Neel et al., 2013; Sadeh et al., 2003; Wheaton et al., 2018). When individuals without ADHD or any other neurodevelopmental disorder, also referred to as typically developing individuals, experience sleep problems that result with inadequate sleep, they may display behaviors that "mimic" symptoms of ADHD (Beebe, 2006; Gruber, 2009). In fact, previous research has found that typically developing individuals who are sleep deprived experience hypoactivation, or under activation, of the frontal lobe, which is something that is commonly seen in those with ADHD

(Kasparek et al., 2013). This could mean that individuals with ADHD who experience sleep problems, may experience further hypoactivation of their frontal lobe.

Biopsychosocial Model

The biopsychosocial model was first proposed by George Engel in 1977 as a rival to the long-standing biomedical model (Engel, 1977). Although the traditional biomedical model was a deficit model focusing only on disease, the biopsychosocial model provided a new way to view a patient by including psychosocial factors in addition to biological factors (Engel, 1977; Smith, 2002). The biopsychosocial model has since been taught and applied in several health care settings and has become a prominent model in the field of health psychology (Lehman et al., 2017).

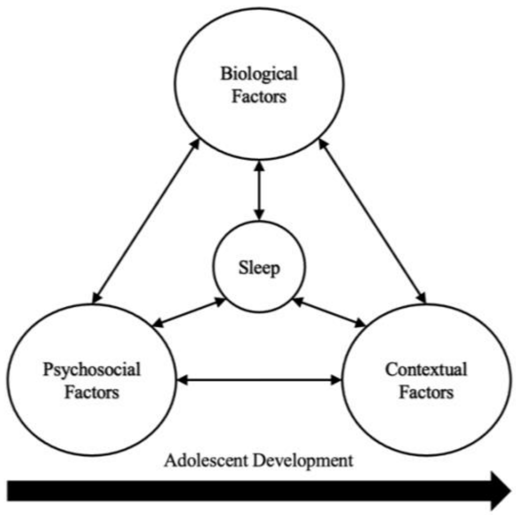
Biopsychosocial and Contextual Model of Sleep in Adolescence

As sleep plays such a vital role in healthy development, some researchers have expanded the biopsychosocial model to focus on sleep in the context of adolescent development. Becker et al. (2015) highlighted how biological, psychosocial, and contextual factors all play a role in sleep during the adolescent period of development (Becker et al., 2015). A depiction of Becker et al.'s (2015) conceptual model of sleep can be seen in Figure 1.

In this model, biological factors affecting sleep focus on the neurodevelopmental changes associated with the transition period from childhood to adolescence. Psychosocial factors affecting sleep focus on the complex and interconnected factors of family, academics, peers, and mental health. Contextual factors affecting sleep refer to things in the adolescent environment such as electronic media, homework, extracurricular activities, neighborhood factors, school start times, and cultural factors (Becker et al., 2015). Figure 1 references the biopsychosocial model as outlined by Becker et al. (2015).

Figure 1

Biopsychosocial Model of Adolescent Development



ADHD and Sleep

Although the increased risk of a myriad of negative health outcomes exists for children and adolescents in the general population, these risks are even more detrimental for children and adolescents with ADHD as they are already more likely than their typically developing peers to experience negative outcomes (Schoenfelder & Kollins, 2015). Adolescents with ADHD are also more likely to report sleep difficulties, which can make obtaining healthy sleep even more challenging (Lunsford-Avery et al., 2016).

Sleep problems are a common occurrence among children and adolescents with ADHD. It has been estimated that as many as 70% of children and adolescents with ADHD may also experience a comorbid sleep problem or difficulty, making sleep problems one of the most common comorbidities with ADHD (Cortese et al., 2013). Many studies have investigated the relationship between sleep and ADHD due to the high prevalence of sleep problems among those with ADHD. As previously defined by Cortese et al. (2013), sleep problems refer to any sleep-related difficulty (e.g., delayed sleep latency) or complaint due to an exacerbating condition like restless leg syndrome, night wakings, insomnia, circadian rhythm sleep disorder (Cortese et al., 2013).

Children and adolescents with ADHD already face daily impairments due to deficits in EF. When these already present impairments are combined with comorbid sleep problems, individuals with ADHD may experience exacerbated symptom expression, though the directionality of the relationship between sleep and symptom expression is unclear (Hvolby, 2015).

Sleep Consistency

Sleep consistency encompasses several aspects of the regularity of sleep duration and sleep timing. For instance, sleep consistency has been characterized by many metrics including intraindividual variability (IIV), the standard deviation of average sleep duration, the coefficient of variation, social jet lag, sleep debt, phase composite index, and sleep regularity index. Becker et al. (2017) conducted a systematic review that included 52 empirical studies examining the correlates of sleep IIV in children and adolescents. IIV refers to an individual's sleep and wake times and the extent to which they regularly vary from night to night. Results from this systematic review indicated that there is not currently a sufficient amount of evidence to support claims that lower levels of IIV in children and adolescents are associated with positive impacts on physical, psychosocial, cognitive, emotional, or behavioral factors, but the existing research does lay a promising foundation (Becker et al., 2017). In fact, this review suggests that greater levels of IIV in children and adolescents appear to be associated with neurodevelopmental conditions, body weight, aspects of cognitive functioning, poorer sleep habits, non-white race, and increased age, though the association is not directional (Becker et al., 2017; Buckhalt et al., 2007; Moore et al., 2011).

Buckhalt et al. (2007) found that children and adolescents with less variable sleep with few disruptions, had better cognitive performance. Additionally, when socioeconomic status (SES) was controlled for, Black children and adolescents had worse cognitive performance than their peers when faced with sleep disruptions (Buckhalt et al., 2007). These findings suggest that variable sleep schedules may directly impact cognitive functioning.

Circadian Rhythm

The suprachiasmatic nuclei (SCN) in the brain are responsible for regulating the circadian rhythm. Circadian rhythm is the body's internal, 24-hour, clock responsible for regulating a cycle of sleep and alertness by responding to cues in the environment such as light (Bijlenga et al., 2019). Although individuals with ADHD experience an array of sleep problems, a delayed sleep/wake cycle, or delayed circadian rhythm, is the most prevalent (Coogan & McGowan, 2017), affecting approximately 73-78% of children and adults with ADHD (Bijlenga et al., 2019). When children and adolescents experience chronic delayed circadian rhythms, they end up going to sleep late and waking up early due to school and other scheduled activities. This ongoing delayed cycle, results in chronic sleep insufficiency, which greatly impacts daily functioning and EF (Bijlenga et al., 2019).

Sleep Duration and Quality

Sleep duration is a term used to refer to the total amount of time a child or adolescent is asleep compared with the recommended hours of sleep for their specific developmental age group (Osamu et al., 2017). The American Academy of Sleep Medicine currently recommends TST of 9 to 12 hours per night for children ages 6 to 12 years, and 8 to 10 hours per night for adolescents ages 13 to 18 years (Paruthi et al., 2016). It is crucial for youth to obtain the recommended hours of sleep for their developmental period in order to promote healthy development. The majority of school-aged children in the US report inadequate sleep duration (Wheaton et al., 2018). Chronic sleep insufficiency is associated with negative cognitive, physical, and psychological effects (Hershner, 2020). When a child or adolescent with ADHD experiences sleep problems resulting in shorter sleep duration, it may further impair EF (Hvolby, 2015).

Sleep quality is a common outcome measure variable in sleep intervention research. It refers to how efficient an individual's sleep is and the self-reported feeling of an individual waking up feeling well rested or restored (Ohayon et al., 2017). This sleep parameter is most often ascertained via self-report. SE, however, can also be derived by dividing the TST by the TIB. The rationale is that spending time awake in bed rather than asleep is less efficient. Typically, individuals with ADHD self-report worse sleep quality than their healthy peers (Owens et al., 2009). Thoma et al. (2018) found that children and adolescents with ADHD reported more behaviors that promote delayed sleep than their peers, and that delayed circadian rhythm, media/screen time, and sleep deviation, were correlated with symptoms of ADHD. These findings suggest that increased screen time and sleep-wake behaviors that do not promote healthy sleep quality increase the risk of ADHD symptom presentation (Thoma et al., 2018).

Becker et al. (2020) investigated the relationship between sleep duration and affect disturbances in adolescents with ADHD through an at-home sleep modification protocol. Participants engaged in sleep restriction (6.5 hours in bed) and sleep extension (9.5 hours in bed) conditions for one week each. Results found that adolescents had more depressive symptoms, negative moods, and more emotional dysregulation during the sleep restriction phase (Becker et al., 2020), suggesting that sleep insufficiency contributes to behavioral and emotional functioning of adolescents with ADHD.

Behavioral Sleep Interventions

Behavioral interventions differ from traditional medical interventions in that they are designed to modify the actions and behaviors of an individual regarding health, as opposed to initially intervening with a drug, device, or surgery. That does not mean that they do not alter brain-behavior relationships, and may potentially even lead to changes in neural signals or activation (Dutcher & Creswell, 2018). However, these interventions are typically delivered by health service psychologists, such as clinical or school psychologists. Moreover, although some may require specialized training or expertise, many behaviorally based sleep interventions targeting sleep problems (as opposed to disorders) are able to be implemented by clinicians in general practice settings or schools (Chung et al., 2017; Gruber et al., 2016; Illingworth et al., 2020). As sleep problems are very common within the ADHD population, research has been conducted in order to find feasible and effective interventions targeting sleep (Malkani et al., 2022). Furthermore, there is limited research investigating the impact of behavioral sleep interventions on outcome measures such as EF within a population of children and adolescents with ADHD.

Feasibility and Acceptability of Behavioral Sleep Interventions

Research has suggested that behavioral sleep interventions are feasible and accepted amongst children and adolescents with ADHD and comorbid sleep problems. A small case series study by Mullane and Corkum (2006) evaluated a 5-week, manualized behavioral sleep intervention for three children between the ages of 6 and 10 years old. The intervention components of this study included researchers providing parents with one chapter of a manual each week, where they were asked to read information about sleep, complete an exercise related to the content, and then connect with the researcher on the phone to discuss the information.

Results from the study found a significant decrease in the children' s sleep problem, suggesting that a behavioral sleep intervention could be a feasible and effective treatment for sleep problems. Although the small sample size (*n* = 3) limits the generalizability of findings, this study provided preliminary evidence for future researchers to build upon. Additionally, this sample size was restricted to elementary school-age children, which highlights the need for further research in older children and adolescent populations.

Vetrayan et al. (2017) also conducted a small case series study with six children between the ages of 6 and 12 years old, who were diagnosed with ADHD and were undergoing stimulant medication treatment. This study used a sleep intervention focusing on implementing a Faded Bedtime with Response Cost (FBRC) and positive reinforcement (Vetrayan et al., 2017). FBRC is the practice of setting a child's bedtime and checking to see if they are asleep after a 15-minute period. If they are asleep within 15-minutes, the parent/caregiver starts the bedtime routine slightly earlier the following night, and if the child is still awake at the 15-minute mark, the parent/caregiver starts the bedtime routine slightly later the following night (Schreck, 2022). Severity of sleep problems, bedtime resistance, and average sleep onset latency were reduced for all participants after the 4-week sleep intervention, again suggesting that behavioral sleep interventions may be feasible and effective within this population. Again, the findings provide additional anecdotal evidence that sleep as a target of intervention can reduce sleep problems in pre-adolescent students.

Sciberras et al. (2011) also conducted a pilot randomized controlled trial (RCT) investigating the feasibility of a behavioral sleep program for a population of children (ages 5 - 14 years) with ADHD and a sleep problem as defined by the American Academy of Sleep Medicine Criteria. The study was a two-arm design, comparing brief (1 session) and extended (2

- 3 sessions) sleep programs that examined outcomes of helpfulness, use of interventions, child sleep, ADHD symptoms, daily functioning, quality of life, and caregiver mental health. All outcome variables were assessed using primary caregiver report and self-report measures completed by primary caregivers. Ninety-five percent of the families who participated in the study indicated that they would recommend the program to others and believed the strategies in the program to be helpful. Five months after the intervention, the majority of parents reported believing that their child's sleep problem(s) had resolved. The findings of this study indicate that it is feasible to implement a behavioral sleep program or intervention in a child ADHD population (Sciberras et al., 2011). Additionally, this study suggests that sleep interventions may produce improvements in outcomes that are related to behavioral functioning and mental health, and that the positive impacts of a sleep intervention may extend past the end of the intervention period.

The aforementioned studies were conducted with elementary to middle school. In one of the only studies that focused on adolescents (ages 13 – 17 years), Becker et al. (2021) conducted an open trial with 14 participants to investigate if the cognitive-behavioral intervention of Transdiagnostic Sleep and Circadian Intervention for Youth (TranS-C) would be a feasible, acceptable, and potentially effective behavioral sleep intervention for adolescents (ages 13 – 17 years) with ADHD and comorbid sleep problems. Trans-C is a manualized intervention based on the transdiagnostic approach, sleep, and circadian principles to promote behavior change (Dong et al., 2019). Data for this study were collected and evaluated using adolescent, teacher, and parent report measures, actigraphy, and sleep diaries. Data were collected pre- and post-intervention, and 3-months follow-up. Participants in this study experienced improvements in mental health, sleep, and EF from pre to post (Becker et al., 2021). Results demonstrated that the six-session TranS-C sleep intervention was acceptable, feasible, and laid the groundwork for the effectiveness within this population (Becker et al., 2021). Studies such as this suggest that behavioral sleep interventions may be an effective strategy for adolescents with ADHD, though further research is needed to confirm validity of interventions such as these. Although this study had a small sample size (*n* = 14), the findings are important in providing preliminary evidence to support the theory that sleep interventions may increase EF skills in youth with ADHD. Since there is limited research on sleep interventions increasing EF skills in adolescents with ADHD, more research is necessary.

Parent Training in Behavioral Sleep Interventions

Including parents in behavioral sleep interventions for youth with ADHD has been found to be an important component of treatment efficacy. Mehri et al. (2020) investigated the impact of Behavioral Parent Training (BPT) on sleep problems for a population of children (ages 6 -12 years) in Iran with ADHD who were receiving methylphenidate treatment. Research was conducted using a two-arm, randomized controlled trial with 28 participants in each arm. The intervention consisted of a five-week BPT curriculum, where parents received 2-hour BPT sessions in-person during the first, third, and fifth weeks. During the second and fourth weeks, follow-ups and education were conducted via telephone. The intervention sessions focused on education surrounding ADHD and sleep problems, sleep hygiene, control of environmental stimuli, and cognitive behavioral therapy (CBT) strategies. Data were collected through parent-completed forms including a demographic questionnaire and the CSHQ. The demographic questionnaires were administered at baseline, before beginning the intervention, and the CSHQ was administered at baseline, immediately following the intervention, and two months after the intervention. Results from the study indicated that BPT may be an effective intervention for sleep problems in children with ADHD which is simultaneously treated by methylphenidate, as total sleep scores improved and sleep problems decreased for children in the intervention group (Mehri et al., 2020).

Similar to Mehri et al. (2020), Shokravi et al. (2016) researched a sleep intervention involving parent training as a major component. Shokravi et al. (2016) investigated the impact of a sleep hygiene intervention on sleep habits in a population of children (ages 7 – 13 years) from Iran, with ADHD and comorbid sleep disorders. Research was conducted using a two-arm, RCT with 62 children as participants. Data were collected using the parent-report CSHQ at pre- and post-intervention time points, and a parent-completed demographic checklist completed at baseline. Mothers of participants in the intervention group were required to attend a 135-minute training session about sleep hygiene and were given an educational package containing more information about sleep hygiene. The mothers were followed up via telephone during the third and fifth weeks to reinforce the suggested intervention techniques. Results from the study indicated that children in the intervention group had significant reductions in bedtime resistance, sleep onset delay, sleep duration, sleep anxiety, and daytime sleepiness, suggesting that a sleep hygiene intervention may improve sleep problems for children with ADHD (Shokravi et al., 2016), and further supporting the idea that including a primary caregiver in a sleep intervention can be effective in promoting positive outcomes in youth with ADHD.

Similar to Mehri et al. (2020) and Shokravi et al. (2016), Corkum et al. (2016) investigated a sleep intervention that heavily involved a primary caregiver. However, Corkum et al. (2016) attempted an intervention that was not delivered through an in-person modality. Corkum et al. (2016) investigated a distance intervention targeting insomnia in school-age children (ages 5 – 12 years) with and without diagnoses of ADHD. Research was conducted using a single center, parallel group, randomized controlled trial design, and stratified by diagnosis. Parents of participants in the intervention group received a five-session behavioral sleep intervention modified from the Mullane and Corkum (2006) study and delivered via telephone. Data from parent-report measures were collected at baseline, 2-months post intervention, and 6-months post intervention. Measures included a demographic questionnaire, Kiddie-SADS-Present and Lifetime Version, Sleep Evaluation Questionnaire, CSHQ, and the Child Behavior Checklist (CBCL). Actigraph data were also collected, as each child wore an actigraphy watch for 1-week at each time point. Results from the study found that children with and without ADHD who were in the intervention group, showed significant reductions in sleep problems, improved psychosocial functioning, and improved sleep onset but not duration, suggesting that a distanced sleep intervention may be an effective way to address insomnia in children with and without ADHD (Corkum et al., 2016). Findings from this study further support the importance of involving parents in a sleep intervention and provide evidence that a behavioral sleep intervention can be delivered virtually and still have a positive impact on psychosocial functioning.

Behavioral Sleep Interventions and EF

Hiscock et al. (2015) conducted research investigating the impact of a behavioral sleep intervention on sleep, ADHD symptoms, working memory, and parent mental health in a population of Australian children (ages 5 -12 years) with ADHD. Research was conducted using a two-arm randomized controlled trial comparing a behavioral sleep intervention with a control of usual clinical care. The behavioral sleep intervention consisted of two in-person consultations two weeks apart, as well as one follow-up phone call (Sciberras et al., 2010). Data were collected at baseline, three months, and six-months. Seventy-nine intervention and 85 control families provided complete data at the three-month follow-up, and 99 intervention and 97 control families provided complete data at the six-month follow-up. ADHD symptoms were measured using parent- and teacher-report versions of the ADHD Rating Scale IV at baseline, three months, and six months. Sleep was measured through primary caregiver reports of their child's sleep, including a sleep log and the CSHQ. All parent-report measures were administered at baseline, three months, and six months. A subset of children wore actigraphy watches for periods of one week, which were used to collect objective sleep data at baseline and follow-up. Working memory was assessed at six months only and was measured using three subtests (backwards digit recall, counting recall, listening recall) from the Working Memory Test Battery for Children. Results from the study indicated that a brief behavioral sleep intervention for children with ADHD and comorbid sleep problems improved sleep, reduced severity of ADHD symptoms, and enhanced working memory up to six months after intervention (Hiscock et al., 2015).

Sleep Extension

A study further investigating psychosocial outcomes of an intervention involving parents, while also including sleep extension, was completed by Keshavarzi et al. (2014). Keshavarzi et al. (2014) conducted a randomized case-control trial with children (ages 8 – 13 years) in Iran with diagnoses of ADHD to investigate the impact of a 12-week sleep-training program. Forty children with ADHD took part in the study, with half assigned to the intervention group and half assigned to the control group. Twenty age-matched children without ADHD were also included in the control group. The intervention included parents recording their child's sleep behaviors and then gradually extending sleep as well as aspects of sleep hygiene, a token system, and parent feedback. Parent-report CSHQ and KID-SCREEN and self-reported KID-SCREEN 52 were collected at baseline and a 12-week follow-up. Results indicated that children and parents in the intervention group reported improved moods, emotions, and relationships with the children. Parents of children in the intervention group also reported improved physical and psychological wellbeing and social acceptance of their child. These findings suggest that training and monitoring parents of children with ADHD regarding sleep schedules, combined with sleep extension, lead to positive outcomes related to emotions, behaviors, and social lives of children with ADHD (Keshavarzi et al., 2014).

A pilot study conducted by Cremone-Caira et al. (2019) also utilized sleep extension as the primary intervention in a population of children (ages 6 – 9 years) with and without ADHD. Cremone-Caira et al. (2019) specifically investigated the effect of sleep extension on inhibitory control, which is a main domain in EF. Results from the study found that the children with ADHD had statistically significant improvements in inhibitory control during the sleep extension intervention compared to the baseline period (Cremone-Caira et al., 2019). This study provides preliminary evidence that sleep extension is an effective way to improve components of EF in children with ADHD. Further research is needed to investigate these effects on older children and adolescents with ADHD.

Moderators of Behavioral Sleep Interventions

In 2019, Sciberras et al. used the same behavioral sleep intervention protocol (Sciberras et al., 2010) used in the study by Hiscock et al. (2015) to investigate the sustained impact and potential moderators of treatment outcome for the intervention with a population of children (ages 5 -13 years) with ADHD in Australia. The randomized controlled trial included 244 children, and data were collected at baseline and follow-up at twelve months post-randomization. All data were collected via parent and teacher report measures such as the CSHQ, PedsQL, Strengths and Difficulties Questionnaire (SDQ), DPREMB, DASS, and the Anxiety Disorders

Interview Schedule for Children/Parent Version-IV (ADIS-C). Results from the study indicated that children who received the brief behavioral sleep intervention were less likely to report sleep problems (by parent report) at 12-months compared to children who received typical clinical care. Moderating factors of medication and parent depression were also identified, as children who did not take ADHD medication or children who had parents experiencing depression reported less benefits from the intervention (Sciberras et al., 2019).

Behavioral Sleep Intervention with Melatonin

Weiss et al. (2006) evaluated the efficacy of sleep hygiene and melatonin as treatment for insomnia in children (ages 6 – 14 years) with ADHD being treated by stimulant medication. Baseline sleep data were collected on all participants via parent report and actigraphy watches for a period of 10 days. Parents were then instructed to enforce sleep hygiene practices, such as consistent sleep and wake times, avoiding caffeine, and reducing stimulus in the sleeping environment and data were collected for ten days. Children whose sleep latency did not decrease significantly with the sleep hygiene intervention, were then randomized for a melatonin intervention. Out of the 28 participants, only 5 responded to the sleep hygiene intervention, while the remaining participants continued to the medication randomization portion of the study. Results from this study show that sleep hygiene did significantly reduce the nightly variability of sleep onset latency, indicating that behavioral sleep interventions may be effective for children with ADHD (Weiss et al., 2016).

Brief Interventions

Peppers et al. (2016) tested a sleep hygiene education intervention aimed at promoting sleep and reducing symptoms of ADHD in a population of children (ages 5 – 11 years) with ADHD. The CHSQ and Vanderbilt were used to measure sleep quality and ADHD symptoms respectively. The sleep hygiene intervention took place in one office visit in a clinical setting. Data were collected at baseline and 6 weeks post intervention. Results indicated that behavioral modification interventions for sleep are effective for a population of children with ADHD (Peppers et al., 2016).

Summary

In summary, investigating a behavioral sleep intervention for children and adolescents ages 11 to 17 years old with ADHD and comorbid sleep problems is important, as it may provide a potentially effective way to improve sleep and EF across settings, including school. Behavioral sleep interventions are a non-invasive and non-pharmacological intervention, which ultimately be implemented in various contexts, making them more accessible than medication-based approaches and more appropriate for school-based services.

Previous research has demonstrated that behavioral sleep interventions are feasible and acceptable among youth with ADHD and their caregivers who play a critical role in successful implementation—including the proposed study. Evidence has suggested that increasing average nightly TST and regularizing timing without sacrificing quality can have lasting impacts on multiple areas of functioning. However, there is limited research on the impact of sleep extension interventions on EF in adolescent populations with ADHD, highlighting a key area for further investigation

Chapter 3: Methods

Participants

Eligibility criteria for this study included being between the ages of 11- and 17-years old, meeting DSM-V-TR criteria for ADHD (any presentation), having an IQ greater than 80, and meeting criteria for a sleep problem. As in previous research investigating behavioral sleep interventions with children and adolescents (Blake et al., 2016, 2018; Harvey et al., 2018; Becker et al., 2022), participants met criteria for a sleep problem if they a) slept less than the American Academy of Sleep Medicine recommendation of 8 hours for participants ages 13 – 17 years, or less than 9 hours for participants ages 11 - 12 years (based on actigraphy data prior to beginning intervention); b) had poor overall sleep quality on the Children's Report of Sleep Patterns (CRSP); c) had poor sleep efficiency (at or below 85%) based on baseline actigraphy data; d) or showed variability in sleep by having a TIB or TST standard deviation of greater than 60 minutes. Based on these criteria, participants were not required to have a pre-existing diagnosis of a sleep disorder. Participants were recruited through licensed psychologists in a southwestern state, and through social media advertisements. Each participant was required to be accompanied by a parent throughout the study. Parents were asked to complete parent-report measures regarding their child's EF and sleep.

Exclusionary criteria for this study included pre-existing diagnoses of any of the following: autism spectrum disorder (ASD), psychosis, bipolar disorders, intellectual developmental disorder (IDD), or an IQ below 80. Psychosis and bipolar disorders were excluded due to unique sleep patterns and circadian rhythm difficulties that often accompany those diagnoses (Davies et al., 2017; Gold & Sylvia, 2016). ASD was excluded because much of the ADHD sleep literature has samples combined with ADHD and ASD, and the focus of this sample was ADHD only. IDD, or an IQ below 80 was excluded due to the level of comprehension needed to fully understand intervention instructions. Other pre-existing mental health diagnoses such as depression and anxiety were not excluded, so as to not further limit the sample. Anxiety and depressive disorders frequently co-occur with ADHD (Meinzer & Chronis-Tuscano, 2017; Mohammadi et al., 2019), and while anxiety and depression can disrupt sleep through rumination, hypersomnia, or insomnia, their effects differ from the more extreme sleep disturbances often seen in bipolar disorder (e.g., decreased need for sleep during mania) or psychosis (e.g., sleep disruption due to delusions or paranoia). Additionally, participants who were undergoing stimulant medication treatment for ADHD were eligible for the study if they did not have a medication change (change of stimulant medication or change of dosage) within one month of beginning participation in the study. Participants were also not expected to have any planned medication changes during the study. All standardized assessment measures used in the present study were normed in English and the primary investigator was only fluent in English. Therefore, all participants and their primary caregivers had to be able to read, understand, and speak in English. Using G*Power software, power analysis was conducted using repeated measures ANOVA with 2 measurements, a power of 0.80, an alpha level of 0.05, and a large effect size ($f = .5$). Results of the power analysis determined that a sample size of 22 participants would be sufficient to detect a statistically significant effect under these parameters, which aligns with best practices in quantitative research for ensuring adequate statistical power and minimizing both Type I and Type II errors. Given the pilot nature of this project, achieving the full calculated sample size may not be feasible. In pilot studies, it is common and acceptable to work with smaller sample sizes, as the primary aim is often to estimate parameters (such as standard deviation) for future, larger-scale studies, rather than to definitively test hypotheses (Leon et al., 2011). Thus, it was determined that if recruitment fell short of the ideal sample size, the study would still provide valuable preliminary insights, especially for the first research question on acceptability as well as when interpreted with caution with emphasis placed on the magnitude and direction of observed effects (effect sizes) and precision of these estimates (confidence intervals)rather than solely on statistical significance (p-values). This approach aligns with current recommendations for reporting and interpreting results from underpowered or pilot studies, ensuring that the findings still contribute constructively to the scientific literature and can inform future, larger-scale research (Albers & Lakens, 2018).

Participant Characteristics

Thirteen adolescents, 11- to 17-years of age, (mean age = 13.62 years; *SD* = 1.80) who met the DSM-V criteria for ADHD participated in this study. Six of the participants were biological males (46.2%) and seven were biological females (53.8%). Two participants in this study identified as Hispanic or Latinx (15.4%). This sample reported the following racial demographics: 84.6% White, and 15.4% reported two or more races. Four participants identified their gender as female (30.8%), eight identified their gender as male (61.5%), and one identified their gender as non-binary (7.7%).

Five participants met diagnostic criteria for ADHD, predominantly inattentive presentation (38.5%), one met diagnostic criteria for ADHD, predominantly hyperactive/impulsive presentation (7.7%), and seven met diagnostic criteria for ADHD, combined presentation (53.8%). Ten of the participants (76.9%) reported taking prescribed stimulant medications for ADHD. Participants who were taking stimulant medication at the time of enrollment were scheduled to start at least one month after their most recent medication change.

All participants in the study attended in-person school, with nine attending public school (69.2%), two attending private school (15.4%), and two attending a charter school (15.4%). Of the 13 participants, nine reported receiving additional services through school due to being a student who met the criteria for having a disability. Six reported having a 504-Plan, two reported having an IEP, and one reported being enrolled in gifted programming.

Thirteen parents participated in this study. Nine (69.2%) parent participants were biological mothers, and four (30.8%) were biological fathers. Each adolescent and parent participant were asked about their family mental health history, including histories of biological parents, grandparents, aunts, uncles, and siblings. Ten out of 13 participants reported family histories of ADHD (76.9%). Of those 10 participants, seven reported that their parent(s) had ADHD, five reported that their sibling(s) had ADHD, and four reported that their first aunt, uncle, or cousin had ADHD. Participant demographic and background characteristics are depicted in Table 1.

Measures

Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-COMP)

The K-SADS is currently one of the most commonly used measures in child and adolescent psychiatry. It is a clinician-administered, semi-structured diagnostic interview, designed to obtain information from both the child or adolescent and their parent or other adult informant. It was originally created by Puig-Antich and Chambers in 1978 and has been routinely updated to stay current with changing diagnostic criteria. In 2013, the American Psychiatric Association released the fifth edition of the DSM and the K-SADS Present and Lifetime Version was updated to reflect new diagnostic criteria in the DSM-V (K-SADS-PL-DSM-5). Additionally, the K-SADS was updated to a computer-based version, the KSADS-COMP, which also reflects the diagnostic criteria of the DSM-V. The KSADS-COMP includes a combined youth and parent clinician-administered version, a self-administered youth version, and a self-administered parent-version. Although the DSM-V was revised in 2022 (DSM-V-TR), the KSADS-COMP has not yet been updated to reflect the most recent version due to the recency of the DSM-V-TR's release (Townsend et al., 2020).

Table 1

Participant Demographics and Background Characteristics

Characteristic	Whole Sample n (%)	Control (n)	Intervention (n)
Age (years)			
Mean	13.62	13.00 (4)	13.89 (9)
Sex			
Male	6 (46.2%)	2	4
Female	7 (53.8%)	2	5
Gender			
Male	8 (46.2%)	3	5
Female	4 (30.8%)	1	3
Non-Binary	1 (7.7%)	0	1
Hispanic/Latinx Ethnicity			
Yes	2 (15.4%)	0	2
No	11 (84.6%)	4	7
Race			
White	11 (84.6%)	4	7
Two or More Races	2 (15.4%)	0	2
ADHD Presentation			
Predominantly Inattentive	5 (38.5%)	0	5
Predominantly Hyperactive/Impulsive	1 (7.7%)	0	1
Combined	7 (53.8%)	4	3
School Type			
Public	9 (69.2%)	4	5
Private	2 (15.4%)	0	2
Charter	2 (15.4%)	0	2
School Services			
504-Plan	6 (46.2%)	1	5
IEP	2 (15.4%)	1	1
Gifted	1 (7.7%)	1	0
Currently Taking Stimulant Medication			
Yes	10 (76.9%)	3	7
No	3 (23.1%)	1	2
Parent Participant			
Biological Mother	9 (69.2%)	1	8
Biological Father	4 (30.8%)	3	1

It is important to note that the DSM diagnostic criteria for ADHD did not change from the DSM-V to the DSM-V-TR, so the KSADS-COMP remains a relevant measure for assessing ADHD in the proposed study.

The KSADS-COMP consists of three core components: 1) unstructured introductory interview, 2) diagnostic screening interview, and 3) supplements that finalize criteria required for specific diagnoses. The introductory interview is unstructured and aims to gather demographic information, family mental health history, presenting problems, previous mental health treatment, information about the child's adaptive functioning and interests, bullying, gender identification, and sexual orientation. The diagnostic screening interview covers 2 to 4 symptoms of each disorder (mood, psychotic, anxiety, and neurodevelopmental disorders) the KSADS assesses to determine which disorder specific supplements should be administered (Townsend et al., 2020).

The clinician-administered version of the KSADS-COMPS was utilized as research has shown that it has a lower average administration time than paper-and-pencil versions of the K-SADS with only one informant (Townsend et al., 2020). Additionally, the KSADS-COMP includes automated scoring and data capture, which increases efficiency. The KSADS-COMP was administered during the consent and initial data collection meeting with the participant and their legal guardian and was used to confirm each participant's pre-existing diagnosis of ADHD and to screen for exclusion criteria: ASD, bipolar disorders, and psychosis. The KSADS-COMP clinician-administered version contains a 4-item consensus ADHD scale that was found to be significantly correlated with the Child Behavior Checklist (CBCL) Attention Problems subscale ($r = .59$, $p < .001$; Townsend et al., 2020).

Children's Report of Sleep Patterns (CRSP)

The CRSP is a self-report questionnaire designed to measure sleep patterns, sleep hygiene, and sleep disturbances for school-aged children. The CRSP contains 60 items with 3 modules: Sleep Patterns, Sleep Hygiene Index, and the Sleep Disturbances Scale. Most items on the CRSP use a Likert-scale, where participants are asked to rate items using the choices: "*Never*" (never happens), "*Not Very Often*" (less than 1 time per week), "Sometimes" (1 or 2 times per week), "*Usually*" (3-5 times per week), or "*Always*" (every day). There are additional items that include indicators for snoring, nightmares, and enuresis.

The CRSP has been found to be a valid and reliable measure for school-age children, ages 8 to 18 years (Meltzer et al., 2013; Meltzer et al., 2014). The CRSP has demonstrated sufficient internal consistency (Cronbach's alpha = 0.77), test-retest reliability (0.82), and has shown construct and convergent validity with actigraphy, sleep hygiene, sleep disturbances, and circadian preference (Meltzer et al., 2012). More specifically, the CRSP sleep hygiene and sleep disturbances scales have been found to be reliable and valid measures within adolescents ages 8 to 18 (Meltzer et al., 2014).

Sleep Patterns. The Sleep Patterns module gathers information on bed and wake times, sleep schedule variability, sleep onset latency, night waking frequency and duration, naps, and subjective sleep quality. The Sleep Patterns module also gathers information about sleep patterns during school days, typical weekends, and when there is no school.

Sleep Hygiene Index. The Sleep Hygiene Index gathers information about activities before bed, sleep location, caffeine use, and electronics used in the hour prior to bed.

Sleep Disturbance Scale. The Sleep Disturbance Scale gathers information about insomnia, parasomnias, bedtime worries, and symptoms of restless leg syndrome.

Participants completed the CRSP at the initial meeting and at the post-intervention meeting as a subjective measure of sleep. This measure was administered to all participants at baseline in order to determine the presence of a sleep disturbance and eligibility for the study, as indicated by elevated scores. Change in sleepiness, sleep habits, and overall sleep disturbance were assessed to aid in determining the impact of the behavioral sleep intervention. Additionally, the CRSP was used as a secondary measure of sleep hygiene habits.

Children's Sleep Habits Questionnaire (CSHQ)

Parents completed the CSHQ at the initial meeting and at the post-intervention meeting as a subjective measure of their child's sleep. This measure was administered to all parents at baseline in order to determine presence of a sleep disturbance and eligibility for the study, as indicated by elevated scores. The CSHQ is a retrospective parent-report measure containing 45 items related to the child's sleep behaviors. Items ask parents to rate the frequency of various sleep behaviors using a 3-point Likert scale with the following options: "Rarely" (0-1 times per week) = 3 points, "Sometimes" (2-4 times per week) = 2 points, or "Usually" (5-7 times per week) = 1 point. Higher scores indicate more disturbed sleep. The CSHQ produces a total sleep disturbance score as well as eight additional subscales: Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Wakings, Parasomnias, Sleep-Disordered Breathing, and Daytime Sleepiness.

Total Sleep Disturbance Score. The Total Sleep Disturbance Score is calculated by summing responses, with higher scores indicating more disturbed sleep. This score can range from 33 to 99, with scores over 41 indicating a sleep disorder (Markovich et al., 2015).

Daytime Sleepiness. The Daytime Sleepiness subscale specifically assesses daytime sleepiness with items about the frequency with which the child falls asleep, presents as tired during the day, and how difficult they are to wake in the morning. This subscale contains eight items and has a possible score range from 8 to 24, with higher scores indicating higher levels of daytime sleepiness.

Bedtime Resistance. The Bedtime Resistance subscale contains six items addressing ways a child may be resistant to bedtime such as difficulty falling asleep alone, fear of sleeping alone, or refusing to go to or get into bed. Scores for this subscale can range from 6 to 18 with higher scores indicating higher levels of bedtime resistance.

Woodcock Johnson Test of Cognitive Abilities, Fourth Edition (WJ-IV)

The WJ-IV is an individually administered measure of intellectual abilities based on the Cattell-Horn-Carrol theory of intelligence and is designed for those ages 2 to 90+. It consists of 18 subtests in total. Three of the 18 subtests, Oral Vocabulary, Number Series, and Verbal Attention, can be used to compute a measure of cognitive abilities or IQ score, known as the Brief Intellectual Abilities (BIA). The BIA was used to obtain a measure of IQ for participants to ensure that all participants met eligibility criteria of an IQ above 80. IQ scores and subtests scores are computed as standard scores with a mean score of 100 and a standard deviation of 15.

In addition to assessing for the cognitive inclusion criteria, subtests from the WJ-IV were used to further assess working memory, inhibition, and cognitive flexibility (Decker et al., 2018).

Oral Vocabulary. The Oral Vocabulary subtest contains two parts: synonyms and antonyms. The synonym section requires the individual to listen to a word and provide a different word with a similar meaning. The antonym section requires the individual to listen to a word and provide a word with the opposite meaning.

Number Series. The Number Series subtest presents the individual with a series of numbers with one missing number in each series. The individual is then expected to determine the missing number. This subtest requires working memory by having individuals hold on to information regarding each series to figure out the missing number(s).

Verbal Attention. The Verbal Attention subtest is a measure of short-term working memory used to assess attention and verbal components of working memory. The subtest measures an individual's ability to use orally presented information and then direct attention to a task requiring the individual to use the information to provide a response.

Concept Formation. The Concept Formation subtest is a measure of fluid reasoning that requires the individual to identify, categorize, and determine rules for a given stimulus set. This subtest requires individuals to use cognitive flexibility to determine changing rules across administered items.

Numbers Reversed. The Numbers Reversed subtest is a measure of short-term working memory, in which individuals are asked to listen to digits presented auditorily and recite them in reverse order.

Millisecond Inquisit

Millisecond Inquisit is a software platform containing various computerized psychological tests. For the purposes of this study, Digit Span Backward (Auditory) was used as a measure of working memory, the Stop Signal Task was used as a measure of inhibitory control, and the Trail-Making Test was used as a measure of cognitive flexibility, also known as set-shifting.

Digit Span Backward (Auditory). The Digit Span Backward (auditory) task is a measure of working memory in which participants hear a sequence of digits and are asked to recall them in reverse order by selecting digits on a screen with the mouse. To assess performance, the backward Two-Error Maximum Length (bTEML) was used. The bTEML is the longest string of digits correctly recalled before two consecutive errors. This scoring approach is modeled after the traditional Wechsler method and provides an estimate of working memory.

The Digit Span Backward task has been found to have high reliability, with an average reliability coefficient of .70 across studies (Schroeder et al., 2012).

Stop Signal Task. The Stop Signal Task is a measure of inhibitory control (Verbruggen et al., 2019) in which individuals are presented with an arrow inside of a circle that points to the right or the left. Individuals are then asked to press the left response key if the arrow points left, and the right response key if the arrow points right, unless a signal beep is played after the arrow is presented. On some trials a stop signal was presented after a short delay (stop-signal delay, or SSD), indicating that participants should not press a key. The primary outcome of the Stop Signal Task is frequently the Stop-Signal Reaction Time (SSRT), which estimates how quickly a person can stop after a signal is presented. However, SSRT could not be validly interpreted in this study as a result of multiple participants having negative SSRT values. Negative SSRT values indicate that core assumptions were violated (e.g., response times on failed stop trials were longer than on go trials). According to Verbruggen et al. (2019), SSRT's should not be calculated if this occurs. As a result, the probability of responding on stop trials (pRs) and average SSD were calculated as alternative measures of stop performance. The pRs reflects how often participants failed to stop when presented with a stop signal, with lower values indicating better inhibitory control. The SSD reflects how long after the go signal the stop signal was presented. Greater SSD values indicate that the participant was able to successfully stop even with more time to process the go response. Greater SSD values are suggestive of better inhibitory control.

Trail-Making Test. The Trail Making Test is a computerized measure of cognitive flexibility and overall EF. In this test, participants are instructed to move their mouse in a specific, predetermined sequence from node to node. This computerized version included two sample trails and two scored trails (Trail-A and Trail-B). Trail A instructs the participant to connect numbers in order from smallest to largest. Trail B instructs participants to switch back and forth between numbers and letters (e.g., 1 to A to 2 to B). To measure cognitive flexibility, or set-shifting, the completion time of Trail A is subtracted from Trail B to get the Trail-Making Test Shift Score (TMT Shift). Since Trail B requires switching between information it taps into the ability to shift attention. Trail B measures speed and visual scanning abilities. Therefore, the TMT Shift score is the extra mental effort it takes to switch between tasks and is considered a valid measure of cognitive flexibility. Based on findings from Sanchez-Cubillo et al. (2009), the TMT Shift score shows strong construct validity for measuring cognitive flexibility, as it has a high correlation with other set-shifting measures ($r = .45$, $p < .001$).

Behavior Rating Inventory of Executive Function (BRIEF)

The BRIEF is questionnaire style measure, designed to assess EF in home and school environments for children and adolescents ages 5 to 18 years. The BRIEF includes self-report for adolescents ages 11 to 18 containing 55 items, and parent-report, and teacher-report forms containing 86 items measuring different aspects of EF, which take approximately 5 to 10 minutes to complete. Each item is rated on a 3-point Likert scale ranging from *1 = never a problem* to *3 = often a problem*, in which higher scores signify poorer EF. T-scores based on age and sex are used to compare an individuals' EF to the normative data, with a mean of 50 and standard deviation of 10. T-scores of 65 or greater indicate impaired EF.

The BRIEF includes eight clinical scales: Working Memory, Inhibit, Shift, Initiate, Emotional Control, Organization of Materials, Plan/Organize, and Monitor. Inconsistency and Negativity scales are also included as measures of validity. The eight scales can be combined to create the Behavior Regulation, Metacognition, and overall Global Executive Composite indexes. The BRIEF has a high internal consistency of .80-.98 and high test-retest reliability for both parents and teachers (.82 for parents, .88 for teachers). Participants and their parents completed self-report and parent-report forms at the pre- and post-intervention time points as a measure of overall EF, with specific attention to the clinical scales of working memory, inhibitory control, and shift, as these are the scales included in most models of EF.

Actigraphy

Actiwatch Spectrum (Philips Respironics) watches were used as an objective measure of participants' sleep duration and quality. Actiwatches are similar in size and shape to a typical wristwatch and are typically worn on the non-dominant wrist. Actiwatches contain accelerometers that are used to estimate sleep-wake patterns of individuals by recording the frequency of movement and light in 30-second intervals. Specifically, actigraph watches provide information about when an individual falls asleep, when they wake up, how long it takes to fall asleep, night wakings, and total time asleep. Specific parameters computed from actigraphy are detailed in Table 2. Each participant was given an actigraph during their initial meeting. Participants were instructed to wear actiwatches continuously for the duration of the naturalistic and intervention sleep periods. Actigraphy data collected during the first two weeks were used to establish baseline sleep-wake patterns for each participant. Participants in the intervention condition were able to view and discuss their own actigraphy data with their parent and the interventionist as part of the behavioral sleep intervention.

Manual Scoring Adjustments. The default Respironics Actiware scoring algorithm, set at a medium threshold, was used to automatically identify nighttime rest intervals from each participant's actigraphy data. Actigraphy data were then manually scored using procedures adapted from prior adolescent sleep research to refine these intervals (Ancoli-Israel et al., 2015;

Perfect et al., 2016). Sleep periods were defined by identifying five consecutive minutes of inactivity (activity count = 0) to mark both the onset and offset of the sleep interval. If a period of inactivity that initially met the criteria for sleep onset early in the night was subsequently followed (i.e., occurring afterward, regardless of immediacy) by more than an hour of wakefulness—evidenced by activity and light exposure—the official start of the sleep period was adjusted to begin after this prolonged wakeful episode. Once the start of the sleep period was established, all subsequent time until the final awakening was considered part of a single sleep interval. For instances in which the actigraph was removed for any duration during the beginning or end of the nighttime period, that interval was excluded from analysis due to the fact that true sleep onset or offset was not possible and the sleep period may have been shorter than actual. Sleep diaries were reviewed to support the identification and confirmation of sleep intervals and to resolve any ambiguities in the actigraphy data. In accordance with prior studies, daytime naps were not included in sleep period scoring (Breneman et al., 2024; Chow et al., 2016).

Acceptability Exit Survey

The exit survey administered to participants and their caregivers after the completion of the study was designed to gather comprehensive feedback about their experience in the study, particularly focusing on the process and outcomes of modifying sleep behaviors. The survey included twelve multiple-choice and six open-ended questions. Participants were first asked whether they were instructed to change their sleep schedule, establishing the relevance of subsequent questions. The survey further inquired about the perceived helpfulness of the research team in supporting sleep schedule changes, using a graded scale from "very helpful" to "not helpful."

Table 2

Sleep Parameters Computed from Actigraphy

Parameter	Description
TIB *	The time that an individual is in bed providing the opportunity to sleep
TST*	TST calculated based on movement counts during rest interval
Sleep Efficiency	TST / TIB
Coefficient of Variation	Standard deviation of TST / mean of TST
Percent Awake	% of minutes awake / TIB
Awakenings (Wake Bouts)	The number of epochs that are scored awake between the sleep onset and sleep offset period
Sleep Onset Latency	Time it takes to fall asleep after turning out the lights/trying to sleep
Average Start Time	Beginning of rest interval
Average End Time	End of rest interval

Note. TIB = Time in Bed; TST = Total Sleep Time
**Denotes a primary outcome variable*

To better understand the perceived intervention's impact, questions probed the ease or difficulty that participants had with extending their sleep, and how successful they felt they were in improving their sleep. The survey also examined the role of parental or guardian involvement, asking whether their participation in the child's sleep routine increased, decreased, or remained the same during the study. Quantitative responses were collected regarding the amount of time participants increased both their TIB and their TST. Open-ended questions allowed participants to elaborate on barriers and facilitators to achieving more sleep, the specific ways their parents or guardians supported them, and to provide suggestions for improving the study. The survey further assessed the likelihood that participants would continue following the assigned sleep schedule after the study concluded. Finally, participants were asked to identify which strategies introduced during the study—such as establishing a nightly routine, adjusting activity schedules, changing the sleep environment, lifestyle modifications, reducing technology use, or increasing parental involvement—were most helpful in supporting their efforts to get more sleep.

Digital Diaries

In order to supplement objective sleep data obtained through actigraphy, participants were instructed to keep narrative records of their sleep experiences in digital diaries. Participants received an email each morning of the study, between 6:00 and 7:00 am, with a link to complete their sleep diary via REDCap. Digital diaries were not used as a measure of sleep on their own, but were used as a way to better understand actigraphy data, and to have some record of sleep experience if an actigraphy watch were to fail to record sleep data for a period of time.

Digital sleep diaries were prospective measures, capturing daily information about sleep. The sleep diaries used in this study contained 12 items asking about the previous night of sleep. Participants were asked to indicate what activities they engaged in the hour before going to bed, what time they fell asleep at, how long it took them to fall asleep, how many times they woke during the night, how long they were awake during the night (WASO), what factors interrupted their sleep, how dark their room was, how quiet their room was, how comfortable the temperature was, what time the woke up at, and how they perceived their overall sleep quality.

Procedures

All procedures of this study were approved by the University of Arizona's Institutional Review Board (IRB) prior to beginning recruitment or data collection. The behavioral sleep intervention was similar to a sleep prescription which included a fixed bedtime and wake time based on the participant's school start time. Participants each had one primary caregiver involved in order to provide intervention reinforcement.

Recruitment

Three streams of recruitment were utilized to find participants. The first method of recruitment was through study recruitment flyers placed in the offices of licensed psychologists in Tucson, Arizona who primarily see children and adolescents. The second method of recruitment was through a local school district. The study recruitment flyer was shared with the district level 504-coordinator, who then dispersed the flyer to the middle and high school level 504-coordinators. 504-coordinators at the school level were instructed to disperse flyers to students with 504 plans. The third method of recruitment was through social media. A digital version of the recruitment flyer was dispersed via Instagram and Facebook through local ads and in local public groups that allowed advertisements. The recruitment flyer for each method of recruitment was the same and contained a QR code for families to use to provide their contact information. Once a family provided their contact information, the researcher called the family to discuss an overview of the study and eligibility criteria. If there was no answer, the researcher left a voicemail and would call an additional two times to leave voicemails at later dates. If the family had not been contacted after three attempts, the researcher would follow up with an email. If a family was contacted and they appeared eligible and interested, the researcher scheduled the three in-person appointments and followed up with a confirmation email including the dates, times, and locations of upcoming meetings.

Forty-three families provided their information to be contacted. Six out of the 43 families contacted were determined to be ineligible for the study after reviewing exclusionary criteria during the initial phone contact. Four of those families reported that the adolescent had a diagnosis of ASD, one reported a diagnosis of an intellectual disability, and one parent was a monolingual Spanish speaker. Three families were eligible during the initial phone screening and scheduled initial meetings but, two cancelled before the initial consent meeting and one no showed. Eleven families were contacted and eligible for participation but did not schedule initial consent meetings. Eleven families were called three times and emailed once but were unable to be contacted. The remaining twelve families were contacted and found to be eligible during the initial phone screening. Eleven of the families scheduled appointments for one of their children, and one family scheduled appointments for two of their children. All 13 adolescents were found to meet eligibility criteria during the initial consent meeting and were enrolled in the study. All 13 participants were randomized and all completed the study. Recruitment and enrollment efforts are summarized in Table 3.

Table 3

Recruitment and Enrollment Flow

Stage	*n*	% of Initial Contacts
Provided contact information	43	100.00
Unable to reach / no response	11	25.6
Completed phone screening	32	74.4
Declined participation after screening	11	25.6
Found ineligible at phone screening	6	14.0
Autism spectrum disorder	4	9.3
Intellectual disability	1	2.3
Spanish monolingual parent	1	2.3
Scheduled for initial meeting	15	34.9
Cancelled/no-showed before initial meeting	3	7.0
Attended initial meeting	13	27.9
Eligible and randomized	13	30.2
Completed study	13	30.2

Note. One family enrolled two children with two caregivers, resulting in 13 participants from 13 family contacts.

Consent and Initial Meeting

Initial meetings were individually scheduled to occur with one research team member, the prospective participant, and their legal guardian. Initial appointments were scheduled for a period of two hours. Consent and assent forms were reviewed and discussed at the beginning of each initial meeting. The research team member reviewed the purpose, duration, and design of the study, as well as data collection measures that would be used, with potential participants and parents. Potential participants and parents were told that if they completed the two-week baseline period and continued to meet eligibility criteria, that they would be randomized into either a daytime or nighttime routine condition. Potential participants and parents were not told that the nighttime routine condition was the intervention being examined during the study. Potential participants and their guardians were given the time and opportunity to ask questions and discuss study procedures before giving consent and assent. After the potential participant and their legal guardian indicated that they understood and were comfortable with study procedures, they were asked to sign assent and consent forms respectively. The researcher then administered a semi-structured diagnostic interview (K-SADS) to confirm pre-existing diagnoses of ADHD (combined, predominantly inattentive, or predominantly hyperactive/impulsive type). After consent and assent forms were signed, the researcher administered participants, and their parents took part in the K-SADS was also used to screen for the exclusion criteria of ASD, bipolar disorders, and psychosis. To get a baseline of sleep habits, participants were asked to complete the self-report CRSP and guardians were asked to complete the CSHQ.

The Woodcock-Johnson Test of Cognitive Abilities, Fourth Edition (WJ-IV) was administered to obtain a measure of IQ for eligibility using the BIA composite score. Two additional subtests (Concept Formation and Numbers Reversed) were administered as additional measures of EF. Participants and their legal guardian also completed their respective forms of the BRIEF as a baseline measure of EF for each participant. Participants completed computerized versions of Stop Signal Task, Trail Making Test, and Digit Span Backward on the Inquisit platform. Finally, participants had an actigraph watch placed on their non-dominant hand before the end of the meeting and were shown how to utilize a digital sleep diary in order to obtain supplementary sleep data throughout the naturalistic sleep period. Participants were stratified by sex and randomly assigned to either the intervention or control group at a 2:1 ratio stratified by sex, at the two-week meeting. Participants were then notified that they had been randomized to the daytime or nighttime condition. A 2:1 intervention to control ratio was chosen due to the desire to obtain acceptability data (Dumville et al., 2006; Nay & Prasad, 2024)

Naturalistic Sleep Period (Baseline)

The baseline period occurred for two weeks, beginning the day of the initial meeting and ending after approximately fourteen nights. During this period, all participants were asked to continuously wear their actigraph watch and complete daily digital sleep diaries. This two-week period of data collection on participants' sleep established a baseline sleep pattern for each participant. Participants were instructed to go about their daytime and nighttime routines as normal throughout this period.

Intervention Period

At the end of two baseline weeks, participants had an in-person consultation meeting with their interventions (i.e., a research team member). The researcher collaborated with the participants and their caregivers to increase total TIB by one hour more than their average baseline sleep, or up to 11 hours per night for participants ages 11 to 12, and up to 10 hours for participants ages 13 to 17, whichever was more. The sleep intervention period occurred for two weeks, beginning approximately on night 15 of the study and ending after approximately night 28. Participants were instructed to follow sleep intervention conditions for two weeks and returned at the end of the two weeks to return their actigraph watches during the post-intervention meeting.

Data from the actiwatches and digital sleep diaries were used to determine each participant's average TIB, TST, bedtimes, and wake times. During the meeting, the researcher reviewed and discussed each participant's actigraphy data with the participant and their guardian. This visually engaging approach not only facilitated a collaborative review of observed sleep patterns and average sleep duration during the baseline period but also encouraged meaningful dialogue between the researcher, participant, and caregiver. The researcher further explored factors that could influence sleep habits, and by extension, daytime functioning. During the discussion, the researcher inquired about typical school and extracurricular schedules, nightly routines, caffeine use, exercise, technology/screen use, stress management, and parental monitoring.

Participants then received a "sleep prescription" that included the collaboratively agreed upon bed and wake times, and strategies that provide the opportunity for healthy sleep. Table 4 provides an example of "sleep prescription" strategies, as originally designed and implemented by Perfect et al. (2016; 2023).

During this meeting, the researcher also scheduled two follow-up phone calls approximately 4 and 10 days following the meeting. The phone calls lasted between 2 and 5 minutes and covered any challenges or successes participants experienced with the "sleep prescription."

Daily Routines (Control) Condition

Sleep was not directly addressed with participants in the daily routines condition. Following the naturalistic sleep period, participants and their caregiver met with the researcher. Meetings focused on the participant and caregiver discussing their typical school-day and weekend schedules and routines. Participants received a "daily routines prescription" that included an agreed upon goal related to some aspect of their routine (non-sleep related). The researcher, participant, and caregiver discussed salient events that may impact daily routines (e.g., holidays, birthday parties, school start times), but no recommendations for modifications will be made.

Table 4

Example of "Sleep Prescription" Strategies to Increase Sleep Duration

Strategy	Description
Knowledge	• Review importance of more sleep • Discuss impact of insufficient sleep • Consider sleepiness levels/sleep pressure
Nightly Routine	• Develop routine that fits bedtime • Start getting ready for bed with enough time to sleep at set bedtime • Develop consistent sleep and wake times
Competing Activities	• Discuss competing activities (e.g., dinner time, sports, homework, clubs) • Adjust timing of competing activities to accommodate bedtime
Environmental Conditions	• Limit light in room at night • Discuss siblings or pets in room that may be distracting • Discuss noises hear in room • Discuss temperature • Comfort level of bed
Lifestyle	• Maintain active lifestyle • Limit moderate-high intensity exercise 2 hours before bedtime • No caffeine in the evening
Parental Monitoring	• Establish sleep schedule for the week with youth and caregiver • Behavior reinforcement
Technology	• Reduce technology/screen use 1-2 hours before bedtime • Limit blue light exposure • No cell phone in room at bedtime
Stress	• Reduce overload of information by breaking down expectations related to sleep schedule • Address basic strategies to manage stress
Motivation	• Address barriers to sleep behavior change • Identify aspects of sleep that are appealing (e.g., reduced sleepiness)
Consider Circadian Preference	• Discuss morningness/eveningness • Discuss how sleep onset can take a while due to being used to a later bedtime

Perfect et al. (2016; 2023)

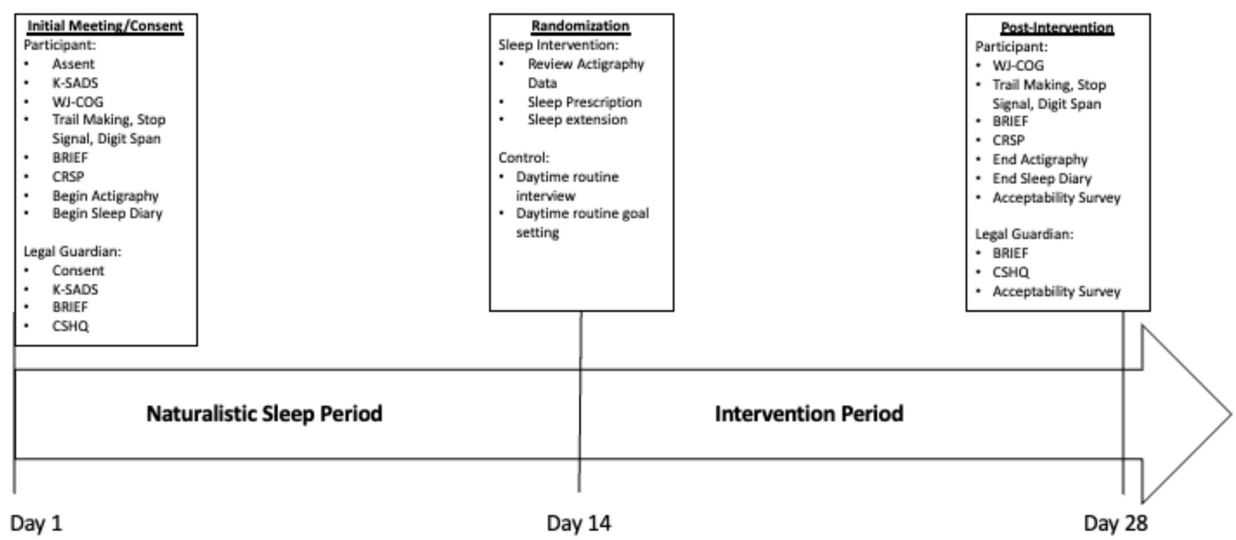
If a participant asked about sleep in relation to ADHD, neutral information was provided. Two phone check ins were scheduled for approximately day 4 and day 10 of the intervention period. Phone calls lasted between 2 and 5 minutes.

Post-Intervention Meeting

Participants and their guardians completed respective measures of the BRIEF as a post-intervention measure of EF. Participants completed the three subtests on the Inquisit platform and 4 subtests from the WJ-COG as objective measures of EF. Participants and caregivers completed the CRSP and CHSQ as measures of sleep quality. Finally, participants and parents were asked about their experiences with the intervention in an exit interview. Figure 2 provides a timeline of the study procedures.

Figure 2

Timeline of Study Procedures



Data Analysis

The study collected digital consent forms via REDCap, which is an online data collection tool for protected information. REDCap was also utilized as the central storage location of participant data. Data analyses were conducted utilizing the 28th edition of the Statistical Packages for the Social Sciences (SPSS).

Research Question 1: Is the behavioral sleep extension intervention acceptable within a population of adolescents with ADHD?

Research Question 1. To address research question 1, participant and caregiver responses from the post-intervention, acceptability interviews were assessed using descriptive statistics and qualitative information was coded an analyzed.

Research Question 2**:** Does a behavioral sleep extension intervention improve sleep for adolescents with ADHD?

Hypothesis: Adolescents in the sleep intervention condition will increase their average sleep duration.

Hypothesis: Adolescents in the sleep intervention condition will reduce the variability of their bedtimes and/or sleep duration across nights

Research Question 3: Does a behavioral sleep extension intervention for adolescents with ADHD positively impact one or more areas of EF (working memory, inhibitory control, or cognitive flexibility)?

Hypothesis: Adolescents in the sleep intervention condition will report improved functioning in one or more areas of EF (working memory, inhibitory control, or cognitive flexibility) as evidenced by a greater increase in scores relative to the control group

Research questions 2 & 3. Given the small sample size, nonparametric analyses were used to evaluate changes in sleep parameters (TST, TIB, SE, variability, and sleep quality), overall EF, working memory, inhibitory control, and cognitive flexibility. For each outcome, Wilcoxon signed-rank tests were conducted separately within the intervention and control groups to assess pre-to-post changes. To compare change scores between groups, Mann-Whitney U tests were performed. Descriptive statistics were calculated for each outcome, and Hedges' g effect sizes were computed to estimate the magnitude of between-group differences (Cohen, 1977; Durlak, 2009; Hedges, 1981). Effect sizes were interpreted according to standard conventions: 0.2 (small), 0.5 (medium), and 0.8 (large; Sullivan & Feinn, 2012). Figure 3 provides the formula for calculating Hedges' g effect sample sizes of less than 20.

Figure 3

Hedge's g formula for small sample sizes

$$g = \frac{M_1 - M_2}{SD^*_{\text{pooled}}} \times \left(\frac{N-3}{N-2.25}\right) \times \sqrt{\frac{N-2}{N}}$$

Chapter 4: Results

Eligibility of Sample

Table 5 provides descriptions of how each participant met the eligibility criteria of poor sleep: short TST during, SE less than 85%, standard deviation of TST greater than 60 minutes, standard deviation of TIB greater than 60 minutes, or a CSHQ Total Sleep Disturbance score greater than 41 during the baseline period.

Table 5

Eligibility Criteria for Poor Sleep Met by Each Participant

Participant	Short TST*	Sleep Efficiency < 85%	TST standard deviation > 60 minutes	TIB standard deviation > 60 minutes	CSHQ Total Sleep Disturbance Score > 41
1	X	X			X
2	X	X	X	X	X
3	X	X	X	X	X
4	X				
5	X		X	X	X
6				X	X
7		X	X	X	X
8	X		X	X	X
9	X		X	X	
10	X			X	X
11	X		X	X	X
12	X	X	X	X	X
13	X	X		X	X

Note: "X" indicates participant met the criteria; TST = Total Sleep Time; TIB = Time in Bed; CSHQ = Children's Sleep Habit Questionnaire (Parent Report)

**Short TST refers to the participant averaging less than 8 hours (ages 13 – 17 years) or 9 hours (ages 11 – 12 years) of TST per night during the baseline period*

Research Question 1: Is the behavioral sleep extension intervention acceptable within adolescents with ADHD?

Adolescent-Reported Acceptability and Perceived Impact

Among the adolescent participants in the intervention group, 89% (n = 8) reported that speaking with a research team member was either *very helpful* (n = 4) or *somewhat helpful* (n = 4) in helping them to change their sleep schedule.

When asked how easy or difficult it was to increase their sleep duration, 33.3% (n = 3) of participants reported that it was *somewhat easy*, 33.3% (n = 3) reported that it was *neither easy nor difficult*, and 33.3% (n = 3) reported that it was *somewhat difficult* (n = 2) or *very difficult* (n = 1) to get more sleep. When asked how easy or difficult it was to improve sleep quality, most participants reported that it was *somewhat difficult* (n = 5), followed by *neither easy nor difficult* (n = 2), and *somewhat easy* (n = 2).

Nearly 78% (*n* = 7) of participants reported feeling successful in getting more sleep, with three participants reporting feeling *very successful* and four participants reporting feeling *somewhat successful*. Most participants (*n* = 6) also reported being somewhat successful at improving sleep quality. When asked about how parent involvement in nighttime routines changed during the intervention, four participants reported that their parents remained as involved in their nighttime routine during the study as they had prior to the study, while two participants reported that their parent became much more involved, two reported that their parent became somewhat more involved, and one reported that their parent was uninvolved. When asked about the likelihood of continuing their new sleep schedule and habits after the study, participants reported that they would be *somewhat likely* (*n* = 4), *very unlikely* (*n* = 3), *very likely* (*n* = 1), and *somewhat unlikely* (*n* = 1) to continue their new sleep schedule and habits after the study concluded.

Parent-Reported Acceptability and Perceived Impact

Participants' parents generally reported that speaking with a research team member was helpful in facilitating sleep-related behavior change. Four (44%) parents reported that speaking with a research team member was *very helpful*, while five (56%) parents found it *somewhat helpful* in helping their child change their sleep schedule and habits. Regarding difficulty, four (44%) parents described it as *somewhat difficult* for their child to increase sleep duration, while three (33%) reported that it was *somewhat easy*. Additionally, one parent reported that it was *very difficult,* and one parent reported that it was *neither easy nor difficult*. When asked how difficult it was for their child to improve sleep quality, four (44%) reported that it was *somewhat difficult*, three (33%) reported it was *somewhat easy*, one (11%) reported it was *neither easy nor difficult*, and one (11%) reported it was *very easy*.

When asked about their child's perceived success, most parents felt that their children were successful in increasing sleep duration with six (67%) parents reporting that their child was *somewhat successful* and two (22%) reporting that their child was *very successful* in increasing their sleep duration. For improvements in sleep quality, seven (78%) parents reported that their child was *somewhat successful*, while one (11%) reported that their child was *very successful*, and one (11%) reported that their child was *very unsuccessful*. When asked about their own involvement in their child's bedtime routines, five (56%) parents reported becoming *somewhat more involved* in their child's bedtime routines, while one (11%) became *much more involved*, and two (22%) *remained as involved* as they were before the intervention began.

When parents were asked about anticipated continuation of sleep schedule changes, four (44%) parents reported that their child would be *somewhat likely* to continue with the new sleep schedule post-intervention. The remaining parents were split between *somewhat unlikely* (n = 2), *very unlikely* (n = 2), and *very likely* (n = 1). Responses were similar regarding the continuation of new sleep habits: *somewhat likely* (n = 5), *very likely* (n = 2), *somewhat unlikely* (n = 1), and *very unlikely* (n = 1).

Adolescent and Parent Reported Factors that Helped Improve Sleep

Adolescents and parents were also asked to select which intervention strategies they found to be most helpful for their child, increasing their sleep duration and improving sleep quality. The most frequently endorsed strategies by adolescents for improving both sleep duration and sleep quality were *creating a nightly routine* (56% and 67%, respectively). Other commonly used strategies among adolescents included *learning about the importance of sleep* (44% for both duration and quality), *making lifestyle changes* (44% for duration, 33% for quality), and *removing technology from the bedroom* (44% for duration, 33% for quality). Fewer adolescents reported using strategies such as *changing the sleep environment* (22% for both) or *reducing stress* (33% for both). Parent reports differed somewhat in their perceptions of what strategies were used. The most frequently reported strategies for improving both sleep duration and quality were *making lifestyle changes* (67% each), followed by *adjusting the schedule of other activities* (56% for duration, 44% for quality), and *creating a nightly routine* (44% for both). Fewer parents endorsed strategies such as *removing technology from the bedroom* (22% for duration, 33% for quality), *reducing stress* (11% each), or *changing the sleep environment* (33% each). Notably, parents and adolescents were aligned in reporting *parental involvement in the sleep schedule* (44% for duration in both groups), though adolescents were less likely to see this strategy as helpful for sleep quality (22%) than parents (44%). A summary of strategies participants found most helpful can be found in Table 6. Overall, both adolescents and parents reported using a range of strategies, with some convergence and divergence in perceived utility. These differences may reflect variations in awareness, communication, or perceived effectiveness of specific strategies between informants.

Table 6

Adolescent and Parent Endorsement of Helpful Strategies for Sleep Duration and Quality

	Adolescents		Parents	
Strategy	Sleep Duration n (%)	Sleep Quality n (%)	Sleep Duration n (%)	Sleep Quality n (%)
Learning about the importance of sleep	4 (44%)	4 (44%)	3 (33%)	4 (44%)
Creating a nightly routine	5 (56%)	6 (67%)	4 (44%)	4 (44%)
Adjusting schedule of other activities to fit sleep schedule	3 (33%)	2 (22%)	5 (56%)	4 (44%)
Changing the sleep environment	2 (22%)	2 (22%)	3 (33%)	3 (33%)
Lifestyle changes (e.g., exercise, diet)	4 (44%)	3 (33%)	6 (67%)	6 (67%)
Removing technology from the bedroom	4 (44%)	3 (33%)	2 (22%)	3 (33%)
Reducing stress	3 (33%)	3 (33%)	1 (11%)	1 (11%)
Parent being more involved in sleep schedule	4 (44%)	2 (22%)	4 (44%)	4 (44%)
Other	0 (0%)	0 (0%)	1 (11%)	0 (0%)

Note. $n = 9$. Participants could select multiple strategies. Percentages reflect the proportion of participants endorsing each strategy within each sleep domain.

Qualitative Feedback on the Intervention

Factors that Helped Improve Sleep. Adolescents and their parents were asked in a free response style about what helped the adolescent get more sleep or improve sleep quality. Adolescents most frequently credited improvements in their sleep to following their new sleep schedule ($n = 5$), with four adolescents specifically mentioning going to bed earlier. Other factors reported to be helpful were removing technology before bedtime ($n = 2$), not eating close to bedtime ($n = 1$), and decreasing stress ($n = 1$). Parents also most frequently identified implementing the new sleep schedule ($n = 4$) as helpful. Other factors that were reported as helpful were lifestyle changes ($n = 1$), such as “not lounging and doing other activities in bed,” removing technology ($n = 1$), reminding the child of commitment to the study ($n = 1$), and speaking with the research team member ($n = 1$).

Barriers to Sleep Improvement. Adolescents and their parents were asked about factors that made it difficult for the adolescent to get more sleep or better sleep quality. Adolescents reported several barriers to improving their sleep, with the most common barrier being related to adjusting to their new sleep schedule to an earlier bedtime (*n* = 3). For example, one adolescent reported that "attempting to go to sleep much earlier was difficult," and another stated that "going to bed when I wasn't really too tired" was difficult. Two adolescents noted cognitive arousal as something that made it difficult to improve sleep, with one stating that "life events and anxiety" were barriers to improving sleep. Other barriers that were reported were lifestyle changes (*n* = 2) such as "not being in my bed during the day" and difficulty not using technology (*n* = 1). Parents most frequently reported competing activities as a barrier (*n* = 5), such as "homework," "soccer that ends close to bedtime," and "schedule of school and home tasks." Four parents reported that their child had difficulty adjusting to an early bedtime, two noted that it was hard for their child to change habits, and one reported an environmental factor stating that "animals woke her up often."

Parent Involvement. Adolescents and their parents were asked about how parent involvement changed during the intervention. Adolescents frequently described their parents' involvement in helping them change their sleep habits through parents providing reminders regarding sleep scheduling (*n* = 6). Five participants described parent bedtime reminders, including statements such as "my mom helped remind me of the time," and "they made me go to bed on time," while one participant found morning reminders to wake up to be helpful. One adolescent reported that their parent's encouragement was helpful. Parents echoed this, with many reporting that they provided reminders (*n* = 7) regarding sleep schedules and habits that were discussed during the intervention meeting. Specifically, four parents reported reminding their child of habit changes such as "reminding to not hang out and lounge in bed during the day," while three parents reported reminders specific to the bed (*n* = 2) and wake (*n* = 1) times. Additionally, one parent reported removing technology from the room, stating that "getting off devices earlier" was helpful. Others reported that they helped with adjusting the timing of their child's caffeine intake and ensuring their child's room was dark and quiet.

Suggestions for Improvement. When asked for suggestions to improve the study and/or the intervention, most adolescents (*n* = 7) reported that they did not have any suggestions; however, two adolescents provided suggestions such as using more efficient daily sleep diaries. Similarly, parents largely reported that they did not have suggestions for improvement (*n* = 6), though three offered suggestions such as extending the duration of the intervention, incorporating an interactive sleep psychoeducation training session, and integrating peer support into the intervention.

Behavioral Indicators of Intervention Acceptability

In the current study, multiple behavioral indicators were used to assess acceptability. All 13 participants attended the three scheduled in-person meetings, with only one participant needing to reschedule the two-week follow-up due to illness. This suggests strong adherence to intervention visits. Engagement with the two intervention booster calls was also high. Five out of nine participants (55.6%) answered both calls, and the remaining four (44.4%) answered one call. Completion of daily sleep diaries further supported acceptability. Among intervention participants, seven out of nine (77.8%) completed at least 75% of the daily diaries (i.e., 21 or more out of 28 days), including one participant who completed all 28 diaries. Two participants (22.2%) completed fewer than 75% of diaries.

Research Question 2: Does a behavioral sleep extension intervention improve sleep for adolescents with ADHD?

Sleep Duration

It was hypothesized that adolescents in the behavioral sleep intervention condition would increase their average sleep duration. Descriptive statistics of actigraphy measures for the intervention and control group at both time points can be found in Tables 10 and 11.

Total Sleep Time (Actigraphy). Wilcoxon signed-rank tests were conducted to evaluate changes in TST from pre- to post-intervention within each group. In the control group (n = 4), there was no significant change in TST, z = 0.00, p = 1.00. Mean TST remained virtually unchanged from pre-intervention (M = 466.59, SD = 46.90, Mdn = 459.61) to post-intervention (M = 466.21, SD = 22.90, Mdn = 462.09). In contrast, the intervention group (n = 9) showed a significant increase in TST from pre- to post-intervention, z = -2.67, p = .008, with all nine participants showing increases in TST. Mean TST rose approximately 34 minutes from M = 444.97 minutes (SD = 53.75, Mdn = 432.50) to M = 478.65 minutes (SD = 52.73, Mdn = 467.62). A Mann-Whitney U test comparing TST change scores between groups was not statistically significant, U = 8.00, z = -1.54, p = .123; however, the between-group effect size was large (g = 0.92), suggesting a potentially meaningful difference favoring the intervention. Results of Wilcoxon's and the Mann-Whitney U test for TST can be found in Table 7.

Table 7

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for TST

Test	Group	z	p	Hedges' g	Interpretation
Wilcoxon	Control	0.00	1.00	--	No significant change
Wilcoxon	Intervention	-2.67	.008	--	Significant increase
Mann-Whitney U	Between-groups	-1.54	.123	0.92	Not significant, large effect

Time in Bed (Actigraphy). Wilcoxon signed-rank tests were conducted to evaluate changes in average TIB from pre- to post-intervention within each group. In the control group there was no significant change in TIB, *z* = -0.37, *p* = .715. Mean TIB remained relatively stable from pre-intervention (*M* = 532.29, *SD* = 49.09, *Mdn* = 489.49) to post-intervention (*M* = 540.95, *SD* = 32.31, *Mdn* = 513.54). In the intervention group, participants demonstrated a significant increase in TIB of approximately 42 minutes from pre- to post-intervention, *z* = -2.55, *p* = .011. Eight of nine participants showed increased TIB, and one remained within one minute of baseline. Mean TIB rose from *M* = 520.18 (*SD* = 63.73, *Mdn* = 496.95) to *M* = 561.82 (*SD* = 51.66, *Mdn* = 532.29). A Mann–Whitney U test comparing TIB change scores between groups was not statistically significant, *U* = 9.00, *Z* = -1.39, *p* = .165. However, the between-group effect size was large (*g* = 0.82), suggesting a meaningful increase in TIB for the intervention group relative to the control group. Results of Wilcoxon's and the Mann-Whitney U test for TIB can be found in Table 8.

Table 8

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for TIB

Test	Group	*z*	*p*	Hedges' g	Interpretation
Wilcoxon	Control	-0.37	.715	--	No significant change
Wilcoxon	Intervention	-2.55	.011	--	Significant increase
Mann-Whitney U	Between-groups	-1.39	.165	0.82	Not significant, large effect

Sleep Onset Latency (Actigraphy). Wilcoxon signed-rank tests were conducted to evaluate changes in sleep onset latency (SOL) from pre- to post-intervention within each group. In the control group, two participants showed reduced SOL and two showed increased SOL. This pattern was not statistically significant, *z* = -0.37, *p* = .715. Mean SOL increased from *M* = 11.72 minutes (*SD* = 19.43, *Mdn* = 2.10) at pre-intervention to *M* = 17.71 minutes (*SD* = 15.21, *Mdn* =

17.83) at post-intervention. In the intervention group, five participants showed increased SOL and four showed reductions, also not statistically significant, $z = -0.42$, $p = .678$. Mean SOL decreased from $M = 12.00$ minutes ($SD = 11.20$, $Mdn = 7.21$) to $M = 10.44$ minutes ($SD = 6.64$, $Mdn = 9.54$). A Mann–Whitney U test comparing change scores between groups revealed no statistically significant difference, $U = 14.00$, $Z = -0.62$, $p = .537$. The between-group effect size was moderate ($g = -0.59$), reflecting a trend toward improved SOL in the intervention group relative to control. Results of Wilcoxon's and the Mann-Whitney U test for SOL can be found in Table 9.

Table 9

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for SOL

Test	Group	*z*	*p*	Hedges' g	Interpretation
Wilcoxon	Control	-0.37	.715	--	No significant change
Wilcoxon	Intervention	-0.42	.678	--	No significant change
Mann-Whitney U	Between-groups	-0.62	.537	-0.59	Not significant, moderate effect

Table 10

Intervention Group Descriptive Statistics for Actigraphy Pre- and Post-Intervention

	Pre		Post	
Variable	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
TST	444.97 (53.75)	432.50 (404.06 - 481.04)	478.65 (52.73)	467.62 (435.42 – 516.61)
TIB	520.18 (63.73)	507.35 (482.04 -537.03)	561.82 (51.66)	553.00 (517.38 – 589.53)
SE	85.59 (4.28)	84.64 (82.43 - 90.34)	85.56 (4.79)	86.07 (84.34 – 88.29)
SOL	12.00 (11.20)	7.21 (3.11 - 22.74)	10.44 (6.64)	9.54 (3.14 – 16.87)
CVTST	0.22 (0.13)	0.18 (0.12 – 0.29)	0.17 (0.08)	0.14 (0.15 – 0.24)
ST	10:55pm (72 mins)	11:34pm (9:41pm – 12:02am)	10:17pm (79 minutes)	10:20pm (9:08pm – 11:26pm)
ET	7:12am (64 minutes)	7:35am (6:23 – 8:04am)	7:29am (116 minutes)	7:53am (6:25 – 8:30am)

Note. TST = Total Sleep Time; TIB = Time in Bed; SE = Sleep Efficiency; SOL = Sleep Onset Latency; CVTST = Coefficient of Variability in Total Sleep Time; ST = Average start time of rest period; ET = Average end time of rest period; SD = Standard Deviation; IQR = Interquartile Range

Sleep Quality

It was hypothesized that adolescents in the behavioral sleep intervention condition would show improvements in sleep quality, as demonstrated by a reduction in the variability of their sleep duration across nights and self- and parent-reports of sleep.

Table 11

Control Group Descriptive Statistics for Actigraphy Pre- and Post-Intervention

	Pre		Post	
Variable	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)
TST	466.59 (46.90)	459.61 (425.43 - 514.74)	466.21 (22.90)	462.09 (446.66 – 489.88)
TIB	532.29 (49.09)	516.61 (496.93 - 583.35)	540.95 (32.31)	548.23 (507.22 – 567.41)
SE	87.95 (3.45)	86.74 (85.49 - 91.61)	86.09 (89.15)	86.51 (82.60 – 89.15)
SOL	11.72 (19.43)	2.10 (1.84 - 31.22)	17.71 (15.21)	17.83 (3.27 – 32.03)
CVTST	0.14 (0.03)	0.14 (0.11 – 0.17)	0.21 (0.11)	0.22 (0.12 – 0.16)
ST	10:18pm (70 minutes)	10:45pm (9:05 – 11:04pm)	10:24pm (34 minutes)	10:36pm (9:48 – 11:04pm)
ET	6:49am (13 minutes)	6:52am (6:36 – 7:01am)	6:26am (20 minutes)	6:53am (6:41 – 7:17am)

Note. TST = Total Sleep Time; TIB = Time in Bed; SE = Sleep Efficiency; SOL = Sleep Onset Latency; CVTST = Coefficient of Variability in Total Sleep Time; ST = Average start time of rest period; ET = Average end time of rest period.

Variability in TST (Actigraphy). Changes in night-to-night variability in TST (Coefficient of Variability TST or CVTST) from pre- to post-intervention were also examined using Wilcoxon signed-rank tests. In the control group (n = 4), there was no statistically significant change, z = -1.46, p = .144. Mean CVTST increased from M = 0.14 (SD = 0.03, Mdn = 0.14) at pre-intervention to M = 0.21 (SD = 0.11, Mdn = 0.22) at post-intervention. In the intervention group, there was also no statistically significant change, z = -1.24, p = .214. Mean CVTST decreased from M = 0.22 (SD = 0.13, Mdn = 0.18) to M = 0.17 (SD = 0.08, Mdn = 0.14). A Mann–Whitney U test comparing change in CVTST between groups approached significance, U = 7.00, Z = -1.70, p = .090. Although the intervention group did not demonstrate a consistent reduction in variability, the group's average CVTST decreased slightly. In contrast, the control group showed a more pronounced and consistent increase in CVTST. This divergence produced a large between-group effect size (*g* = -1.11), which primarily reflects worsening variability in the control group rather than robust improvement in the intervention group. Results of Wilcoxon's and the Mann-Whitney U test for SOL can be found in Table 12.

Table 12

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for CVTST

Test	Group	*z*	*p*	Hedges' g	Interpretation
Wilcoxon	Control	-1.46	.144	--	No significant change, slight increase in variability
Wilcoxon	Intervention	-1.24	.214	--	No significant change, trend toward reduced variability
Mann-Whitney U	Between-groups	-1.70	.090	-1.11	Approached significance, large effect

Sleep Efficiency (Actigraphy). Wilcoxon signed-rank tests were conducted to evaluate changes in SE from pre-to post-intervention within each group. In the control group, there was no significant change in SE, $z = -1.10$, $p = .237$. Mean SE decreased from pre-intervention (*M* = 87.95%, *SD* = 3.45, *Mdn* = 86.74) to post-intervention (*M* = 86.09%, *SD* = 3.51, *Mdn* = 86.51). The intervention group also showed no significant change, $z = -0.30$, $p = .767$. Mean SE remained stable from pre-intervention (*M* = 85.59%, *SD*= 4.28, *Mdn* = 84.64) to post-intervention (*M* = 85.56%, *SD* = 4.79, *Mdn* = 86.07). A Mann–Whitney U test comparing SE change scores between groups was not statistically significant, $U = 13.00$, $Z = -0.77$, $p = .440$. The between-group effect size was small to moderate ($g = 0.44$), favoring the intervention group. Results of Wilcoxon's and the Mann-Whitney U test for SE can be found in Table 13.

Table 13

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for SE

Test	Group	*z*	*p*	Hedges' g	Interpretation
Wilcoxon	Control	-1.10	.237	--	No significant change, slight decrease in SE
Wilcoxon	Intervention	-0.30	.767	--	No significant change, stable SE
Mann-Whitney U	Between-groups	-0.77	.440	0.44	Not significant, small-to-moderate effect

Child's Report of Sleep Patterns (Self-Report) Activities Before Bed Index. Wilcoxon signed-rank tests were used to evaluate within-group changes in evening activities before bedtime, as measured by the CRSP Activities Before Bed Index. This pattern in the control group was not statistically significant, $z = -0.56$, $p = .577$. The average change was -1.00 (*SD* = 3.46, *Mdn* = -2.00). The pattern in the intervention group was also not statistically significant, $z = -1.55$, $p = .121$. The mean change was -1.78 (*SD* = 3.03, *Mdn* = -1.00). Between-group differences in change scores were examined using a Mann–Whitney U test, which was not statistically significant, $U = 17.00$, $Z = -0.16$, $p = .877$, yielding a small group effect size ($g = -0.21$) in favor of the intervention group.

Child's Report of Sleep Patterns (Self-Report) Electronics Use at Sleep Index. Wilcoxon signed-rank tests were used to evaluate within-group changes in use of electronics at bedtime, as measured by the CRSP Electronics Use at Sleep Index. This pattern was not statistically significant, $z = -0.56$, $p = .577$. The mean change was -0.50 (*SD* = 3.32, *Mdn* = -1.00). The pattern in the intervention group was also not statistically significant, $z = -1.23$, $p = .211$. The mean change was 0.89 (*SD* = 1.90, *Mdn* = 0.00). Between-group differences in changes in electronics use were examined using a Mann-Whitney U test on change scores. This difference was not statistically significant, $U = 10.50$, $z = -1.19$, $p = .233$. However, the between-group effect size was moderate (*g* = 0.50), suggesting a small increase in electronics use in the intervention group relative to a slight reduction in the control group.

Child's Report of Sleep Patterns (Self-Report) Insomnia Scale. Insomnia symptoms, measured by the CRSP Insomnia Scale, were evaluated as a self-reported indicator of quality, Wilcoxon signed-rank tests did not reveal significant pre- to post-intervention changes in insomnia within the control group, $z = -0.58$, $p = .564$. The mean change score was –0.50 (*SD* = 1.91, *Mdn* = -1.00). No statistically significant change was observed within the intervention group, $z = -0.14$, $p = .888$. The mean change score was 0.11 (*SD* = 2.47, *Mdn* = 0.00). Between-group differences in insomnia were also not statistically significant, $U = 16.00$, $z = -0.31$, $p = .753$. The between-group effect size was small ($g = 0.22$), reflecting slightly more improvement in the control group.

Child's Report of Sleep Patterns (Self-Report) Sleepiness Scale. Wilcoxon signed-rank tests did not reveal significant pre- to post-intervention changes in sleepiness in the control group, $z = 0.00$, $p = 1.00$, or the intervention group, $z = -0.14$, $p = .887$. The control group showed no average change in self-reported sleepiness (*M* = 0.00, *SD* = 1.41, *Mdn* = -0.50). The intervention group reported a slight reduction in sleepiness (*M* = -0.33, *SD* = 2.24, *Mdn* = 0.00). A Mann–Whitney U test indicated no significant between-group difference in change scores, $U = 17.50$, $Z = -0.08$, $p = .937$. The between-group effect size was also negligible ($g = -0.14$). Test and descriptive statistics for CRSP subscales can be found in Tables 14 and 15.

Table 14

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for CRSP Activities Before Bed Index

Subscale	Test	Group	*z*	*p*	Hedges' g	Interpretation
Activities Before Bed	Wilcoxon	Control	-0.56	.577	--	No significant change
	Wilcoxon	Intervention	-1.55	.121	--	No significant change
	Mann-Whitney U	Between-groups	-0.16	.877	-0.21	Not significant, small effect
Electronics Use at Sleep	Wilcoxon	Control	-0.56	.577	--	No significant change
	Wilcoxon	Intervention	-1.23	.211	--	No significant change
	Mann-Whitney U	Between-groups	-1.19	.233	0.50	Not significant, moderate effect
Insomnia Scale	Wilcoxon	Control	-0.58	.564	--	No significant change
	Wilcoxon	Intervention	-0.14	.888	--	No significant change
	Mann-Whitney U	Between-groups	-0.31	.753	0.22	Not significant, small effect
Sleepiness Scale	Wilcoxon	Control	0.00	1.00	--	No significant change
	Wilcoxon	Intervention	-0.14	.887	--	No significant change
	Mann-Whitney U	Between-groups	-0.08	.937	-0.14	Not significant, negligible effect

Children's Sleep Habits Questionnaire (Parent-Report) Total Sleep Disturbance. Wilcoxon signed-rank tests used to evaluate within-group changes in total sleep disturbance, as measured by the CSHQ Total Sleep Disturbance Scale. Results did not yield statistically significant patterns for the control group, $z = -0.27$, $p = 0.785$, or the intervention group, $z = -0.17$, $p = .864$. The control group had a mean change score of -0.25 ($SD = 2.50$, $Mdn = -0.50$). The intervention group had a mean change of -0.22 ($SD = 4.71$, $Mdn = 0.00$). A Mann–Whitney

U test comparing change scores between groups also indicated no significant difference, U = 16.50, z = –0.24, p = .814. The between-group effect size was negligible (g = 0.01).

Table 15

Descriptive Statistics for CRSP Subscales by Group

CRSP Subscale	Intervention Mean (SD)	Intervention Median (IQR)	Control Mean (SD)	Control Median (IQR)
Activities (Pre)	19.33 (2.35)	18.00 (18.00–20.00)	14.50 (6.61)	12.00 (10.00–21.50)
Activities (Post)	17.56 (2.35)	18.00 (16.00–19.50)	13.50 (5.00)	13.00 (9.00–18.50)
Insomnia (Pre)	10.33 (3.32)	9.00 (7.00–14.00)	11.50 (1.00)	12.00 (10.50–12.00)
Insomnia (Post)	10.44 (2.79)	11.00 (8.00–12.00)	11.00 (2.58)	11.00 (8.50–13.50)
Electronics (Pre)	5.67 (2.92)	4.00 (3.00–8.00)	6.25 (2.36)	7.00 (3.75–8.00)
Electronics (Post)	6.56 (3.01)	7.00 (3.00–9.00)	5.75 (1.50)	6.00 (4.25–7.00)
Sleepiness (Pre)	10.33 (4.87)	8.00 (7.50–12.00)	10.25 (4.79)	9.00 (6.50–15.25)
Sleepiness (Post)	10.00 (4.03)	10.00 (6.00–13.00)	10.25 (3.86)	8.50 (8.00–14.25)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

Children's Sleep Habits Questionnaire (Parent-Report) Daytime Sleepiness. Wilcoxon signed-rank tests were used to evaluate within-group changes in daytime sleepiness, as measured by the CSHQ Daytime Sleepiness Scale. Results were not statistically significant in the control group, z = -1.13, p = .257, or in the intervention group, z = -0.32, p = .752. The control group had a mean change score of 0.75 (SD = 1.26, Mdn = 1.00). The intervention group showed no average change (M = 0.00, SD = 3.16, Mdn = 0.00). A Mann–Whitney U test indicated no significant difference in change scores between groups, U = 15.00, Z = –0.39, p = .696. The between-group effect size was small (g = -0.23), favoring the intervention group. Test and descriptive statistics for the CSHQ subscales can be found in Tables 16 and 17.

Table 16

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for CSHQ Subscales

Subscale	Test	Group	*z*	*p*	Hedges' g	Interpretation
Total Sleep Disturbance	Wilcoxon	Control	-0.27	.785	--	No significant change
Total Sleep Disturbance	Wilcoxon	Intervention	-0.17	.864	--	No significant change
Total Sleep Disturbance	Mann-Whitney U	Between-groups	-0.24	.814	0.01	Not significant, negligible effect
Daytime Sleepiness	Wilcoxon	Control	-1.13	.257	--	Slight increase
Daytime Sleepiness	Wilcoxon	Intervention	-0.32	.752	--	No change
Daytime Sleepiness	Mann–Whitney U	Between-groups	-0.39	.696	-0.23	Not significant, small effect favoring intervention

Table 17

Descriptive Statistics for CSHQ Subscales by Group

CSHQ Subscale	Intervention Mean (SD)	Intervention Median (IQR)	Control Mean (SD)	Control Median (IQR)
Total Sleep Disturbance (Pre)	46.67 (4.97)	47.00 (43.00–49.00)	47.50 (5.51)	48.00 (42.00–52.50)
Total Sleep Disturbance (Post)	46.44 (6.54)	46.00 (41.00–50.50)	47.25 (5.85)	47.00 (41.75–53.00)
Daytime Sleepiness (Pre)	15.67 (3.04)	17.00 (14.00–17.50)	16.00 (2.45)	15.50 (14.00–18.50)
Daytime Sleepiness (Post)	15.67 (4.24)	17.00 (11.50–19.00)	16.75 (2.87)	15.50 (15.00–19.75)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

Research Question 3: Does a behavioral sleep extension intervention for adolescents with ADHD positively impact one or more areas of EF (working memory, inhibitory control, or cognitive flexibility)?

Working Memory

It was hypothesized that adolescents in the behavioral sleep intervention condition would demonstrate improvements in working memory post-intervention. Test statistics and descriptive statistics for performance-based measures of working memory can be found in Tables 18 and 19.

BRIEF Self-Report. To examine whether working memory improved from pre- to post-intervention, Wilcoxon signed-rank tests were conducted separately within each group using scores from the BRIEF Working Memory subscale. The control group did not demonstrate significant change, $z = 0.00$, $p = 1.00$. The intervention group also showed no statistically significant change, $z = -0.49$, $p = .620$. The control group showed a slight increase in self-reported working memory problems ($M = 0.50$, $SD = 4.80$, $Mdn = 1.50$). The intervention group showed a small improvement ($M = –1.78$, $SD = 6.72$, $Mdn = 0.00$). A Mann–Whitney U test comparing change scores between groups indicated no significant difference, $U = 14.50$, $z = –0.55$, $p = .580$. The between-group effect size was small-to-moderate ($g = -0.31$), favoring the intervention group.

BRIEF Parent-Report. To evaluate changes in parent-reported working memory, Wilcoxon signed-rank tests were conducted within each group using the BRIEF Working Memory subscale scores. Results did not produce significant results for the control group, $z = -1.60$, $p = .110$, or the intervention group, $z = -0.93$, $p = .35$. The control group showed a mean reduction in working memory difficulties of -4.25 ($SD = 4.03$, $Mdn = –4.00$). The intervention group showed a smaller change ($M = -1.67$, $SD = 6.28$, $Mdn = 0.00$). A Mann–Whitney U test indicated no significant difference in working memory change between groups, *U* = 13.00, *z* = -0.78, *p* = .440. However, the between-group effect size was small-to-moderate (*g* = 0.38), favoring the control group.

Digit Span Backward. Wilcoxon signed-rank tests were used to evaluate within-group changes in working memory, as measured by the backward digit span score (bTEML). Results were not statistically significant in the control group, *z* = 0.00, *p* = 1.00, *g* = 0.00, or in the intervention group, *z* = -1.30, *p* = .19. Between group differences in working memory were examined using a Mann-Whitney U test on change scores from the bTEML. This difference was not statistically significant, *U* = 13.50, *z* = - 0.72, *p* = .47, though the between-group effect size was small-to-moderate (*g* = 0.40), indicating slightly greater improvement in the intervention group. The intervention group had a mean change score of 0.56 (*SD* = 1.33, *Mdn* = 1.00), while the control group had a mean change score of 0.00 (*SD* = 0.82, *Mdn* = 0.00).

WJ Number Series. Wilcoxon signed-rank tests were conducted to examine within-group changes in working memory, as measured by the WJ Number Series subtest. Results for the control group were not statistically significant, *z* = -0.92, *p* = .36. Results for the intervention group were also not statistically significant, *z* = -0.89, *p* = .37. A Mann-Whitney U test was conducted to examine between-group differences in working memory. This difference was not statistically significant, *U* = 10.50, *z* = -1.16, *p* = .25. The between-group effect size was moderate (*g* = 0.59), favoring the intervention group. The intervention group had a mean change score of 2.78 (SD = 8.74, Mdn = 3.00), while the control group had a mean of -2.75 (SD = 5.44, Mdn = -2.00).

WJ Numbers Reversed. Wilcoxon signed-rank tests were conducted to examine working memory, as measured by the Numbers Reversed subtest of the WJ IV. Results were not significant for the control group, $z = -0.73$, $p = .47$. The intervention group also did not show a statistically significant change, $z = -1.05$, $p = .292$. A Mann–Whitney U test was used to examine between-group differences in working memory. The difference was not statistically significant, $U = 13.00$, $z = -0.78$, $p = .44$, and the between-group effect size was negligible-to-small ($g = 0.18$). The intervention group had a mean change score of -3.44 (SD = 9.36, *Mdn* = -5.00), while the control group had a mean of -5.75 (SD = 14.89, *Mdn* = -7.50).

Inhibitory Control

It was hypothesized that adolescents in the behavioral sleep intervention condition would demonstrate improvements in inhibitory control post-intervention. Test and descriptive statistics for performance-based measures of Inhibitory Control can be found in Tables 20 and 21.

BRIEF Self-Report. To evaluate changes in inhibitory control from pre- to post-intervention, Wilcoxon signed-rank tests were conducted using scores from the BRIEF Inhibit subscale. The control group did not demonstrate a statistically significant change, $z = -0.18$, $p = .850$. The intervention group also did not have a significant change, $z = -0.66$, $p = .510$. The control group reported a mean change of =1.00 (*SD* = 7.07, *Mdn* = 0.00). The intervention group reported a mean change of -1.33 (*SD* = 6.02, *Mdn* = -3.00). A Mann–Whitney U test comparing change scores between groups also indicated no significant difference, $U = 17.50$, $z = -0.08$, $p = .940$. The between-group effect size was negligible ($g = -0.04$).

BRIEF Parent-Report. In the control group, no statistically significant change was observed on the parent-reported BRIEF Inhibit subscale, $z = -1.34$, $p = .180$. The control group showed a mean reduction of -4.75 (*SD* = 6.18, *Mdn* = –3.00). The intervention group also did not show a statistically significant change, $z = -0.77$, $p = .440$, with a mean reduction of -2.11 (*SD* = 8.87, *Mdn* = -3.00). A Mann–Whitney U test comparing change scores between groups indicated no significant difference, $U = 15.00$, $z = -0.47$, $p = .640$. However, the between-group effect size was small ($g = 0.27$), suggesting greater improvements in inhibitory control in the control group relative to the intervention group.

Table 18

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for Performance-Based Measures of WM

Measure	Test	Group	*z*	*p*	Hedges' g	Interpretation
Digit Span Backward	Wilcoxon	Control	0.00	1.00	--	No significant change
	Wilcoxon	Intervention	-1.30	.190	--	No significant change
	Mann-Whitney U	Between-groups	-0.72	.470	0.40	Not significant, small-to-moderate effect
Number Series	Wilcoxon	Control	-0.92	.36	--	No significant change, negligible effect
	Wilcoxon	Intervention	-0.89	.37	--	No significant change, small effect
	Mann-Whitney U	Between-groups	-1.16	.25	0.59	Not significant, moderate effect favoring intervention
Numbers Reversed	Wilcoxon	Control	-0.73	.47	--	No significant change, small effect
	Wilcoxon	Intervention	-1.05	.292	--	No significant change, small effect
	Mann-Whitney U	Between-groups	-0.78	.44	0.18	Not significant, negligible-to-small effect

Table 19

Descriptive Statistics for Performance-Based Working Memory Measures by Group

Measure	Intervention Mean (SD)	Intervention Median (IQR)	Control Mean (SD)	Control Median (IQR)
Digit Span Backward bTEML (Pre)	4.11 (1.27)	4.00 (3.00–4.50)	4.75 (0.50)	5.00 (4.25–5.00)
Digit Span Backward bTEML (Post)	4.67 (1.50)	5.00 (3.50–6.00)	4.75 (0.50)	5.00 (4.25–5.00)
Number Series (Pre)	100.22 (15.08)	94.00 (90.00–114.00)	110.50 (15.07)	113.00 (95.25–123.25)
Number Series (Post)	103.00 (13.77)	98.00 (92.00–114.50)	107.75 (17.95)	107.50 (90.50–125.25)
Numbers Reversed (Pre)	98.67 (14.76)	103.00 (83.50–110.50)	105.50 (5.32)	105.50 (100.50–110.50)
Numbers Reversed (Post)	95.22 (13.69)	97.00 (84.00–107.50)	99.75 (11.18)	98.00 (90.00–111.25)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

WJ Verbal Attention. The Verbal Attention subtest of the WJ IV was not statistically significant in the control group, $z = -0.37$, $p = .72$, or the intervention group, $z = -0.34$, $p = .73$. Between-group differences were also not statistically significant, $U = 13.00$, $z = -0.78$, $p = .44$, although the between-group effect size was small-to-moderate ($g = 0.34$), favoring the intervention group. The intervention group had a mean change score of 2.33 (SD = 11.54, *Mdn* = 0.00), while the control group had a mean of -2.25 (SD = 11.95, *Mdn* = -6.00).

Stop Signal Task. Wilcoxon signed-rank tests were conducted to examine pre-post changes in inhibitory control, as measured by the probability of responding on stop trials (pRs). In this task, lower pRs values indicate better inhibitory control, as they reflect fewer failed stop attempts. The difference in the control group was not statistically significant, $z = -0.37$, $p = .72$, with a mean change of -8.49 (SD = 29.60, *Mdn* = 5.21). In the intervention group, six participants showed improvement in pRs, while three declined. This change did not reach statistical significance, $z = -1.84$, $p = .07$, though the average improvement was -8.37 (SD =

11.16, *Mdn* = -10.48). Wilcoxon signed-rank tests were also completed to examine pre-post changes in stop signal delay (SSD), a complementary marker of inhibitory control that adjusts dynamically based on performance. In this task, an increase in SSD reflects better inhibitory control, as it indicates the participant was able to stop successfully more often, prompting the task to become more difficult. In the control group, the difference was not statistically significant, $z = -0.37$, $p = .72$. The average SSD change was 32.72 (SD = 154.31, *Mdn* = -12.60). In the intervention group, the change was also not statistically significant, $z = -1.84$, $p = .07$; however, participants demonstrated greater improvement (M = 189.23, SD = 238.78, *Mdn* = 76.47). A Mann–Whitney U test comparing pRs change scores between groups was not statistically significant, $U = 11.00$, $z = -1.08$, $p = .28$, and the between-group effect size was negligible ($g = 0.01$). A Mann–Whitney U test comparing SSD change scores between groups was also not statistically significant, $U = 10.00$, $z = 1.23$, $p = .22$, but yielded a large effect size ($g = 0.61$), favoring the intervention group.

Table 20

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for Performance-Based Measures of Inhibitory Control

Measure	Test	Group	*z*	*p*	Hedges' g	Interpretation
Verbal Attention	Wilcoxon	Control	-0.37	.72	--	No significant change, negligible effect
	Wilcoxon	Intervention	-0.34	.73	--	No significant change, small effect
	Mann-Whitney U	Between-groups	-0.78	.44	0.34	Not significant, small-to-moderate effect
Stop Signal Task (pRs)	Wilcoxon	Control	-0.37	.72	--	No significant change
	Wilcoxon	Intervention	-1.84	.07	--	No significant change, small-to-moderate effect
	Mann-Whitney U	Between-groups	-1.08	.28	0.01	Not significant, negligible difference
Stop Signal Task (ssd)	Wilcoxon	Control	-0.37	.72	--	No significant change, negligible effect
	Wilcoxon	Intervention	-1.84	.07	--	Not statistically significant
	Mann-Whitney U	Between-groups	1.23	.22	0.61	Not significant, large effect favoring intervention

Table 21

Descriptive Statistics for Performance-Based Measures of Inhibitory Control

Measure	Group	Mean (SD)	Median (IQR)
Verbal Attention (Pre)	Control	104.75 (6.40)	102.50 (11)
	Intervention	102.78 (10.32)	102.00 (16)
Verbal Attention (Post)	Control	102.50 (10.76)	101.00 (21)
	Intervention	105.11 (10.22)	105.00 (16)
pRs (Pre)	Control	70.28 (31.28)	70.76 (57.08)
	Intervention	52.70 (17.66)	48.08 (13.49)
pRs (Post)	Control	61.79 (25.55)	50.00 (40.58)
	Intervention	44.34 (21.55)	45.28 (14.12)
SSD (Pre)	Control	303.07 (290.61)	288.68 (518.16)
	Intervention	365.86 (218.20)	319.81 (199.88)
SSD (Post)	Control	335.79 (217.93)	364.37 (415.17)
	Intervention	555.09 (319.35)	473.15 (560.55)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

Cognitive Flexibility

It was hypothesized that adolescents in the behavioral sleep intervention condition would demonstrate improvements in cognitive flexibility post-intervention. Test and descriptive statistics for performance-based measures of Cognitive Flexibility can be found in Tables 22 and 23.

Self-Report BRIEF. To examine whether cognitive flexibility improved from pre- to post-intervention, Wilcoxon signed-rank tests were conducted using scores from the BRIEF Shift subscale. The control group showed a marginally significant improvement, $z = -1.84$, $p = .070$. The intervention group also did not have statistically significant results, $z = –1.61$, $p = .110$. The control group had a mean change of 7.50 ($SD = 2.38$, $Mdn = 6.50$). The intervention group had a mean change of 2.78 ($SD = 4.71$, $Mdn = 3.00$). A Mann–Whitney U test comparing change scores between groups was not statistically significant, $U = 7.00$, $Z = -1.71$, $p = .088$. However, the between-group effect size was large ($g = -0.96$).

BRIEF Parent-Report. Wilcoxon signed-rank tests were used to assess changes in parent-reported cognitive flexibility from pre- to post-intervention, as measured by the BRIEF Shift subscale. The control group demonstrated a non-significant change, $z = -1.60$, $p = .110$, with a mean reduction in symptoms of -7.00 ($SD = 6.22$, $Mdn = -7.00$). The intervention group also showed no statistically significant change, $z = -1.53$, $p = .130$, with a mean change of -3.22 ($SD = 5.76$, $Mdn = -3.00$). A Mann–Whitney U test revealed no significant between-group difference in cognitive flexibility change scores, $U = 11.50$, $z = -1.02$, $p = .310$. However, the between-group effect size was moderate ($g = 0.55$), suggesting greater improvements in cognitive flexibility among adolescents in the control group compared to those in the intervention group, based on parent report.

Trail Making Test. Wilcoxon signed-rank tests were conducted to assess within-group changes in cognitive flexibility, as measured by the difference between Trail Making Test Time Trial 2 and Time Trial 1 (i.e., TMT shift score). Results did not produce statistically significant change in the control group, $z = -0.37$, $p = .72$, with a mean change score of -5,661.00 (SD = 36,708.43, *Mdn* = -4,621.50). The change in the intervention group was not statistically significant, $z = -1.96$, $p = .51$. The intervention group demonstrated a mean change of -10,611.89 (SD = 13,926.57, *Mdn* = -16,196.00). Between-group differences in change in cognitive flexibility, as measured by the TMT shift score, were examined using a Mann–Whitney U test. This difference was not statistically significant, $U = 16.00$, $z = -0.31$, $p = .76$, and the between-group effect size was small ($g = -0.19$), favoring the intervention group.

WJ Concept Formation. Wilcoxon signed-rank tests were used to assess changes in cognitive flexibility, as measured by the Concept Formation subtest of the WJ IV. The change in the control group was not statistically significant, $z = -1.83$, $p = .68$. Change in the intervention group approached statistical significance, $z = -1.96$, $p = .05$, indicating potential gains in cognitive flexibility. Using a Mann–Whitney U test to assess between-group differences in cognitive flexibility, the difference was not statistically significant, $U = 9.00$, $z = -1.39$, $p = .16$. However, the between-group effect size was moderate ($g = -0.61$), favoring the intervention group. The intervention group had a mean change score of 7.78 (SD = 11.90, *Mdn* = 6.00), while the control group had a mean of 15.50 (SD = 7.05, *Mdn* = 16.50).

Table 22

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for Performance-Based Measures of Cognitive Flexibility

Measure	Test	Group	*z*	*p*	Hedges' g	Interpretation
Trail Making Test (shift score)	Wilcoxon	Control	-0.37	.72	--	No significant change, negligible effect
	Wilcoxon	Intervention	-1.96	.51	--	No significant change, moderate effect
	Mann-Whitney U	Between-groups	-0.31	.76	-0.19	Not significant, small effect favoring intervention
Concept Formation	Wilcoxon	Control	-1.83	.68	--	No significant change
	Wilcoxon	Intervention	-1.96	.05	--	Approached significance
	Mann-Whitney U	Between-groups	-1.39	.16	-0.61	Not significant, moderate effect favoring intervention

Table 23

Descriptive Statistics for Performance-Based Measures of Cognitive Flexibility

Measure	Group	Mean (SD)	Median (IQR)
TMT Shift (Pre)	Control	32049.25 (26134.06)	34198.00 (49906.25)
	Intervention	16318.89 (19314.43)	11848.00 (22560.00)
TMT Shift (Post)	Control	26388.25 (11636.28)	29576.50 (21066.25)
	Intervention	5707.00 (15222.19)	4898.00 (24420.00)
WJ CF (Pre)	Control	108.50 (7.59)	110.00 (14.00)
	Intervention	109.22 (6.34)	111.00 (13.00)
WJ CF (Post)	Control	124.00 (11.49)	121.00 (21.00)
	Intervention	117.00 (11.03)	120.00 (20.00)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

EF Overall

It was hypothesized that adolescents in the behavioral sleep intervention condition would demonstrate improvements in overall EF post-intervention. Test and descriptive statistics for BRIEF (Self- and Parent-Report) can be found in Tables 24 through 27.

Self-Report BRIEF. To examine overall EF, Wilcoxon signed-rank tests were conducted using the BRIEF Global Executive Composite (GEC) scores. The control group did not show a statistically significant change from pre- to post-intervention, $z = -0.74$, $p = .46$. The intervention group also showed no statistically significant change, $z = -0.07$, $p = .94$. The control group had a mean change of 0.75 (*SD* = 2.06, *Mdn* = 1.00). The intervention group had a mean change of -0.56 (*SD* = 3.21, *Mdn* = 0.00). A Mann–Whitney U test revealed no significant between-group difference, $U = 14.00$, $Z = -0.63$, $p = .530$. The between-group effect size was small-to-moderate ($g = -0.38$), favoring the intervention group.

BRIEF Parent-Report. Changes in overall EF were assessed using Wilcoxon signed-rank tests conducted within each group. In the control group, no significant change was detected, $z = -0.55$, $p = .58$, with a mean change score of -2.25 (*SD* = 5.44, *Mdn* = -0.50). In the intervention group, the change was also not statistically significant, $z = -1.26$, $p = .21$, with a mean change score of -2.56 (*SD* = 5.27, *Mdn* = -2.00). A Mann–Whitney U test indicated no significant between-group difference, $U = 16.50$, $z = -0.23$, $p = .82$. The between-group effect size was negligible ($g = -0.05$), suggesting that both groups showed similar reductions in EF difficulties based on parent report.

Table 24

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for BRIEF Self-Report Subscales

Subscale	Test	Group	*z*	*p*	Hedges' g	Interpretation
Working Memory	Wilcoxon	Control	0.00	1.00	--	No significant change
	Wilcoxon	Intervention	-0.49	.620	--	No significant change
	Mann-Whitney U	Between-groups	-0.55	.580	-0.31	Not significant, small-to-moderate effect favoring intervention
Inhibit	Wilcoxon	Control	-0.18	.850	--	No significant change
	Wilcoxon	Intervention	-0.66	.510	--	No significant change
	Mann-Whitney U	Between-groups	-0.08	.940	-0.04	Not significant, negligible effect
Shift	Wilcoxon	Control	-1.84	.070	--	Marginally significant improvement, very large effect
	Wilcoxon	Intervention	-1.61	.110	--	Not significant
	Mann-Whitney U	Between-groups	-1.71	.088	-0.96	Not significant, large effect favoring intervention
GEC	Wilcoxon	Control	-0.74	.460	--	No significant change
	Wilcoxon	Intervention	-0.07	.940	--	No significant change
	Mann-Whitney U	Between-groups	-0.63	.530	-0.38	Not significant, small-to-moderate effect favoring intervention

Table 25

Descriptive Statistics for BRIEF Self-Report Subscales by Group

BRIEF Subscale	Intervention Mean (SD)	Intervention Median (IQR)	Control Mean (SD)	Control Median (IQR)
Working Memory (Pre)	70.11 (14.60)	72.00 (58.00–83.50)	68.00 (11.83)	64.00 (59.50–80.50)
Working Memory (Post)	68.33 (15.93)	66.00 (54.00–85.00)	68.50 (13.48)	68.00 (55.75–81.75)
Inhibit (Pre)	64.78 (9.74)	67.00 (56.50–73.00)	61.25 (8.62)	58.00 (55.75–70.00)
Inhibit (Post)	63.44 (10.54)	64.00 (53.50–74.00)	60.25 (5.68)	62.50 (54.25–64.00)
Shift (Pre)	62.33 (11.63)	64.00 (55.50–71.00)	62.25 (11.53)	64.50 (50.25–72.00)
Shift (Post)	65.11 (12.62)	69.00 (55.50–75.50)	69.75 (12.82)	70.50 (57.00–81.75)
GEC (Pre)	67.11 (12.07)	72.00 (52.50–75.00)	67.00 (10.61)	63.50 (59.25–78.25)
GEC (Post)	66.56 (12.33)	71.00 (54.00–77.00)	67.75 (11.12)	65.50 (58.50–79.25)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

Table 26

Wilcoxon Signed-Rank and Mann-Whitney U Test Results for BRIEF Parent-Report Subscales

Subscale	Test	Group	*z*	*p*	Hedges' g	Interpretation
Working Memory	Wilcoxon	Control	-1.60	.110	--	No significant change
	Wilcoxon	Intervention	-0.93	.350	--	No significant change
	Mann-Whitney U	Between-groups	-0.78	.440	0.38	Not significant, moderate effect favoring control
Inhibit	Wilcoxon	Control	-1.34	.180	--	No significant change
	Wilcoxon	Intervention	-0.77	.440	--	No significant change
	Mann-Whitney U	Between-groups	-0.47	.640	0.27	Not significant, small effect favoring control
Shift	Wilcoxon	Control	-1.60	.110	--	No significant change
	Wilcoxon	Intervention	-1.53	.130	--	No significant change
	Mann-Whitney U	Between-groups	-1.02	.310	0.55	Not significant, moderate effect favoring control
GEC	Wilcoxon	Control	-0.55	.580	--	No significant change
	Wilcoxon	Intervention	-1.26	.210	--	No significant change
	Mann-Whitney U	Between-groups	-0.23	.820	-0.05	Not significant, negligible effect

Table 27

Descriptive Statistics for BRIEF Parent-Report Subscales by Group

BRIEF Subscale	Intervention Mean (SD)	Intervention Median (IQR)	Control Mean (SD)	Control Median (IQR)
Working Memory (Pre)	64.89 (8.42)	67.00 (60.00–70.50)	72.50 (7.05)	71.50 (66.50–79.50)
Working Memory (Post)	63.22 (8.23)	61.00 (58.50–69.00)	68.25 (8.58)	70.50 (59.50–74.75)
Inhibit (Pre)	59.44 (12.31)	66.00 (48.00–71.00)	63.00 (10.10)	63.00 (53.25–72.75)
Inhibit (Post)	57.33 (7.00)	57.00 (53.00–62.00)	58.25 (4.92)	60.00 (53.25–61.50)
Shift (Pre)	60.78 (17.09)	56.00 (45.50–74.00)	70.25 (11.21)	74.00 (58.50–78.25)
Shift (Post)	57.56 (12.97)	56.00 (45.00–68.50)	63.25 (8.62)	63.50 (55.00–71.25)
GEC (Pre)	61.78 (8.33)	63.00 (55.50–70.50)	68.50 (4.73)	67.00 (65.00–73.50)
GEC (Post)	59.22 (7.82)	60.00 (51.50–66.00)	66.25 (3.40)	65.50 (63.50–69.75)

Note. SD = Standard Deviation. IQR = Interquartile Range based on weighted average percentiles.

Chapter 5: Discussion

The purpose of the current study was to investigate the acceptability of a behavioral sleep intervention emphasizing adolescents with ADHD extending their sleep consistently to increase their overall sleep duration and improve sleep quality. The second objective was to determine the impact of a behavioral sleep intervention on sleep duration, sleep quality, and EF, in a population of adolescents with ADHD. Specifically, this study examined 1) the acceptability of the intervention, 2) sleep duration and quality (variability and self- and parent-ratings), and 3) EF abilities, working memory, inhibitory control, and cognitive flexibility. The present study consisted of 13 adolescents and one of their caregivers from a southwestern state. Study hypotheses predicted that the adolescents in the behavioral sleep extension intervention condition would show increases in sleep duration (i.e., increased TST and TIB via actigraphy data), decreases in average sleep duration variability (i.e., decreased variance in total sleep time across nights via actigraphy data), and would demonstrate improvements in working memory, inhibitory control, and cognitive flexibility (i.e., increases in WJ-IV standard scores, and decreases in BRIEF t-scores for overall EF, working memory, inhibit, and shift (which suggest improved functioning) and increases in z-scores for trail making, stop signal, and digit span backward). Most parents and adolescents found the concept of getting more sleep acceptable but acknowledged challenges of changing habits to successfully increase TST and readily identified barriers to providing themselves a healthy sleep opportunity window on a consistent basis. Further, despite the small sample size, which compromised power for statistical testing, the effect sizes suggest that the intervention may have been effective in increasing sleep duration, time in bed, and improvement in some domains of EF.

Framing this behavioral sleep intervention through the biopsychosocial model provides a valuable lens for understanding and targeting the multiple influences on adolescent sleep behavior. This framework recognizes that sleep is not solely a biological process, but is shaped by the interaction of internal rhythms, environmental cues, individual psychology factors, and the broader social context (Becker et al., 2015). By applying this model, the intervention allowed for a flexible, individualized approach that targeted biological, psychological, and social domains relevant to each adolescent's unique sleep challenges. Although the primary target was sleep extension, the interventional components were not implemented universally; rather, they were collaboratively selected and tailored based on each participant's specific sleep profile, preferences, and barriers.

Acceptability of Intervention

This study examined the acceptability and perceived impact of a behavioral sleep extension intervention among adolescents with ADHD and their parents. Overall, both adolescents and their parents rated the intervention positively, with most participants finding the research team member helpful, reporting at least some success in sleep duration and quality, and identifying several helpful strategies related to behavior change affecting sleep. The acceptability of this intervention was consistent with previously established acceptability of behavioral sleep interventions in populations of children and adolescents with ADHD (Becker et al., 2021; Sciberras et al., 2011).

A key finding was the strong endorsement of the intervention's feasibility and perceived helpfulness. The majority of adolescent participants (89%) reported that speaking with a research team member was helpful in modifying their sleep behaviors. Similarly, all parents reported that support from the research team member was at least somewhat helpful. This suggests that adolescents with ADHD, and their parents, may be receptive to guided behavioral interventions for sleep when provided with clear support and structure. Rapport between the interventionist and family likely played a role in fostering engagement and trust, especially in a population where motivation and follow through can be challenging (Smith & Langberg, 2018). Adolescents may have been more willing to reflect on and change sleep behaviors when information was delivered by someone they perceived as supportive, nonjudgmental, and consistent. The structured format of the sessions, including regular check-ins, individualized feedback, and collaborative goal setting, may have further reinforced accountability and made the intervention feel manageable. Together, these relational and structural elements likely enhanced both the acceptability and impact of the intervention, highlighting the importance of rapport building in behavioral sleep interventions for adolescents with ADHD.

Both adolescents and parents reported moderate success in improving sleep duration and quality. Importantly, most adolescents (78%) perceived themselves as at least somewhat successful at increasing their sleep duration. This finding was largely echoed by parents, with

89% reporting that their child was at least somewhat successful at increasing their sleep duration. Despite this perceived success, few participants expressed strong confidence in maintaining these changes beyond the intervention period, which may suggest a need for additional booster sessions or ongoing support to promote long-term success.

Qualitative feedback provided more insight into the factors that served as facilitators and barriers to success. Adolescents frequently attributed their improvements in sleep to implementing a consistent sleep schedule, while parents highlighted structural supports such as reminders to abide by the sleep schedule, lifestyle changes, and environmental modifications. These responses affirm the value of targeting daily routines to promote healthy sleep. This aligns with prior research demonstrating that consistent sleep routines are associated with earlier sleep onset, longer sleep duration, and improved sleep quality in adolescents (Buxton et al., 2015). Structured routines help counteract natural shifts in adolescents' biological sleep timing and support sleep patterns that are better suited to meet the demands of early school start times and family schedules. Moreover, routines may be especially important for adolescents with ADHD, who often struggle with self-regulation and benefit from predictable, externally supported frameworks to guide behavior.

Barriers to implementation primarily included adolescents expressing difficulty adjusting to an earlier bedtime, struggles adjusting long-standing routines, and some internal factors with cognitive arousal at night. Parents also described a central role in reinforcing new sleep habits and routines, primarily through reminders, suggesting that caregiver involvement may be a key mechanism for promoting adherence in adolescents with ADHD.

Finally, most participants did not offer specific suggestions for improving the study, though some ideas such as more efficient sleep diaries, a longer intervention period, and adding components of peer support, were offered. Although participants noted that the sleep diaries were delivered in an inefficient manner, their continued use in future research is warranted. Sleep diaries are more strongly correlated with adolescents' reports of sleep problems, better discriminate WASO, and show stronger associations with daytime functioning compared to actigraphy (Short et al., 2012).

The duration of the study was one month (28-days) from initial to final meeting with participants and their parent or guardian. The first two weeks of the study was used to collect baseline sleep data from each participant in a naturalistic sleep period. A naturalistic baseline period of two weeks allowed for patterns to be observed (Perfect et al., 2023) and was an initial check in for a longer-term study if research were to continue. While this intervention was brief, it was rated as acceptable by adolescents with ADHD, similar to previous brief behavioral sleep interventions (Malkani et al., 2022). Initial feasibility of this intervention examined the impact of sleep extension over one week and then expanded to three months to correspond with quarterly visits of individuals with type 1 diabetes (Perfect et al., 2023). Future research should consider expanding the timeframe for individuals with ADHD.

Although this study did not include a formal, validated measure, multiple fidelity components were tracked and implemented throughout the intervention. Fidelity refers to the degree to which an intervention is delivered as intended and is critical for ensuring consistency and replicability of results (Bellg et al., 2004). In the present study, adherence was supported by the use of a structured checklist for the intervention content delivery, and all sessions were conducted by a single interventionist to maintain consistency. Exposure or dose was standardized across participants, with each receiving three in-person sessions and two follow-up calls. While the short intervention period may be considered a limitation, it may also represent an efficient and acceptable dose for brief behavioral sleep interventions.

Overall, findings indicate that the behavioral sleep extension intervention was acceptable and feasible for adolescents with ADHD and their families, with encouraging evidence provided from adolescents and parents' perceived success. Acceptability is a critical construct in evaluating behavioral interventions, especially during early-stage trials. It reflects participants' willingness and ability to engage with intervention components, offering insight into the acceptability of the intervention in real-world settings (Finn & Sladeczek, 2001This was demonstrated in the current study, through high attendance at in-person meetings, strong engagement with booster calls, and frequent completion of daily sleep diaries. These patterns suggest that while there was some variability, the majority of participants demonstrated sustained engagement across multiple domains. Together, these findings support the acceptability of the intervention and underscore the value of acceptability-focused metrics as a primary aim in early behavioral intervention research.

Sleep Modification

This study examined whether a behavioral sleep extension intervention for adolescents with ADHD led to improvements in sleep. It was hypothesized that adolescents in the intervention group would demonstrate increased sleep duration and/or reduced variability in sleep timing compared to those in the control group. Findings provided preliminary support for this hypothesis. Adolescents in the intervention condition showed statistically significant within-group improvements in both TST and TIB, with large effect sizes. These changes were consistent across nearly all participants in the intervention group and contrasted with variable changes observed in the control group. Although between-group comparisons did not reach statistical significance, the observed effect sizes for TST (*g* = 0.93) and TIB (*g* = 0.83) suggest large effects favoring the intervention. Although not statistically significant due to small sample size and limited statistical power, these results provide early evidence supporting the need for future research to evaluate the efficacy of this intervention in a large-scale randomized control trial. These results reflect the feasibility of at home sleep interventions for adolescents that have been established through previous research (Beebe et al., 2025; Fidler et al., 2024; Perfect et al., 2016; 2023).

Other objective sleep outcomes also demonstrated patterns consistent with positive intervention effects. While changes in SE and SOL were not statistically significant, the direction of effects and associated effect sizes support a potential intervention benefit. SE remained stable in the intervention group but declined in the control group, yielding a small to medium effect size (*g* = 0.44). Similarly, SOL decreased in the intervention group and increased in the control group, producing a medium-to-large effect (*g* = -0.60). Notably, night-to-night variability in TST (CVTST) improved in the intervention group and worsened in the control group, resulting in a large between-group effect (*g* = -1.11). Although the absolute change in variability was modest, this pattern suggests that the intervention may promote a more consistent sleep schedule.

In contrast, self- and parent-report measures of sleep behaviors and sleep disturbance symptoms showed minimal change. No statistically significant changes were observed across the CRSP indices (caffeine use, electronics before bed, evening activities, and sleep location), with small effect sizes that were mixed in direction. Similarly, self- and parent-reported sleep disturbance (e.g., bedtime resistance, parasomnias, insomnia, and daytime sleepiness) did not show statistically significant improvements, with several outcomes showing small to medium effects favoring the control group. These findings suggest that while the intervention was effective in increasing sleep duration and consistency, it may not have been a long enough intervention to impact broader sleep-related behaviors or symptoms, especially those that may require parental involvement to address.

Viewed together, the results provide initial support for this behavioral sleep extension intervention as a feasible and promising approach for improving sleep in adolescents with ADHD. Objective actigraphy data captured consistent improvements in sleep duration and consistency within the intervention group, with medium-to-large effect sizes across most parameters. Although many findings did not reach statistical significance, likely due to the small sample size, the direction and magnitude of effects consistently favored the intervention group.

However, the brief duration of the intervention is an important limitation. Sustained behavioral change often requires longer-term support, and without follow-up data, it remains unclear whether improvements were maintained beyond the active intervention phase. It is also important to consider that adolescents with ADHD may face unique challenges in implementing and maintaining sleep-related strategies. Some youth may be unwilling to give up competing activities, may not perceive the value in changing their sleep behaviors, or may be less likely to adopt strategies if they feel they are being told what to do. These motivational and self-regulatory barriers could limit real-world effectiveness without individualized, ongoing support. Regarding the control group, while some improvements were noted, the very small sample size ($n = 4$) and lack of baseline equivalence checks make it difficult to determine whether these changes reflected genuine within-group improvement or simply differences from the intervention group at post-test. Future studies with larger samples and extended follow-up periods are needed to clarify these patterns and determine the durability and generalizability of treatment effects.

Importantly, the brief nature of the intervention underscores its potential for scalability and real-world application. The total contact time across the intervention meeting (30 – 45 minutes) and two brief follow-up calls (10 – 20 minutes combined) amounted to under 90 minutes per participant. This stands in contrast to many ADHD sleep interventions that require extended coaching sessions or multiple parent-training modules (Becker et al., 2022; Malkani et al., 2022). Rather than focusing on prescriptive instruction, this intervention emphasized collaborative, solution-focused problem solving between the interventionist, adolescent, and the parent. By guiding families in identifying barriers to sleep extension and co-developing actionable strategies, the intervention supported autonomy and internal motivation. These dyadic interactions may have provided added a relational mechanism that helped facilitate behavioral change. These interactions not only helped normalize sleep difficulties but also framed recommendations with a rationale that emphasized adolescent well-being and functioning. In this way, the intervention integrated psychoeducation with relational support, which may have helped reduce resistance to implementation.

These preliminary findings indicate that behavioral sleep extension interventions may be effective in addressing short sleep duration and variability in adolescents with ADHD. This study adds to the existing literature of case and pilot studies that have found acceptability, feasibility, and preliminary evidence for behavioral sleep interventions in populations of adolescents with ADHD (Becker et al., 2021; Mullane & Corkum, 2006; Sciberras et al., 2011Vetrayan et al., 2017)

Impact on EF

This study's emphasis on EF drew on previous research that has found associations between sleep and neurocognitive outcomes, particularly EF (Clarck et al., 2017; Kuula et al., 2015). This study examined whether a behavioral sleep extension intervention for adolescents with ADHD was associated with improvements in EF. EF was assessed using a global composite score and domain-specific measures of working memory, inhibitory control, and cognitive flexibility, based on self- and parent-report as well as performance-based tasks. It was hypothesized that adolescents in the intervention group would report greater positive changes in one or more areas of EF compared to those in the control group. Although no statistically significant between-group differences were observed, several small to medium effect sizes suggest potential intervention-related improvements in EF.

Across working memory measures, results suggested potential benefits of the sleep extension intervention, though the pattern of findings varied by task and informant. Adolescents in the intervention group showed signs of improvement on multiple performance-based tasks and in self-reported executive functioning, whereas parent ratings suggested fewer changes. This divergence between adolescent and parent perspectives is not uncommon in ADHD research and may reflect differences in insight versus observable behavior (Conijin et al., 2023). However, previous research, related to sleep and adolescents with ADHD, has shown parent-reported improvement in EF with longer intervention periods (3 months), which may allow for more observable change (Becker et al., 2021).

This discrepancy may also be partially explained by the nature of the tasks themselves. Some standardized measures, such as the WJ Numbers Reversed, may be less sensitive to short-term cognitive changes due to their design as assessments of more stable cognitive abilities. This echoes conclusions from previous work suggesting that performance-based executive functioning tasks may not fully capture functional improvements unless the intervention is extended over a longer period or paired with more ecologically valid assessment tools (Becker et al., 2021; Krieger & Amador-Campos, 2017).

A similar pattern emerged for inhibitory control. Although overall group differences were modest, after the intervention adolescents in the intervention group tended to perform better on tasks that directly measure response inhibition and attentional control. These results align with findings from both experimental and intervention studies showing that inadequate sleep can lead to impaired inhibition, greater distractibility, and reduced arousal in adolescents (Hershner, 2020; Hvolby, 2015). The fact that performance-based measures showed more consistent improvement than subjective reports may indicate that these tasks are more sensitive to the types of cognitive and attentional shifts promoted by improved sleep duration and consistency.

Cognitive flexibility findings were less consistent. Although some evidence suggested that adolescents in the intervention group experienced fewer increases in shifting difficulties than those in the control group, this effect was not mirrored in parent reports or across all performance-based tasks. These discrepancies may be due to differences in how cognitive flexibility manifests behaviorally versus in structured test settings, or due to the short duration of the intervention. It is also possible that the stressors and transitions of adolescence complicate shifts in flexibility, especially given the complex interplay between sleep, emotional regulation, and cognitive adaptability noted in prior research (Deldar Gohardani et al., 2023).

When considering global executive functioning, adolescent self-report again suggested greater improvements in the intervention group. This is consistent with previous studies reporting improvements in daily executive functioning and attention following behavioral sleep interventions in adolescents with ADHD (Becker et al., 2021). However, parent-report data revealed little change, suggesting again that perceived improvement may not always be externally observable in the short term.

Taken together, these findings align with emerging literature emphasizing the importance of individualized, developmentally appropriate sleep interventions for adolescents with ADHD. Behavioral changes stemming from improved sleep may first emerge as internal experiences, such as feeling more focused, alert, or organized, before becoming apparent in externally observable behavior. This underscores the need for both multi-informant and multi-method assessment approaches when evaluating intervention outcomes. It also suggests that further research with larger samples and extended follow-up periods is needed to fully capture the trajectory of executive functioning improvements following sleep-focused interventions.

In summary, while no statistically significant group differences were found, several indicators pointed to modest improvements in working memory, inhibitory control, and overall EF among adolescents in the intervention group. Trends were most consistently observed in self-report data and performance-based tasks, with effect sizes ranging from small to large. Although findings were mixed across informants and measures, the pattern of results suggests that behavioral sleep extension may contribute to improvements in specific areas of EF in adolescents with ADHD.

Limitations

Several limitations should be considered when interpreting the findings of this pilot study. These include the small sample size, intervention matters (duration, fidelity), measurement of executive function (EF), and limitations inherent to actigraphy particularly for youth with ADHD.

Sample Size

First, and most notable, is the small sample size (*n* = 13), which is typical for early-stage feasibility research and consistent with other recent home-based sleep intervention studies (e.g., Martyn-Nemeth et al., 2023; Mathew et al., 2023; Meltzer et al., 2022). Although this limited statistical power to detect between-group differences, the primary aim of this pilot was to assess feasibility, acceptability, and the potential impact of the intervention by examining changes in key outcomes. Limited power may have reduced the ability to detect between-group differences, even in the presence of moderate to large effect sizes. However, this sample size is consistent with other recent home-based sleep intervention studies, including those in pediatric and adolescent populations such as Meltzer et al. (2022; crossover, 10 youth with asthma), as well as small randomized pilot studies in adults, such as Martyn-Nemeth et al. (2023; 3:2 allocation, 14 adults with type 1 diabetes) and Mathew et al. (2023; crossover, 12 college students). These small samples reflect the logistical and methodological challenges of intensive, home-based sleep research and are typical in early-stage feasibility and pilot work (Mathew et al., 2024; crossover, 12 participants). Nonetheless, small sample sizes can inflate effect sizes and limit generalizability, but they are a necessary step in intervention development and refinement. Additionally, families who volunteered may have been more motivated or interested in sleep improvement than the general population of adolescents with ADHD, potentially limiting external validity. Future research could expand recruitment efforts to local libraries, pediatricians, and behavioral health clinics (Mire et al., 2024).

Demographic Diversity

Second, although the small sample size in this study was adequate for establishing acceptability, it lacked demographic diversity and was drawn from a single geographic region. The sample also skewed slightly towards younger adolescents. Although the inclusion of gender-diverse participants is a strength in terms of inclusivity, it also means the findings may not be representative of all adolescents with ADHD. The biological sex distribution in this sample also deviated from expected ADHD prevalence ratios. In community samples, ADHD is typically diagnosed at a rate of approximately 2:1 in males to females (Polanczyk et al., 2007). In contrast, this sample included more biologically female participants (53.8%) than males, which may have influenced presentation, treatment responsiveness, or reporting patterns.

Intervention Matters

The brief two-week intervention period, while sufficient to impact sleep duration and timing, may have been too short to produce sustained changes in executive function. A longer intervention period and follow-up periods are warranted to assess the durability of effects (see Perfect et al., 2023). Future research should evaluate longer-term effectiveness. Quality of delivery was supported by the interventionist's training as a doctoral-level clinician with specialized experience in behavioral sleep medicine. Participant responsiveness was high, with strong engagement in scheduled sessions and sleep diary completion. Finally, program differentiation was maintained, as the control group did not receive sleep-related psychoeducation or behavioral strategies, nor did they have access to view their actigraphy data. Together, these elements support a moderate level of intervention fidelity, even in the absence of formal observational fidelity monitoring.

Tracking Daily Sleep

Data from actigraphy also demonstrated an interesting obstacle. First, although actigraphy was able to provide valuable information on sleep timing and duration, many participants forgot to wear their device at times or wore the actiwatch too loosely to record data for periods of time. Sleep periods are manually adjusted on actigraphy data. The start of these sleep periods is typically marked by five or more consecutive minutes without movement (ac = 0). However, it was difficult to find such periods within this population, as most participants had low level movements throughout their sleep periods. Children and adolescents with ADHD often exhibit elevated levels of motor activity, including during the sleep onset period. Meta-analysis findings indicate that youth with ADHD show higher average activity levels throughout the day and night, including sleep onset, compared to typically developing peers, even when overall sleep duration is similar (De Crescenzo et al., 2016). The increased movement during the transition to sleep may reduce the accuracy of standard actigraphy scoring algorithms, which typically rely on immobility to detect sleep onset. As a result, sleep latency may be overestimated and TST may be underestimated, especially with higher immobility thresholds (e.g., 10 minutes or more) are used. In populations with more movement than typical, it may be important to use visual inspection of light and movement patterns to more accurately define rest intervals (Chow et al., 2016).

In terms of subjective sleep data, the use of sleep diaries should be carefully considered (Aili et al., 2017; Rogers, 1993). This study administered daily sleep diaries through REDCap each morning but had inconsistent response rates. Alternative approaches, such as app-based diaries with automated prompts could improve engagement and provide more complete data. User-friendly, low-burden tools with reminders are likely to be more effective for adolescents with ADHD.

To remedy challenges with monitoring compliance and sleep patterns, it may be useful to incorporate alternative objective sleep measures to improve data quality. As such, it may be useful to collect objective sleep data through the use of an under-the-bed sensor to collect sleep data with fewer adherence issues. Combining multiple objective measures may also serve as a way to enhance reliability. Recent advances in sleep measurement technology, including contactless sensors and wearable devices with improved adherence, should be considered in future studies (Haghi et al., 2024).

Measurement of EF

A strength of this study was the use of multi-informant and multi-method assessment of EF, including self-report, parent-report, and performance-based measures (BRIEF, WJ-IV, Stop Signal, Trail Making, Digit Span Backward). However, the WJ-IV subtests purported to capture EF have not been specifically validated for short-term intervention sensitivity in adolescents with ADHD. Additionally, the time between baseline and post-intervention assessments was brief, which may limit the ability to detect meaningful changes in cognitive performance. For example, one subtest showed improvement across all participants, which may reflect practice effects rather than true intervention impact. Future research should consider longer intervals between assessments and the use of EF tasks with established sensitivity to change.

Future Directions

Information obtained through this pilot study may help inform future research on behavioral sleep extension interventions for adolescents with ADHD. A larger-scale randomized control trial (RCT) is needed to replicate these preliminary findings with greater statistical power. A larger sample would not only enhance the ability to detect between-group differences but would most likely yield a more representative sample of ADHD presentations and demographic characteristics. A larger-scale RCT would allow for generalizability of findings as well as allowing for deeper investigation into potential moderators of treatment response. In addition, future studies should examine potential mediators, such as parent involvement and baseline sleep characteristics, to better understand mechanisms of intervention response.

Future research may consider extending the duration of the intervention and follow-up period to allow for a more in-depth evaluation of behavior change and its effects on EF. While this brief intervention was effective in promoting short-term changes in sleep duration and consistency, a longer intervention window may be necessary to produce meaningful changes in behaviors. A longer follow-up study would also help to determine if observed sleep improvements are sustained over time. Optimal follow-up intervals, as suggested by prior studies, should be considered to capture both immediate and longer-term effects.

Lastly, caregiver scheduling and follow-through presented a logistical challenge that should be anticipated in future studies. Several parent participants forgot or needed to reschedule appointments, which required extensive follow-up from the researcher team. As this pattern became prevalent, the research team began sending appointment reminder texts and emails two days prior to appointments and the morning of appointments, instead of one reminder one week before the appointment, in efforts to reduce no-shows. Future studies may benefit from adding additional support tools for caregivers such as calendar invites or automated text reminders. Based on these findings, the next phase of research should focus on developing and evaluating a three-month behavioral sleep extension intervention, allowing for a longer period to support habit formation, address barriers, and monitor maintenance of sleep and EF improvements. This extended intervention could include regular booster sessions, enhanced caregiver involvement, and ongoing monitoring of both sleep and executive functioning outcomes. If results remain promising, the ultimate goal would be to expand this protocol to a multi-site RCT, enabling the assessment of efficacy, generalizability, and implementation across diverse clinical and educational settings.

Implications

Findings from this pilot study provide initial evidence that a behavioral sleep extension intervention may be both acceptable and beneficial for adolescents with ADHD. Although the small sample size greatly limited statistical power to detect between-group differences, consistent medium-to-large effect sizes across objective sleep outcomes were observed. Most notable were the meaningful improvements associated with changes in TST, TIB, and CVTST. These improvements were observed across nearly all adolescents in the intervention group, underscoring the potential for real-world impact in this population.

The intervention was also rated as acceptable and helpful by both adolescents and caregivers. High levels of satisfaction with intervention support, along with adolescents' perceived improvements in sleep, suggest that behavioral sleep intervention strategies can be well-received by adolescents with ADHD. Home-based sleep manipulation studies in youth have frequently been designed to examine not only changes in sleep amount, but also a range of outcomes including neurocognitive performance, mood, and dietary behaviors (Beebe et al., 2010;2023, Demons et al., 2017; Duraccio et al., 2021;2023). Many of these studies employ an experimental design that contrasts a sleep restriction or curtailment condition with a sleep extension condition, allowing researchers to observe the acute effects of both shortening and lengthening sleep duration relative to a participant's baseline. Alternatively, some studies have implemented sleep extension as a stand-alone intervention, in which participants are encouraged to increase their TST above their habitual levels (Moreno-Frias et al., 2020; Perfect et al., 2016;2023). Although these approaches provide valuable insights, it remains unclear whether the cumulative benefits of achieving a healthy, recommended sleep duration, particularly among youth who chronically obtain insufficient sleep, can be realized within the relatively short time frames typical of experimental studies. The effects of sleep extension may require a longer period to manifest compared to the more immediate and often pronounced effects observed with acute sleep restriction. Moreover, while it is often feasible to experimentally increase or decrease TST for a brief period, the more meaningful and challenging goal is to support sustained changes in sleep as part of a healthy lifestyle. Thus, future research should prioritize interventions that not only manipulate sleep duration in the short term but also promote lasting behavioral changes that help youth consistently achieve adequate sleep over time.

The context in which this intervention could be delivered further underscores its practical relevance for school settings. The present study highlights the high prevalence of sleep difficulties among adolescents with ADHD, reinforcing evidence that problems such as delayed bedtimes, inconsistent routines, and insufficient sleep are common and impactful in this population. These findings carry important implications for school-based mental health professionals, such as school psychologists, who are often involved in evaluating and supporting students with academic, behavioral, and emotional challenges. Incorporating brief sleep screening tools into psychoeducational assessments, particularly during evaluations for ADHD, could lead to more comprehensive and accurate understandings of student needs. Moreover, because sleep disruptions can affect attention, emotion regulation, and learning, they are likely relevant to nearly all psychoeducational evaluations, not just those focused on ADHD. Addressing sleep early may help distinguish between primary disabilities and secondary effects of poor sleep, informing more targeted interventions. Previous research has established that school-based behavioral sleep interventions can be both feasible and effective (Buckhalt et al., 2009; Kaar et al., 2020; Perfect et al., 2020). The behavioral sleep extension intervention evaluated in this study is brief, structured, and requires minimal face-to-face contact, making it a feasible option for school-based implementation. With appropriate training, school psychologists could be well-positioned to deliver this intervention, enhancing their capacity to address an often overlooked but modifiable contributor to student functioning.

This study reflects a Tier 2 approach within a multi-tiered system of support (MTSS) for addressing adolescent sleep difficulties. Unlike universal (Tier 1) strategies such as delayed school start times or curriculum-based education, this intervention provided individualized support to adolescents experiencing insufficient sleep duration (Meltzer et al., 2021; Mousavi & Troxel, 2023; Perfect et al., 2020). By tailoring behavioral strategies to each participant's unique schedule, barriers, and goals, the intervention offered a level of personalization consistent with Tier 2 services. These findings suggest that individualized sleep interventions can be feasibly implemented and accepted by adolescents with significant but subclinical sleep concerns, bridging the gap between broad school-based prevention efforts and specialized clinical treatment.

Summary and Conclusions

The intervention's effects on objective sleep parameters are especially promising given the high prevalence of insufficient sleep and irregular sleep patterns in adolescents with ADHD (Cortese et al., 2013). Improving sleep duration and consistency may not only benefit physical health but may also support cognitive functioning. Although changes in EF were mixed, the performance-based EF measures appeared to be more sensitive to the intervention than self- and parent-report questionnaires. Specifically, the Stop Signal Task (inhibitory control) showed a medium-to-large effect size ($g = 0.61$), Digit Span Backward (working memory) demonstrated a small-to-medium effect size ($g = 0.40$), and the Verbal Attention subtest (inhibitory control) showed a small to medium effect size ($g = 0.34$), all favoring the intervention group. These findings suggest that a behavioral sleep extension intervention may positively influence EF, especially in the areas of working memory and inhibitory control. This multi-method approach strengthens the evidence that behavioral sleep extension can positively influence key domains of executive function.

Importantly, the intervention was individualized to each adolescent's schedule and lifestyle, allowing for personalized adjustments to routines and behaviors that may impact bedtime routines and sleep. This flexibility may have contributed to the intervention's feasibility and acceptability, especially in a population with varying schedules and support needs. However, limited reported changes in sleep hygiene behaviors and sleep-related symptoms suggest that more intensive or extended intervention may be needed to influence habits. Adding additional booster sessions or check-ins may enhance intervention effectiveness. Overall, these findings contribute to a growing body of evidence suggesting that sleep may be a treatment target for adolescents with ADHD. Behavioral sleep extension interventions present individualized, low-risk interventions that have potential to be delivered in clinical or school-based settings.

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