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Exploring The Effectiveness Of Telehealth Adolescents' Interventions On Sleep: A Meta-Analysis

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EXPLORING THE EFFECTIVENESS OF TELEHEALTH ADOLESCENTS’ INTERVENTIONS ON SLEEP: A META-ANALYSIS

BY

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EXPLORING THE EFFECTIVENESS OF TELEHEALTH ADOLESCENTS’ INTERVENTIONS ON SLEEP: A META-ANALYSIS

BY

YOUMNA HAKOUM

Submitted to the Faculty of the Graduate School of Eastern Kentucky University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

2023
DEDICATION

This thesis is dedicated to my family who I would not be here without. Thank you for helping me get here and being my rock throughout my whole life. Lastly, this thesis is dedicated to my grandfather who passed away this past summer. My grandfather loved me unconditionally and cheered me on everyday growing up. I miss him every day and I owe a lot of who I am today to him as he truly wanted everything good in life for me. This one is for you, Jido.
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ABSTRACT

The purpose of this meta-analysis was to explore the effectiveness of any telehealth interventions that report sleep outcomes on adolescents, ages 11-20 years old. It was hypothesized that most studies will favor telehealth treatment, regardless of type of treatment, and will present medium to high effect sizes sleep improvements. The following databases were searched to determine any research articles published after 2000 and present as of 8 July 2023: PsycINFO, PubMed, and Cochrane. In total, 15 studies, five pre-post and ten Randomized Controlled Trials (RCT), fit the inclusion and exclusion criteria and were analyzed. Subjective (self-report) and objective (actigraphy based) sleep outcomes were reported pre-post and pre-follow up, if any reported. Some of the sleep outcomes analyzed, Total Sleep Time (TST), SE (Sleep Efficiency), SOL (Sleep Onset Latency), Wake sleep Onset (WASO), Time in Bed (TIB), SQ (Sleep Quality), ISI (Insomnia Sleep Index) and Holland Sleep Disorder Questionnaire (HSDQ), reported small to medium effect sizes, except for subjective Sleep Efficiency (SE) and the sleep questionnaires, Holland Sleep Disorders Questionnaire (HSDQ) and Insomnia Sleep Index (ISI). Subjective SE had medium to high effect size for both pre-post (d= .78) and pre-follow (d= 1.19). ISI also reported medium to high effect size (d= -1.37), along with HSDQ (d= -1.00). The sleep questionnaires reported negative effect sizes as lower scores in both HDSQ and ISI indicate less presence of sleep disorders. This meta-analysis is in line with previous relevant meta-analyses as it highlights the effectiveness of telehealth and the promise it holds for the future of sleep interventions, along with other disorders interventions.
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CHAPTER I
INTRODUCTION

The importance of sleep has been a topic that has been discussed for more than twenty centuries. Studies conducted by Ramar and colleagues (2017) presented the importance of a good night’s sleep as it leads to many benefits related to cognitive functioning, cardiovascular, and psychological health. However, as time goes on, things are taking the wrong turn in relation to sleep. Since 2004 and up until 2017, there has been a 15% increase in U.S. adults reporting six hours or less of sleep time (Sheehan et al., 2019). Such a decrease in sleep time duration has presented many challenges. For example, one longitudinal study found that people sleeping less or more than seven to nine hours a night have a higher risk of morbidity than those who sleep seven to nine hours (Vgontzas et al., 2010).

This current study explores telehealth interventions effectiveness on adolescents’ sleep. Such meta-analysis is necessary as telehealth can broaden the resources people have access to when attempting to solve sleep-related and other issues, if found effective.

Sleep Regulators

As the poor sleep epidemic has been taking over the world these past few years, it is important to understand how such a problem came into existence in the first place. When thinking of sleep, many associate such an act with emotions of relaxation and peace. With that, when did sleep present itself as an issue? To answer such a question, a closer look should be taken into circadian rhythms and pacemakers.
Circadian pacemakers are found inside the suprachiasmatic nucleus (SCN), located above the eyes in the anterior part of the hypothalamus (Lack & Wright, 2007). With the help of retinohypothalamic tract (RHT), pathway from eyes to SCN that transmits light/dark cues to SCN using photosensitive ganglion cells in the retina (Welsch et al., 2010), a circadian pacemaker plays a part in the synthesis of melatonin. To do this, the SCN innervates the pineal glands, which promotes such glands to release melatonin at dark and inhibit such production during daytime (Masters et al., 2015). Such hormone’s regulation is stabilized with the help of the circadian rhythms, present in the SCN. The production of melatonin increases sleep need, while the inhibition of melatonin’s secretion decreases the need and promotes wakefulness.

Circadian rhythm, or sleep/wake cycle, is a self-sustaining internal biological clock-controlled cycle that is in the SCN. To understand circadian rhythms better, it is best for such a concept to be broken down into pieces. The rhythm in “Circadian rhythm” refers to a sequence that is repeated. The circadian, from the Latin phrase “circa diem”, means about a day. With that, a circadian rhythm can be defined as a self-sustained twenty-four-hour cycle that is constantly repeating and is free running, not entrained by any physical stimuli. While free running, circadian rhythms still choose to align with external cycles, main cycle being light/dark cycle, and is influenced by any external cycles’ changes (Vitaterna et al., 2001). Though the light/dark cycle is the primary cycle that influences circadian rhythms, circadian rhythms can also be affected by external, social and environmental cues, such as temperature, change in activity, light intensity, along with other cues. The mentioned external factors cause the circadian rhythm to regulate multiple behavioral processes.
Along with circadian rhythms and melatonin, there are other factors that regulate sleep. Sleep-wake homeostasis is one. To best explain this concept, imagine being sleep deprived from the night before, and having to get up every day at six am until Friday. With that, you would plan to extend your sleeping period during the weekend to make up for all the lost sleep. Sleep-wake hemostasis is that in a nutshell. It is the body’s natural tendency to balance the sleep-wake time. Sleep-wake homeostasis investigates how sleep time depends on wake time and vice versa. When sleep time declines, one is more likely to be sleepier during wake time, which results in naps and extended sleep time when possible (Borbely & Achermann, 1992).

Unlike circadian rhythms, sleep-wake hemostasis is influenced by Adenosine buildup. Adenosine is a chemical synthesized in the brain due to the byproduct of energy release during the day. This chemical operates like a homeostatic regulator, as a buildup in Adenosine leads to an increase in sleep need and decrease in wake-activity (Landolt, 2008). Adenosine is accumulated throughout the day by binding to Adenosine receptors, which can be found in the brain. Such bind causes an increase in sleep need by inhibiting the activity of certain neurotransmitters, which relate to wake-time (Basheer et al., 2004). Reducing brain activity promotes relaxation and calmness.

As Adenosine build up occurs during wake-time, causing an increase in sleep need, another factor is needed to be present during sleep-time to maintain continuous sleep. That factor is referred to as Gamma-aminobutyric acid (GABA). GABA is an inhibitory transmitter, found in the central nervous system (CNS), that promotes sleepiness (Gottesmann, 2002). To maintain and improve sleep time, GABA reduces
brain activity by inhibiting the activity of neural firing, causing inhibitory postsynaptic potential (ISPS) to occur (Leon & Tadi, 2023). In other words, GABA is achieving a state of hyperpolarization in the CNS. Such a state causes difficulty for the postsynaptic neurons to reach action potential, signals that transfer along the neurons. With that, the effects of GABA promote sleep by causing anxiety relief & feelings of relaxation (Yamatsu et al., 2016).

**Sleep Disturbances**

After getting a better understanding of how sleep is regulated and influenced, it is important to dig deeper to explore how sleep disturbances occur. According to the U.S. Department of Health and Human Services, 50 to 70% of U.S. adults struggle with chronic sleep disorders (2022). With so many people experiencing multiple sleep disorders, it has been found that the four major sleep complaints for which people seek medical help for were regarding insomnia, excessive daytime somnolence (EDS), inability to sleep at specified time, and abnormal behavior throughout sleep-time (Chokroverty, 2010). As these sleep disorders become more prevalent, it is essential to explore how such sleep disturbances come to life in the first place. How do sleep disturbances occur when there are all those factors present to regulate sleep? What internal and external forces are causing such sleep irregularities?

While sleep regulators are always present, sleep disturbances are still bound to occur sometimes due to internal and external factors that lead to impairments within the sleep regulators’ processes. For instance, internal factors such as stress and anxiety have been greatly associated with sleep disturbances to the point where sleep disturbances are
becoming integrated into some anxiety disorders definitions (Staner, 2003). Such association has occurred due to the connection stress and anxiety share with sleep disturbances. In both animal and human studies, it has been found that acute and chronic stress influence Rapid Eye Movement (REM) sleep, associated with increased brain activity and dreaming, the most by altering the activity of corticotropin-releasing hormone (CRH) in the locus coeruleus (LC), small structure that promotes and regulates wakefulness (Staner, 2003).

As LC is a structure located in the brainstem, it is no surprise that LC is interconnected to different other structures and systems, including the Hypothalamic-Pituitary-Adrenal (HPA) Axis (Ziegler et al., 1999). HPA is a complex neuroendocrine system that operates with the help of the hypothalamus along with the pituitary and adrenal glands. The interconnections present between the LC and HPA cause hormones, such as CRH, to be shared. With that, alterations in the activity and levels of CRH in the HPA cause irregularities to occur within the HPA, which leads to insomnia along with other sleep disorders (Hirotsu et al., 2015).

Sleep and anxiety are just one of the many factors that elicit such alteration within the brain. External/environmental factors, such as sleep time, medication, and others also may present similar, if not even more intense alterations, causing more extreme sleep disorders. In a cross-sectional study attempting to understand the factors contributing to sleep disorders, more than 50% of university students participants rated noise as a big environmental contributor to sleep disturbances (Altun et al., 2012). The environmental factor noise, specifically nocturnal noise, which is noise that occurs
during the night, has become a topic of discussion in past years as studies have been exploring how nocturnal noise influences sleep patterns.

While noise throughout the day might be tolerable, many find nocturnal noise to be more challenging to cope with. The disturbances caused by nocturnal noise cause sleep to become fragmented, which impairs and irregulates the duration of the sleep stages (Halperin, 2014). This fragmentation increases the duration of certain sleep stages, such as stage 1 sleep, associated with transition from wakefulness to sleepiness, and decreases other sleep stages’ durations, such as REM sleep (Griefahn et al., 2006). With wakefulness duration increasing, day-time functions become impaired and daytime sleepiness become more prevalent in the individual’s life (Stepanski, 2002). Such excessive daytime sleepiness is the root of many sleep disorders, such as narcolepsy along with other disorders (Slater & Steier, 2012).

With sleep disturbances occurring independent from the presence or absence of sleep regulators, external and internal factors should remain being investigated due to the strong influence they have on sleep disturbances. As such factors are causing sleep irregularities, sleep disturbances are in turn leading to even more impairments related to the cognitive and psychological processing of the brain (Altun et al., 2012).

Adolescents and Sleep

As infants grow up and start progressing through life stages, infancy, childhood, adolescence, and adulthood, they start going through emotional, social, cognitive, and other developmental processes. While each stage is essential for the individual’s development, there are some age periods that do hold more significance over others as
such stages have more developmental processes occurring within them. Adolescence, for instance, is one of the most essential periods due to the rapid development that occurs within it (Viner et al., 2017).

According to the World Health Organization (WHO), Adolescence is a stage of life that occurs between the ages of 10 to 19 years old (2001). In this stage, puberty most likely starts taking place (Christie & Viner, 2005) as adolescence is the time for growth spurt along with essential developmental processes, such as complex psychosocial development. Erik Erikson focused on developmental processes theories occurring throughout the life stages. In Erikson’s theory, the Erikson Identity Development Theory, Erikson organized psychosocial development into eight stages, with the crucial development, the development of identity, occurring in adolescence stage (Sokol, 2009). The exploration that leads to the development of identity stems from the sense of independence and autonomy adolescents start experiencing throughout the adolescence stage. Adolescents start asking questions of who they are and what part they play in the world (McAdams et al., 2006).

While puberty usually occurs during the adolescence stage, such a biological process has its own effects that are independent from the effects the adolescence stage causes. Puberty is a biological process that is associated with a period of sexual maturation, which leads to physical and nervous system changes, along with developmental processes (Patton & Viner, 2007). Throughout the puberty period, sexual desires and occurrence of physical sex characteristics start emerging. Also, gonadal hormones, which are sex hormones such as estrogen and testosterone, increase in rate
A rate increase in gonadal hormones have been found to lead to many neural processes to occur, such as synaptic formation and elimination, along with other processes. In addition to the physical changes the sex hormones cause, gonadal hormones have also been found to influence cognitive skills relating to verbal and spatial performances (McEwen & Alves, 1999).

As transitioning into adolescence and experiencing puberty lead to various unique developmental processes, disruptions to either or both periods due to internal or external factors lead to many risks, including sleep disorders. In an experimental study to explore the effects of different sleep durations on adolescents’ mood, Booth and colleagues (2021) found that adolescents who experienced the most sleep deficit, five hours of sleep time only, reported the worst mood and were the most depressed and angriest out of the other groups who had more sleep. Long term sleep deprivation in adolescents leads to negative consequences, such as hypertension development, high body mass index (BMI) (Mediac et al., 2017), and cognitive functions deteriorations. High BMI is associated with obesity, which is associated with further negative health consequences.

The harms sleep impairments cause raises questions about how many adolescents are being affected and what can be done to prevent such consequences. According to a 2018 Centers for Disease Control and Prevention (CDC) data estimate, seven out of ten highschoolers, ages 13 to 18, reported not getting enough sleep where the recommended sleep time for adolescents is eight to ten hours. Much of this sleep
deprivation stems from two main reasons’ types, voluntary and involuntarily reasons (Seton & Fitzgerald, 2021).

Voluntary sleep restriction refers to the adolescent’s personal choice to not sleep enough, leading to sleep deprivation. Such choice occurs from the distracting environments that adolescents are surrounded by. In a previous systemic study aiming to understand the association between screen time and sleep in school children and adolescents, Hale & Guan (2015) reported a negative correlation between screen time exposure and sleep duration. External factors like screen time along with other factors, such as homework, are subject to intensity depending on the pressure associated with such factors. Over the years, screen time has become more of a social norm where one is more peer pressured to do it, especially when discussing such factors from an adolescent’s perspective.

Involuntary sleep restriction focuses on adolescents who cannot sleep due to social, biological, and psychological reasons. Associated with puberty, hormonal time shift, another name for phase delay, is a prevalent factor that is associated with sleep deprivation. Hormonal time shift refers to the shift that occurs within the circadian rhythm, which pushes the sleep need for adolescents by an hour or two (Carskadone et al., 1993). Due to the delay in the hormones being secreted, many psychological processes become influenced. Among those secreted hormones are the ones relating to sleep, melatonin. Hormonal time shift causes melatonin to shift in its secretion, leading to disturbance in the circadian rhythm and causing sleep (Khullar, 2012).
Treatments Available

As sleep disorders are affecting all age groups, including adolescents, a closer look should be taken into the available treatments. The current treatments for sleep disorders include medications and behavioral treatment options. Both options will be discussed in this section.

Medications Treatment

As of 2020, National Center for Health Statistics, part of CDC, reported that 18% percent of American adults use medications every day or every other day to help them sleep. While this percentage may seem low, it is triple what it was in 2010 were only 4% of American adults depended on sleep medication, according to CDC. Many researchers associated such increase with the growing stress people are experiencing. In 2022, 76% percent of U.S. adults reported experiencing stress symptoms, which are impacting their health (American Psychological Association [APA], 2022).

Getting access to sleeping medications is not an issue in today’s world. With over a hundred over the counter (OTC) sleeping medications, including the popular drug class antihistamine, readily available, people can get a hold of sleeping medications within a couple of hours. Access to even stronger sleeping medications is available with the presence of prescribed sleeping medications. The two most prescribed drug classes are Benzodiazepines and Nonbenzodiazepines.

Antihistamines are one of the most sold OTC drugs classes. Both Doxylamine and Diphenhydramine, part of antihistamines, are usually sold under brand names, such as Benadryl, Nytol, and Sleep Aid. Both those antihistamines aid in sleep due to their
antihistamine action, reducing the impact of histamine, a CNS neurotransmitter. The purpose of histamine is to activate the cortex’s neurons that promote wakefulness and inhibit sleepiness (Thakkar, 2011). Ozdemir (2014) conducted an experiment to further explore the effects of classic antihistamines, which Doxylamine and Diphenhydramine are part of, compared to new-generation antihistamines. After taking either the new-generation or classic antihistamine, all 92 patients reported similar antihistamines effects. Daytime sleepiness and nocturnal sleep quality increased for both groups.

As Antihistamines are the most popular OTC drug class, Benzodiazepines (BZDs) and Nonbenzodiazepines are the most prescribed drug classes used for sleep aid. Both classes are sedative hypnotics as they mainly resolve issues of anxiety and sleep with the help of GABA. They increase sleepiness by binding to specific GABA receptors, which increase GABA’s activity, and lead to sedation and a calm feeling (Gunja, 2013). The difference between the two drug classes lies in the receptors they bind to along with the risks associated with each. When binding to GABA receptors, BZDs binds to more general GABA receptors, alpha-1,2,3, and 5 subtypes, compared to Nonbenzodiazepines, which bind to more selective GABA receptors, alpha-1 (Agravat, 2018). Such selectivity reduces the risks associated with Nonbenzodiazepines and increases that of BZDs, which causes Nonbenzodiazepines to be more therapeutically useful (Möhler, 2010). The risks associated with BZDs include greater possibility for rebound insomnia, anxiety that remains for more than the half-life of BZDs’ agents, and long-term cognitive impairment risks (Pagel & Parnes, 2001) (Zetsen et al., 2022). While the BZDs’ risks are less likely to occur with Nonbenzodiazepines, short-term risks like hallucinations and amnesia can still occur Nonbenzodiazepines (Gunja, 2013).
Behavioral Treatment

With so many internal and external factors causing sleep disturbances, behavioral treatments are becoming more and more prevalent. Light therapy, orofacial therapy, along with cognitive behavioral therapy have been showing great promise in resolving sleep issues as each of them battles a different number of sleep disorders, including sleep apnea, insomnia, and others.

It is no secret that exposure to light is essential for certain developments and functions in the body. The circadian rhythm is one that depends on light as the release of melatonin occurs in response to dark cues and inhibited in response to light cues. Light therapy takes such cycles into account when treating sleep disorders. With resolving sleep issues, not every light exposure is effective as the minimum light needed to cause a change to the sleep-wake cycle is 2500 lux of white light for two hours of timed exposure or 10,000 lux for 30 minutes timed exposure (Sloane et al., 2008). The timing of when the light therapy is administered is critical as different light exposures and or times are needed at different times of the day to achieve the needed therapeutic effects. To explore the efficacy of light therapy, a total of 24 adults experiencing early-morning awakening insomnia were exposed to either 2400 lux white light, treatment group, or dim red light, control group. Following two evenings of light therapy, the treatment group’s circadian rhythm shifted, which resulted in better daytime functioning (Lack et al., 2005). Such interventions present the potential light therapy has for sleep aid.
Orofacial myofunctional therapy (OMT) has been found as a great treatment option for sleep disorders that are associated with breathing difficulties such as sleep apnea. From its name, OMT focuses on exercising the oral structures of the face to improve the mobility and functions of the structures, which in turn lead to facial and breathing improvements (Homem et al., 2014). Mazzeo and colleagues (2020) conducted an experimental design to explore the effects of OMT on the sleep quality of student athletes experiencing concussion symptoms. Sleep quality differences were found between pre-exposure to OMT and post- as participants receiving OMT reported an 80% sleep quality improvement.

Cognitive behavioral therapy (CBT) is by far the most popular behavioral treatment option as it integrates multiple components, including sleep hygiene, relaxation technique, sleep consolidation, and others (Rossman, 2019). CBT has proven its efficiency in treating sleep disorders, such as insomnia, due to the minimal risks and side effects it presents. The process of CBT includes learning the individual’s sleep through sleep diary and/or actigraphy, a wearable machine to track sleep. Such monitoring with the help of a specialist allows the individual to reflect on triggering thoughts or behaviors, which might cause sleep disorder, and work on changing such thoughts.

**Barriers with Seeking Help**

While treatment options are available, access to such resources is challenging due to several reasons, including cost, social factors, and distance. Many individuals attempt to seek treatment. Unfortunately, not every request is fulfilled due to the cost of
the treatment. Substance Abuse and Mental Health Services Administration (SAMHSA) 2013 survey reported almost 50% of adolescents were unable to get treatment due to cost and or health coverage absence (Lipari et al., 2014). The cost of treatments is a lot, especially if multiple treatment components are needed. To explore the economic cost of insomnia, a total of 948, insomniac and good sleepers, Québec adults were asked to complete sleep-related questionnaires. For insomniac adults, the average annual direct, such as visits and medication costs, and indirect, such as losses due to insomnia, costs per person had a total of $5,010. On the other hand, the cost was $421 for good sleepers (Daley et al., 2009).

When discussing access to treatment options that require in-person consultations and treatments, it is essential to recognize the challenges that the rural population face when seeking in person treatments. In a 2020 US Census, it was reported 22% percent of the elderly population live in rural areas (Cohen & Greaney, 2023). As the rural elderly populations deal with many more chronic conditions compared to urban elderly (Hutchison et al., 2005), closeness to and quick access to treatments is essential, especially when such treatments require multiple visits. In the case of CBT for insomnia (CBT-I), the range of required sessions for a standard treatment is six to eight sessions (Walker et al., 2022). With that, people living in rural areas, including the elderly population, who struggle with chronic insomnia might skip seeking such treatment option due to the travel expenses and distance needed to get help.

As sleep disorders worsen the overall wellness of the individuals struggling, many avoid seeking mental health help due to the stigma associated with such pursuit.
The presence of such stigma stems from lack of knowledge and/or the fear associated with such topic. In a systematic review conducted by Clement and colleagues (2014) to explore the association between stigma and help-seeking, a small to moderate negative association between treatment stigma and help-seeking was present as many participants did not want to seek treatment due to the stigma associated with receiving such help.

**Telehealth is an Option**

Treatments for sleep-aid exist; however, such treatments are hard to get access to due to the barriers that are in place. To resolve the many barriers, telehealth was introduced with many treatments, such as CBT-I, developing to become more digital. Telehealth focuses on technology-based treatments in which technology is used to aid in the delivery of the treatments. In the case of mental health disorders, which are associated with sleep disorders sometimes, 66% percent of young adults and 36% of old adults reported favoring telehealth for mental health treatment (APA, 2021).

Cognitive behavioral therapy for Insomnia (CBT-I) has been found to be an effective treatment for insomnia. However, due to the geographical, financial, and social barriers present, more emphasis started being placed on digitalizing such treatment options. Digital service is an umbrella term that includes two main digital forms, telephone- and Internet- based (Buenaver et al., 2019). Both delivery forms have shown great promise.

Arnedt and colleagues (2013) explored the effectiveness of telephone based cognitive behavioral therapy by recruiting a total of 30 participants with chronic
insomnia. With the participants being randomly assigned to either telephone-based CBT-I, 15 participants, or, information pamphlet group who were also 15 participants, sessions took place and responses were recorded using sleep/wake diary and sleep questionnaires. Significant improvements were present in both groups. However, telephone-based CBT-I presented better improvement in daytime sleep symptoms, high effect size, compared to the control group, small to moderate effect size. While such results are promising, limitations do occur with this delivery option due to the lack of a set structure that should be followed by trained clinicians (Buenaver et al., 2019). Such absence allows for incoherent results in some cases.

Internet based CBT-I has been becoming increasingly prevalent thanks to the digital world. Many studies have found this delivery option to be as effective as face-to-face CBT-I due to it having a highly structured format that depends on continuous monitoring of objective and subjective sleep assessments (Siengsukon et al., 2021). Such assessments include keeping track of a subjective sleep diary, in which participants complete daily, and objective sleep diaries, in which actigraphy is used to monitor sleep parameters and physical activity over a period of time. McCrae and colleagues (2021) conducted a single arm study to explore the efficacy of internet CBT-I. A total of 17 children, ages 6-12 years old, with autism spectrum disorder (ASD) presented high completion sessions’ rates, along with overall improvements in both objective and subjective sleep assessments when baseline to posttreatment was compared.
The Current Study

The literature on the usage of telehealth to treat sleep disorders has shown great promise for the future as such treatment options are cost-effective, effective in treatment, and reachable to a larger population. However, with so many studies investigating the effectiveness of telehealth by comparing it to face-to-face interventions, there becomes ambiguity on the effectiveness of telehealth interventions regarding the improvement levels such interventions promise. The current study is a meta-analysis that explores the effectiveness of multiple telehealth adolescents’ interventions that report sleep outcomes. This current study is of importance as it does not only explore sleep-focused interventions, but all other telehealth interventions, addiction interventions for example, that promise its participants some sleep improvements. The research question guiding this meta-analysis is “How effective are telehealth interventions in improving sleep outcomes?” It is hypothesized that most studies will favor telehealth treatments, regardless of type of treatment, and will present medium to high effect sizes sleep improvements. As far as this past year, no previous meta-analysis exists where the adolescents’ age (11-20 years old) is being explored and all types of interventions are being explored. The most recent relevant systemic review and meta-analysis was conducted by Tsai and colleagues (2022) and was to compare the effectiveness of Internet based CBT-I type interventions only on adolescents, ages 10-19 years old, to face-to-face interventions.
CHAPTER II

METHODS

Search strategy

When working on a meta-analysis, it is important to keep track of any previous meta-analyses that were done in previous years. First and foremost, previous meta-analyses and systemic review studies for adolescents’ telehealth interventions, which report sleep outcomes, were searched for to determine what studies are previously present. All reference lists for the found studies were searched and potential studies were extracted. To check for any new and or other studies that might have not been included in the previous studies, four electronic databases—PsycINFO, PubMed, and Cochrane Library were also checked using combinations of the following search terms: Telehealth, internet-based interventions, teletherapy, telemedicine, ehealth, adolescents, young adults, teenagers, youth, sleep interventions, sleep, sleep outcomes, and sleep struggles. The search date for all the mentioned databases was set from the year 2000 and after for relevancy purposes. Following the search process, potential studies were extracted, and their references lists were manually checked. The search process was continued, until confidence that all potential studies were found was established. Figure 1 visualizes the search strategy and inclusion and exclusion processes.
Studies identified from multiple databases, including PubMed (N= 337), Cochrane (N= 24), PsycINFO (N= 18)

Studies identified from manual search, such as references sections (N=70)

Records screened through title/abstract (N= 27)

Studies excluded if sample was not adolescents’ age (11-20 yrs. old) and/or if there was no mention of sleep outcomes.

N=10

Full-text studies assessed for eligibility (N=17)

15 Studies met the inclusion criteria and are present in the meta-analysis.

Figure 1: Flowchart for Search Strategy
Inclusion and Exclusion

For this meta-analysis, the adolescents’ age was set to be 11-20 years old, similar to the typical adolescents’ age range WHO has set up. With that, inclusion criteria included the following: (1) participants ages between 11-20 years old; (2) the study is published year 2000 or after; (3) internet-interventions of any kind as long as sleep outcomes are reported; (4) the main purpose of the intervention is to treat the disorders and or disturbances, not just monitor; (5) the reported sleep outcome in a study had to be present in at least four other studies; (6) the study had to report both pre-test and post-test results. Failure to meet any of these criteria resulted in the exclusion of the studies from the analysis. This approach was essential to ensure homogeneity in relation to participants’ age, type of interventions, and reported sleep outcomes among the selected studies exist and eliminate any potential biases among the researchers.

Measurement Domains

Following the inclusion & exclusion studies, the shared sleep outcomes were extracted. Most of the extracted sleep outcomes were discussed as essential outcomes to explore when analyzing sleep disorders (Buysse et al., 2006). Both subjective and objective sleep outcomes were reported. The difference between the two lies in the data collection method. Subjective sleep outcomes depend on sleep report as it is based on the individual’s sleep diary, while objective sleep outcomes depend on actigraphy, an objective data collection method that measures and tracks motor activity over a period of days using non-invasive accelerators that are usually found in many wrist watches, including actigraphs. Actigraphs are usually a form of wristwatches usually worn to monitor motor activity. As actigraphy depends on motor activity, sleep is measured in
this context by the actigraphs by monitoring physical activity and rest to measure for periods of wakefulness and sleep.

The reported outcomes for both subjective and objective sleep reports included the following: total sleep time (TST), sleep onset latency (SOL), wake after sleep onset (WASO), sleep efficiency (SE), time in bed (TIB), and sleep quality (SQ). Sleep-related questionnaires, including Insomnia Sleep Index (ISI) and Holland Sleep Disorders Questionnaire (HSDQ), were also analyzed.

**Definitions of sleep Outcomes**

As multiple sleep outcomes were reported, it is essential to understand what each outcome entails. While some outcomes are self-explanatory, such as total sleep time (TST), which refers to the sleep duration and measured in hours, other outcomes are not. Sleep onset latency (SOL), measured in minutes, refers to the duration of time it takes for an individual to fall asleep, after turning the lights off. Wake after sleep onset (WASO), measured in minutes, focuses on the periods of wakefulness that occur after initially falling asleep (Shrivastava et al., 2014). Sleep efficiency (SE) is usually a percentage and is mainly the ratio of total sleep time (TST) to time in bed (TIB). SE assesses the quality and effectiveness of an individual’s sleep while considering the individual sleep outcomes TST and TIB. The higher the percentage, the better the individual’s sleep. Sleep Quality (SQ), a subjective sleep outcome measured with the usage of a Likert scale, usually on scale from 1 to 5, focuses on the overall satisfaction and effectiveness of the individual's sleep.

Two questionnaires’ outcomes were analyzed within this meta-analysis. The insomnia sleep index (ISI) is a self-reported seven-item questionnaire that detects the
presence and intensity of insomnia. It is often also used to monitor treatment effects and track improvement in struggling individuals (Morin et al., 2011). The higher the ISI score, the more severe insomnia with a score of 0 indicating no insomnia present, to a score of 28 indicating severe insomnia. The other questionnaire, the Holland Sleep Disorders Questionnaire (HSDQ), is a self-reported measure that focuses on detecting sleep problems based on the six sleep categories discussed in the International Classification of Sleep Disorders-2 (ICSD-2), including Insomnia, sleep-related breathing, parasomnia, and other disorders (Khazaie et al., 2022). HSDQ mainly focuses on investigating the individual’s sleep habits and experiences. Similar to ISI, higher scores in HSDQ indicate worse sleep experience and vice versa.

**Data Analysis**

Due to the lack of Randomized Controlled Trial Studies (RCTs) and pre-post designs that report sleep outcomes for adolescents, both designs were analyzed together. To successfully achieve that and to investigate the main premises of the hypothesis, within groups pre-post effect sizes for the treatment groups only were calculated. Standardized mean differences (SMDs) were calculated using Cohen’s d, an effect size, for the analysis. Standardized effect sizes, such as Cohen’s d was decided upon, rather than unstandardized effect sizes, due to the different operationalizations present across the included studies (Lipsy & Wilson, 2001, p. 44) Cohen’s d was used to remain consistent with previous meta-analyses that investigated telehealth sleep interventions on different age groups (Zhu et al., 2021). While one other relevant previous meta-analyses (Tsai et al., 2022) reported Hedge’s g effect size, another standardized effect size, Cohen’s d was still used due to such effect size being more widely reported in the
included analyzed studies. A Cohen’s d of 0.2, 0.5, and 0.8 correspond to small, medium, and high effect sizes (Chi et al., 2019). For both RCTs and pre-post studies, the mean differences of the baseline and post-treatment scores, for both subjective and objective sleep outcomes, were analyzed. Studies that included short-term follow-up (2-4 months) were analyzed as Cohen's d for the sleep outcomes reported in those studies was calculated using baseline to follow-up.

The data analysis was conducted using JASP software (version 0.17.1.0). 95% confidence intervals along with other analysis were calculated using a continuous random effects model (the restricted maximum likelihood method). The random effects model was used instead of the fixed-effect model due to the random effects model accounting for variability between the studies analyzed using a distribution of true effect sizes, which showcase that such model acknowledges the variability that occurs within the studies due to the different methodologies, intervention styles, and other differences. On the other hand, while the fixed effects model also accounts for variability, it assumes one single true effect size common to all studies, instead of a distribution of effect sizes. With that, for this meta-analysis, as different interventions, sleep-focused and not, were being explored, variability with the usage of true effect sizes’ distributions is needed (Dettori et al., 2022).

Heterogeneity estimates were also examined and reported as such estimates focus on the variation present across the different studies’ outcomes. The variations could be due to many factors, including different methodologies, interventions’ styles, along with others. When calculating heterogeneity estimates, the commonly used statistics include Q-statistic, $I^2$, and $H^2$. For this meta-analysis, $I^2$ was used as the
main heterogeneity statistic focus to determine how much random variation across, between, the studies occurred, if any. $I^2$ percentages range anywhere from 0%, indicating absence of heterogeneity, to 100%, indicating high presence heterogeneity. In general, $I^2$ of 25%, 50%, and 75% correspond to small, medium, and high levels of heterogeneity (Zhu et al., 2022).

As random effects model was used instead of a fixed-effects model, it is important to acknowledge the context of which $I^2$ is to be analyzed. If $I^2$ reported low heterogeneity (25% or less), a fixed-effects model would have been more appropriate as such model assumes a one common true effect size. However, if $I^2$ reported moderate to high heterogeneity estimates, a random effects model is the most appropriate choice as such model considers the distribution of variation among the studies (Barili et al., 2018).

**Meta-analytical Calculations**

As not all studies had Cohen’s d reported and or calculated for the treatment groups, Cohen’s d was calculated using the pre-, post-, and follow-up means and standard deviations reported in the studies. This was done by dividing the pre- and post-difference mean score by the pooled standard deviation of the two groups, as seen in (1). In addition to calculating effect sizes, standard error for each sleep outcome had to be reported for analysis and visualization purposes. Standard error calculations for within-groups were conducted by finding the square root of the sum of two times the difference between one and the correlation coefficient ($r$), plus Cohens’ d squared. The whole numerator is then divided by two times the sample size ($n$) (Lipsey & Wilson, 2001), as seen in (2). Correlation coefficients ($r$) were found by converting Cohen’s d to
r using the following equation: dividing Cohens’ d by the square root of Cohens’ d plus four, as seen in (3).

**Within-subjects Cohens’ d:**

\[
\text{Cohens’ } d = \frac{\bar{x}_{post} - \bar{x}_{pre}}{SD_{pooled}} \quad (1)
\]

\(\bar{x}_{post}\) = Post-intervention mean

\(\bar{x}_{pre}\) = Pre-intervention mean

\(SD_{pooled}\) = pooled Standard deviation = \(\sqrt{\frac{SD_{pre}^2 + SD_{post}^2}{2}}\)

**Within-subjects Standard Error:**

\[
\text{Standard Error (SE)} = \sqrt{\frac{2(1-r)}{n} + \frac{d^2}{2n}} \quad (2)
\]

\(r\) = Pearsons’ r

\(d\) = Cohens’ d

\(n\) = sample size

**Pearsons’ r:**

\[
\text{Pearson’s } r = \frac{d}{\sqrt{d^2 + 4}} \quad (3)
\]
CHAPTER III

RESULTS

Study Characteristics

A total of 15 studies that met the inclusion criteria were included in this meta-analysis. The overall average participants’ age was found to be 15.5 years old with a combined total of 504 participants, excluding the participants in irrelevant conditions (e.g., waitlist and group therapy). The sample sizes for the treatment groups ranged from 6 to 59 participants. Of the studies included, only 5 studies were pre-post designs, while the other 10 studies were randomized controlled trials (RCTs). Only 6 studies reported subjective short-term follow up. Due to the limited follow up studies present, studies were considered to have short-term follow up if they reported 2 to 4 months follow up data. Due to drop out rates in some studies being high, researchers in some studies had to seek the Maximum Likelihood model to match the number of baseline results to post-test and/or follow-up results. In other instances, missing data was just excluded from studies. Table 1 is a more descriptive table that reports all the studies’ information and their reported sleep outcomes in more depth. The studies in the table were ordered based on their year of publication, starting at the beginning from the oldest, being a 2014 study, and ending with the most recent, a 2023 study.
<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Design</th>
<th>Total N</th>
<th>Treatment N</th>
<th>Age</th>
<th>Disturbance</th>
<th>Treatment Type</th>
<th>Follow-up?</th>
<th>Subjective Sleep</th>
<th>Objective Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Bruin et al. (2014)</td>
<td>RCT</td>
<td>26</td>
<td>13</td>
<td>M=14.3 y (SD=1.3)</td>
<td>Insomnia Complaints</td>
<td>Internet CBTI</td>
<td>2 months (TST, SE)</td>
<td>TST, SOL, WASO, SE, TIB, HSDQ, ISI</td>
<td>TST, SE</td>
</tr>
<tr>
<td>De Bruin et al. (2015)</td>
<td>RCT</td>
<td>32</td>
<td>18</td>
<td>M=15.9 y (SD=1.6)</td>
<td>DSM-5 Insomnia</td>
<td>Internet CBTI</td>
<td></td>
<td>TST, SOL, WASO, SE, TIB, SQ,</td>
<td>TST, SE</td>
</tr>
<tr>
<td>De Bruin et al. (2015)</td>
<td>RCT</td>
<td>116</td>
<td>39</td>
<td>M=15.6 y (SD=1.6)</td>
<td>DSM-4 Insomnia</td>
<td>Internet CBTI</td>
<td>2 months (TST, SE)</td>
<td>TST, SOL, WASO, SE, TIB, SQ,</td>
<td>TST, SE</td>
</tr>
<tr>
<td>Fales et al. (2015)</td>
<td>RCT</td>
<td>33</td>
<td>17</td>
<td>M=14.8 y</td>
<td>Chronic Pain</td>
<td>Internet CBTI+  Standard Care</td>
<td></td>
<td>SQ</td>
<td>TST, SE</td>
</tr>
<tr>
<td>Law et al. (2015)</td>
<td>RCT</td>
<td>83</td>
<td>44</td>
<td>M=14.5 y (SD=1.7)</td>
<td>Chronic headache</td>
<td>Internet CBTI</td>
<td></td>
<td></td>
<td>TST, SE</td>
</tr>
<tr>
<td>De Bruin et al. (2016)</td>
<td>RCT</td>
<td>62</td>
<td>31</td>
<td>M=15.6 y (SD=1.8)</td>
<td>DSM-4 Insomnia</td>
<td>Internet CBTI</td>
<td>2 months (SE)</td>
<td></td>
<td>SE</td>
</tr>
<tr>
<td>Author (year)</td>
<td>Design</td>
<td>Total N</td>
<td>Treatment N</td>
<td>Age</td>
<td>Disturbance</td>
<td>Treatment Type</td>
<td>Follow-up?</td>
<td>Subjective Sleep</td>
<td>Objective Sleep</td>
</tr>
<tr>
<td>-----------------------------------</td>
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<td>-----------------</td>
</tr>
<tr>
<td>Fucito et al. (2017)</td>
<td>RCT</td>
<td>42</td>
<td>21</td>
<td>M= 20.71 y (SD=1.42)</td>
<td>Sleep concerns with heavy drinking</td>
<td>Evidence based sleep strategies</td>
<td>SQ</td>
<td>TST, SE</td>
<td></td>
</tr>
<tr>
<td>De Bruin &amp; Meijer (2017)</td>
<td>RCT</td>
<td>152</td>
<td>57</td>
<td>M= 15.43 y (SD=1.74)</td>
<td>DSM-4 insomnia</td>
<td>Internet CBTI</td>
<td>2 months (TST, SE)</td>
<td>TST, SE, TIB, HSDQ</td>
<td></td>
</tr>
<tr>
<td>De Bruin et al. (2018)</td>
<td>RCT</td>
<td>116</td>
<td>39</td>
<td>M= 15.3 y (SD=1.4)</td>
<td>DSM-5 Insomnia</td>
<td>Smartphone CBTI</td>
<td>2 months (TST, SE)</td>
<td>TST, SOL, SE, HSDQ</td>
<td>TST, SE</td>
</tr>
<tr>
<td>Wener-Seilder et al. (2019)</td>
<td>Pre-post</td>
<td>50</td>
<td>50</td>
<td>M= 13.71 y (SD=1.35)</td>
<td>Sleep difficulties</td>
<td>Smartphone CBTI app: Sleep Ninja</td>
<td>TST, SOL, WASO, SE, TIB, ISI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cliffe et al. (2020)</td>
<td>Pre-post</td>
<td>39</td>
<td>19</td>
<td>M= 15.6 y (SD=1.21)</td>
<td>Mental health issues and comorbid insomnia</td>
<td>Self-directed CBTI: Sleepio</td>
<td>TST, ISI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zetterqvist (2021)</td>
<td>Pre-post</td>
<td>21</td>
<td>21</td>
<td>M=15.48 y (SD=1.29)</td>
<td>Comorbid insomnia (DSM-5)</td>
<td>Internet CBTI</td>
<td>4 months (TST, SE)</td>
<td>TST, SOL, WASO, SE, SQ, ISI</td>
<td></td>
</tr>
</tbody>
</table>
Table 1: Descriptive Table of Included Studies

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Design</th>
<th>Total N</th>
<th>Treatment N</th>
<th>Age</th>
<th>Disturbance</th>
<th>Treatment Type</th>
<th>Follow-up</th>
<th>Subjective Sleep</th>
<th>Objective Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khor et al. (2021)</td>
<td>RCT</td>
<td>71</td>
<td>70</td>
<td>M= 15.02 (SD=1.56)</td>
<td>Depression and/or Anxiety</td>
<td>Therapist Online Parenting Programme</td>
<td>TST, SOL, WASO, SE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Georen et al. (2022)</td>
<td>RCT</td>
<td>6</td>
<td>6</td>
<td>M= 15.5 (SD=1.6)</td>
<td>ASD &amp; Insomnia</td>
<td>Internet CBTI</td>
<td>TST, SOL, WASO, SE, ISI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathews et al. (2023)</td>
<td>RCT</td>
<td>59</td>
<td>59</td>
<td>M= 15.1 y (SD=1.3)</td>
<td>Depression, anxiety, &amp; Insomnia</td>
<td>Internet CBTI (Sleepio)</td>
<td>SOL, SE, SQ, ISI</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N- Sample Size, RCT- Randomized Controlled Trials

Sleep Outcomes:

TST- Total Sleep Time, SE- Sleep Efficiency, SOL- Sleep Onset Latency, WASO- Wake After Sleep Onset, TIB- Time in Bed

Sleep Questionnaires:

HSDQ- Holland Sleep Disorders Questionnaire, ISI- Insomnia Sleep Index
Studies Intervention Analyses

As multiple sleep outcomes were measured and analyzed within this meta-analysis, multiple subgroups analyses were conducted to explore the efficacy of the telehealth interventions on each of the reported sleep outcomes. A forest plot for each pre-post sleep, pre-follow-up outcome was reported for both the subjective (self-report) and objective (actigraphy based) sleep outcomes. The two sleep questionnaires, Holland Sleep Disorders Questionnaire (HDSQ) and Insomnia Sleep Index (ISI), were analyzed pre-post for all the studies that reported both and or one of the sleep questionnaires.

To assess potential publication bias, funnel plot asymmetry tests were conducted. Publication bias investigates the bias that exists within the studies where some researchers might only report statistically significant results that support their preset predictions. Any non-significant and or negative results would not be reported (Nair, 2019). The usage of funnel plots aids in the process of determining whether publication bias exists within the studies or not. Kendall’s tau ($\tau$) and the p-value are the two statistics reported for the funnel plot asymmetry tests. In meta-analyses context, Kendall $\tau$ is assessed to determine the relationship between the effect size and the individual studies’ precision (standard error). A significant Kendall $\tau$ ($p<.05$) indicates that the relationship between the two variables did not occur due to random chance, but due to external forces, such as the presence of publication bias. A non-significant Kendall $\tau$ indicates that not enough evidence is presented to conclude presence of publication bias.

To further evaluate robustness of the results, Rosenthal Fail-Safe was calculated. While there are other better methods available, such as P-curve analysis, to assess
publication bias on a more evidential value and investigate the robustness of the results, Rosenthal Fail-Safe N was reported in this paper for consistency purposes, as previous similar meta-analyses in sleep research tend to report Fail-Safe N (Murawski et al., 2018).

Rosenthal Fail-Safe N was used to assess the meta-effect, overall effect of the selected, analyzed studies, and determine the possibility of insignificance, significant results overturned to non-significant, to occur if a specific number of nonsignificant and or null unpublished studies were to be included in the analysis. The higher the Rosenthal Fail Safe N is, the more studies that are needed to overturn the significant results. For non-significant sleep outcomes, did not report significant results, Fail-Safe N is still reported to assess the robustness of the selected studies’ overall impact.

Subjective (self-report) Pre-post Sleep Analysis

Subjective sleep outcomes were reported in Table 1. Figures 2-6 are the forest plots that relate to all the reported pre-post treatments subjective sleep outcomes. Table 2 presents the heterogeneity estimates, funnel plot asymmetry tests, and Rosenthal Fail safe N statistics that correspond with the reported sleep outcomes.

Heterogeneity Estimates:

Moderate heterogeneity was observed in subjective (self-report) Total Sleep Time (TST) (41%), while high heterogeneity was present in subjective Sleep Onset Latency (SOL), Sleep Efficiency (SE (%)), and Sleep Quality (SQ) (87%-97%). Heterogeneity was absent in both Wake After Sleep Onset (WASO) and Time in Bed (TIB)as they both reported 0% $I^2$. All the high heterogeneity outcomes, SOL, SE (%), and SQ, reported significant heterogeneity (<0.001). Such results indicate that the effect
sizes present across the studies in these three outcomes did not occur due to random variation but due to true differences among the studies. In contrast, WASO and SQ did not yield significant results.

**Funnel Plot Asymmetry Test:**

Regarding Kendall’s τ, all the subjective pre-post sleep outcomes reported non-significant p-values (p> .05). Such non-significance indicates that not enough evidence is present to conclude the presence of publication bias. Such insignificance opens the door for the option that the relationship between the effect sizes and standard errors might have occurred due to random chance, and not publication bias. More complex tests are needed to provide evidential value regarding the relationship and presence of publication bias.

**Rosenthal Fail-Safe N:**

For the significant results, the Fail-Safe N ranged from 0, for SOL, to 887, for SE. The number of the studies indicates how many non-significant or null unpublished studies need to be included in the analysis for the significant results to be overturned. For the nonsignificant results, the Fail-Safe N was 35 for WASO and 18 for TIB.

The forest plot for each sleep outcome includes an a RE model (Randomized Effects model). Such models are based on the included studies in the forest plot as the RE models indicate the overall effect sizes, along with the overall confidence intervals. High RE model effect size was indicated for SE (d= 0.78). Small to moderate effect sizes were reported for the rest of the sleep outcomes, TST (d= .21), SOL (d= -0.24), WASO (d= -0.39), TIB (d= -0.29), and SQ (d= 0.05).
<table>
<thead>
<tr>
<th>Sleep Outcome</th>
<th>Heterogeneity Estimates</th>
<th>Funnel Plot Asymmetry Test</th>
<th>Rosenthal Fail Safe N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q (Residual)</td>
<td>p(Q)</td>
<td>I² %</td>
</tr>
<tr>
<td>TST</td>
<td>15.193</td>
<td>.001</td>
<td>41.089</td>
</tr>
<tr>
<td>SOL</td>
<td>109.478</td>
<td>&lt;.001</td>
<td>92.150</td>
</tr>
<tr>
<td>WASO</td>
<td>3.602</td>
<td>.608</td>
<td>0</td>
</tr>
<tr>
<td>SE (%)</td>
<td>69.011</td>
<td>&lt;.001</td>
<td>87.732</td>
</tr>
<tr>
<td>TIB</td>
<td>2.825</td>
<td>.587</td>
<td>0</td>
</tr>
<tr>
<td>SQ</td>
<td>78.633</td>
<td>&lt;.001</td>
<td>97.038</td>
</tr>
</tbody>
</table>

Table 2: Pre-post Subjective (self-report) Sleep Statistics
Figure 2: Forest Plot for Subjective Total Sleep Time (TST)
**Figure 3:** Forest Plot for Subjective Sleep Onset Latency (SOL)
Figure 4: Forest Plot for Subjective Wake After Sleep Onset (WASO)
Figure 5: Forest Plot for Subjective Sleep Efficiency (SE)
Figure 6: Forest Plot for Subjective Time in Bed (TIB)
Figure 7: Forest Plot for Subjective Sleep Quality (SQ)
Subjective (self-report) Pre-follow up Sleep Analysis

Two sleep outcomes, Total Sleep Time (TST) and Sleep Efficiency (SE (%)), had follow-up results for. Figures 8 and 9 are the two sleep outcomes’ forest plots. Table 3 presents the residual heterogeneity estimates, funnel plot asymmetry tests, and Rosenthal Fail Safe N statistics analyses conducted for TST and SE (%), an explanation of what the tests and estimates entail were discussed earlier in the “Studies Interventions Analyses” section.

Heterogeneity Estimates:

Moderate to high heterogeneity was observed in subjective pre-follow up TST (71.2%), and high heterogeneity was present in subjective pre-follow up SE (90.6%). In addition, both sleep outcomes reported such heterogeneities to be significant, indicating that the effect sizes present across the studies in these outcomes did not occur due to random variation but due to true differences among the studies.

Funnel Plot Asymmetry Test:

Both sleep outcomes yielded non-significant Kendall’s τ values. While such insignificance can be interpreted as absence of potential bias, it is important to acknowledge that absence of evidence (non-significance) does not always mean evidence of absence. Insignificant potential bias might indicate bias presence; however such value might be small due to the sample sizes, number of studies, along with other factors. With that, a non-significant Kendall’s τ value entail that there is not enough evidence to conclude presence of publication bias. Hence, an affirmative conclusion about the presence or absence of publication bias cannot be reached.

Rosenthal Fail-Safe N:
For Total Sleep Time (TST), a total of 15 non-significant or null studies are needed for its significant result to be overturned to non-significant. Similarly, for SE (%), a total of 298 of non-significant or null studies are needed for significance to be overturned.

The forest plots for each sleep outcome included RE models (Randomized Effects model). High RE model effect size was indicated for follow-up SE (d= 1.19). Small to moderate effect size was reported for TST (d= 0.33) (see Figures 8 &9).
Table 3: Pre-follow up Subjective (self-report) Sleep Statistics

<table>
<thead>
<tr>
<th>Sleep Outcome</th>
<th>Heterogeneity Estimates</th>
<th>Funnel Plot Asymmetry Test</th>
<th>Rosenthal Fail Safe N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q (Residual)</td>
<td>p(Q)</td>
<td>(\tau)</td>
</tr>
<tr>
<td>TST</td>
<td>15.349</td>
<td>.004</td>
<td>71.169</td>
</tr>
<tr>
<td>SE (%)</td>
<td>33.900</td>
<td>&lt;.001</td>
<td>90.641</td>
</tr>
</tbody>
</table>
**Figure 8:** Forest Plot for Subjective Follow-up Total Sleep Time (TST)

<table>
<thead>
<tr>
<th>Study</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Bruin et al. (2014)</td>
<td>-0.04 [-0.59, 0.51]</td>
</tr>
<tr>
<td>De Bruin et al. (2015)</td>
<td>0.24 [0.00, 0.48]</td>
</tr>
<tr>
<td>De Bruin &amp; Meijer (2017)</td>
<td>0.70 [0.51, 0.90]</td>
</tr>
<tr>
<td>De Bruin et al. (2018)</td>
<td>0.25 [0.01, 0.49]</td>
</tr>
<tr>
<td>Zetterqvist (2021)</td>
<td>0.24 [-0.33, 0.81]</td>
</tr>
<tr>
<td>RE Model</td>
<td>0.33 [0.08, 0.58]</td>
</tr>
</tbody>
</table>
Figure 9: Forest Plot for Subjective Follow-up Sleep Efficiency (SE)
Objective (actigraphy based) Pre-post Sleep Analysis

Two sleep outcomes, Total Sleep Time (TST) and Sleep Efficiency (SE (%)), were analyzed from both a subjective and an objective approach. Figures 10 and 11 are the two sleep outcomes’ forest plots. Table 3 presents the residual heterogeneity estimates, funnel plot asymmetry tests, and Rosenthal Fail Safe N statistics analyses conducted for objective TST and SE (%).

Heterogeneity Estimates:

High significant heterogeneity was observed for TST (86%) and SE (93%). The significant presence indicates that the effect sizes present across the studies in these outcomes did not occur solely due to random variation, such as sampling error and or environmental factors, but also due to the true differences, such as interventions used and studies’ designs, that exist among the studies.

Funnel Plot Asymmetry Test:

To test for any potential bias regarding significant results, funnel plots asymmetry tests were conducted. In the context of Kendall’s τ, both sleep outcomes reported non-significant Kendall’s τ values, TST (p=0.543) and SE (%) (p=0.068). Such insignificance indicates lack of evidence to conclude the absence of publication bias.

Rosenthal Fail-Safe N:

Rosenthal Fail-Safe N were also calculated for both outcomes with TST requiring 27 nonsignificant and or null studies to become insignificant and SE requiring 78 studies.
In figures 10 & 11, the forest plots for each sleep outcome included RE models. Small to moderate RE model effect size were reported for objective TST (d= 0.23) and SE (d= 0.24).
### Table 4: Pre-post Objective (actigraphy based) Sleep Statistics

<table>
<thead>
<tr>
<th>Sleep Outcome</th>
<th>Heterogeneity Estimates</th>
<th>Funnel Plot Asymmetry Test</th>
<th>Rosenthal Fail Safe N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q (Residual)</td>
<td>p(Q)</td>
<td>$I^2$ %</td>
</tr>
<tr>
<td>TST</td>
<td>33.288</td>
<td>&lt;.001</td>
<td>86.040</td>
</tr>
<tr>
<td>SE (%)</td>
<td>76.609</td>
<td>&lt;.001</td>
<td>93.184</td>
</tr>
</tbody>
</table>
Figure 10: Forest Plot for Objective Total Sleep Time (TST)
**Figure 11:** Forest Plot for Objective Sleep Efficiency (SE)
Sleep Questionnaires Outcomes Analysis

Two sleep questionnaires, Holland Sleep Disorders Questionnaire (HSDQ) and Insomnia Sleep Index (ISI) were assessed pre-post intervention. Table 3 presents the residual heterogeneity estimates, funnel plot asymmetry tests, and Rosenthal Fail Safe N statistics analyses conducted for HSDQ and ISI. Figures 12 and 13 present the forest plots for both sleep questionnaires.

**Heterogeneity Estimates:**

Both sleep questionnaires yielded non-significant moderate heterogeneity, HSDQ (49.6%) and ISI (31.8%) as presented in Table 3. The non-significance indicates that the variability within the analyzed studies for both sleep questionnaires likely result from random variation, such as sampling error and or other external not meaningful variability, and not true differences, such as studies’ designs and interventions.

**Funnel Plot Asymmetry Test:**

No significant potential bias was found for any of the sleep questionnaires, HSDQ (p=0.801) and ISI (p=0.083). Such non-significance indicates the lack of evidence to reach a conclusion regarding the absence of potential bias.

**Rosenthal Fail-Safe N:**

The usage of Rosenthal Fail-Safe N for the insignificant sleep questionnaires was calculated to investigate the meta-effect of the studies analyzed and the possibility of turning significant results to non-significant in the presence of the inclusion of future non-significant or null studies. As both sleep outcomes reported non-significant results,
Rosenthal Fail-Safe N was calculated to assess the robustness of the meta-effect presence. For HSDQ, Fail-Safe N was found to be 211 studies, and for ISI, it was 137 studies.

The forest plots for each sleep outcome included RE models. High RE model effect sizes were reported for both questionnaires, HSDQ (d= -1.00) and ISI (d= -1.37). Negative effect sizes were anticipated for both questionnaires as for both, lower scores mean less sleep disorders presence. While negative effect sizes are sometimes seen as a harmful effect, in some cases, such as the sleep questionnaires, the negative effect sizes are what are expected as that would indicate less presence of sleep disorders post-intervention.
Table 5: *Sleep Questionnaires Statistics*

<table>
<thead>
<tr>
<th>Sleep Questionnaires</th>
<th>Heterogeneity Estimates</th>
<th>Funnel Plot Asymmetry Test</th>
<th>Rosenthal Fail Safe N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q (Residual)</td>
<td>p(Q)</td>
<td>I² %</td>
</tr>
<tr>
<td>HSDQ</td>
<td>7.732</td>
<td>.102</td>
<td>49.641</td>
</tr>
<tr>
<td>ISI</td>
<td>5.535</td>
<td>.237</td>
<td>31.861</td>
</tr>
</tbody>
</table>
Figure 12: Forest Plot for Holland Sleep Disorders Questionnaire (HSDQ)
Figure 13: Forest Plot for Insomnia Sleep Index (ISI)
CHAPTER IV
DISCUSSION

Summary of Findings

This meta-analysis investigated the effects of telehealth interventions on adolescents aged 11 to 20 years old. The main hypothesis was supported as telehealth interventions had an overall positive effect on the reported sleep outcomes as positive sleep outcomes, such as Total Sleep Time (TST), Sleep Efficiency (SE), and Sleep Quality (SQ), increased post-intervention, for both subjective and objective approaches, and subjective follow-up. In addition, telehealth interventions reduced negative sleep outcomes, such as Wake After Sleep Onset (WASO), Sleep Onset Latency (SOL), and Time in Bed (TIB), post-intervention. The presence of positive and negative sleep outcomes is the reason why for some effect sizes, a negative effect size is better as that would mean a decrease in the presence of the negative sleep outcomes.

While all the analyzed sleep outcomes, negative and positive, and the sleep questionnaires presented improvements post intervention and at follow-up, the hypothesis was partly supported as almost all the sleep outcomes RE models reported overall small to moderate effect sizes, instead of medium to high effect sizes. Only subjective sleep efficiency (SE) and the sleep questionnaires reported high effect sizes as considered by typical standards. Such high effect sizes indicate that telehealth interventions, regardless of type, significantly improved the subjective SE post-intervention and in follow-up. Regarding sleep questionnaires, telehealth interventions significantly reduced the participants’ scores post-intervention.
In line with the study’s purpose and previous meta-analyses that explored the effectiveness of specific telehealth interventions on different age groups (Zhu et al., 2022), the current meta-analysis found small to medium effect sizes for the majority of sleep outcomes and high effects sizes for others along with sleep questionnaires.

A powerful conclusion regarding the efficacy of telehealth interventions could be drawn from the subjective (self-report) sleep outcome SE and the reported sleep questionnaires reported pre-post. As only subjective forest plots supported the hypothesis, it can be indicated that the present available telehealth interventions are effective in mainly improving the patients’ perceptions regarding their sleep. A lot of the content of the telehealth interventions available, such as CBT-I, focus on subjective aspects of sleep, such as meditation techniques and other behavioral aspects, which lead to improvements in one’s perception of sleep.

Implications

Sleep telehealth interventions improve sleep outcomes, with the interventions having greater positive effects on certain sleep outcomes than others. The results from this meta-analysis contribute to the existing research as it explores telehealth efficacy on age group that was not properly explored in previous meta-analyses. With face-to-face traditional interventions becoming harder to access, telehealth interventions become a more prevalent choice due to the many advantages it holds, including faster access at a lower cost. Investigating the efficiency of already existing telehealth interventions for young adults is a good start to understanding the shortcomings that exist within such an area of research. Overall, the current meta-analysis resulted in three main implications.
First, this study provides exposure to the age period 11-20 and how telehealth interventions might be of benefit for this age group, especially as this age period includes stressful periods, such as school and college transitions and the stressors included within such transitions (Hicks & Heastie, 2008). Such a transition always results in an overwhelming amount of stress. Second, the study explores the effectiveness of telehealth interventions, rather than the comparison to face-to-face interventions, which is prevalent in older meta-analysis (Tsai et al., 2022). This is an important implication to highlight as no previous meta-analysis explored the effectiveness of the content of telehealth interventions. Comparing telehealth interventions to face-to-face allows researchers to only investigate whether the format of the intervention is having an influence on the results participants are reporting. However, a within subjects’ telehealth interventions exploration, as presented in this meta-analysis, explores how much are the telehealth interventions presented improving the said sleep outcomes that they are promising the participants to improve.

Lastly, this study can be a great tool for clinics, especially those that specialize in sleep treatments, as it provides great evidence on the efficacy of telehealth interventions. The current meta-analysis allows clinics to integrate customized telehealth interventions, to fit different needs, in addition to their face-to-face interventions. Such customization must consider the different needs that patients might require along with the content of the interventions as different content, more focus on objective aspects of sleep, might be needed.

Figures 5 and 11 show the forest plots for subjective (self-report) and objective (actigraphy based) sleep efficiency (SE). While the subjective SE forest plot was in line
with the hypothesis, such a case was not present for the objective SE forest plot as the forest plot resulted in a small to medium effect size (see Figure 11). The main difference between the two lies in the data collection method where the objective SE depended on the usage of an actigraph, while the subjective SE relied on the participants’ self-report sleep diary. Such discrepancy in the results between the two forest plots raises the question of why are some of the subjective measures the only outcomes that are presenting medium to high effect sizes in this meta-analysis? This question can be answered by considering the interventions that were analyzed in this meta-analysis. In Table 1, most of the interventions focused on were CBT and some other evidence-based interventions. Both types of interventions focus on the subjective aspects of sleep, rather than the objective aspects. Subjective aspects of sleep focus on the behavioral aspects, including the participant’s perceived stress levels, and other cognitive factors that influence sleep. The objective aspects of sleep, which many interventions fail to acknowledge, include sleep hygiene, medications’ regulations, diet, along with other objective factors. With that, when implementing customized interventions, clinics must consider the content of the intervention and integrate the needed details.

**Limitations**

While this current meta-analysis demonstrated great promise for digitizing face-to-face interventions, certain limitations were present and need to be acknowledged. First, Zhu and colleagues (2022) discussed one of the limitations with exploring the efficacy of telehealth interventions to be the different types of interventions present and being compared. As different components exist for the different types of interventions,
it can be difficult to identify which treatment type is of greater benefit for the selected age group. This current meta-analysis also had such limitation as different treatment types were explored within the study.

Another limitation can be drawn from the studies selected. Table 1 presented a full list of all the included studies being analyzed. A total of six studies out of the total fifteen studies were conducted by the same researcher. With some sleep outcomes only being reported in 5 studies, sleep outcomes, such as subjective (self-report) Wake After Sleep Onset (WASO) and Time in Bed (TIB), reported 0% percent heterogeneity. Such absence in variability can be explained by the presence of three studies from the same researcher out of the five or six selected for each of the sleep outcomes. With some of the same researcher studies having more weight, due to sample size, on the analysis compared to others, the researcher's consistent methodology across these studies could have resulted in the lack of heterogeneity.

A third limitation considers the combination of pre-post designs with RCT designs. While both study designs offer great insight to the effectiveness of telehealth interventions, both designs are inherently different from each other in terms of control and presence of confounding variables. As pre-post designs are not controlled, potential confounding variables may arise during the interventions’ periods. Confounding variables might include changes in the participants’ lifestyles or other uncontrolled influences that could affect the sleep outcomes independently of the telehealth interventions.

A fourth limitation considers the publication bias methods used, specifically the Rosenthal Fail-Safe N. While Safe-Fail N focuses on assessing publication bias, its
method of reaching such conclusion is a bit problematic as Fail-Safe N depends mainly on p-values and whether the intervention being explored led to a significant effect or not. In other words, Fail-Safe N mainly focuses on the p-value reaching the desired threshold (less or more than .05 in most cases). Relying solely on statistical significance, rather than the effectiveness significance, causes Fail-Safe N to become somewhat ambiguous and vague in nature.

Another limitation with Rosenthal Fail-Safe N is associated with heterogeneity. Fail-Safe N fails to recognize heterogeneity and assumes homogeneity. Such assumption is problematic as doing that causes any variation among the studies to be thought of as sampling error, meaning errors arising due to different samples being used, rather than true differences in the studies, due to study designs, methodologies, and others (Iyengar & Greenhouse, 1988). While it has its limitations, Rosenthal Fail-Safe N does provide a good rough estimate conclusion without the usage of a more complex model (Orwin et al., 1983).

**Future Research**

As this current meta-analysis had some limitations, for future research, six suggestions could be offered. First, as presented in table 1, most of the studies’ disturbances focused on insomnia, which is one out of thousands of sleep disorders. With that, more studies, preferably RCTs, are needed to explore the efficacy of telehealth interventions on the different sleep disorders, such as sleep apnea, along with others.

Second, as mentioned in the limitations, there is a lack of research by different researchers, leading to possible 0% variations. A variety of researchers are needed in
the area of telehealth intervention to ensure some variation in study and participants designs are present.

Third, as the current meta-analysis found telehealth interventions to have great promise on treating sleep disorders, especially insomnia, for the age group 11-20 years old, conducting a between-subjects meta-analysis for such age group would be effective as such design would allow telehealth interventions to be compared to face-to-face interventions. Previous studies have shown the effectiveness of face-to-face sleep interventions as they greatly improve sleep outcomes (Xu et al., 2021).

Fourth, only subjective short-term follow-up analysis was conducted, leading to limitation in exploring how effective telehealth interventions are long-term for subjective and objective sleep outcomes. More longitudinal studies are needed to investigate the long-term effect of subjective and objective sleep outcomes.

Fifth, with technology becoming more advanced, more research should be conducted on the role and effectiveness of the different actigraph types present, such as Oura rings, fit-bit, apple watches, and others. All the mentioned types are used to track and optimize sleep. That said, it is critical to investigate the accuracy of such types, along with exploring how they can be integrated into the telehealth interventions present.

Sixth, as discussed earlier, due to the limitations associated with Rosenthal Fail-Safe N, future research must consider the usage of newer, up-to-date publication bias assessment methods, such as P-curve analysis. P-curve analysis provides great evidential value for the presence or absence of publication bias as it assesses for p-hacking, which focuses on researchers running multiple statistical tests until they reach
a worth-reporting significant results (Head et al., 2015). P-curve analysis assesses p-hacking by considering the distribution of the p-values across the studies being analyzed.

**Conclusion**

With many people worldwide struggling with sleep on a daily basis, the current meta-analysis gives great promise for the future of sleep interventions. As sleep plays a critical role in everyone’s lives, it is essential to continually investigate how to better such a process. The results for this meta-analysis presented small to moderate effects, with some high effect sizes, on the effectiveness of telehealth sleep interventions for individuals aged 11-20 years old. Such results align with previous meta-analyses (Zhu et al., 2022; Tsai et al., 2022) that explored the effectiveness of telehealth sleep interventions on younger and or older age groups. Further research should take the positive effects telehealth interventions have presented and consider expanding on it by conducting longitudinal studies and exploring the efficacy of telehealth interventions on other disorders.
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