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The prevalence of sleep disturbances in adolescents and the link to mental health disorders

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THE PREVALENCE OF SLEEP DISTURBANCES IN ADOLESCENTS AND THE LINK TO MENTAL HEALTH DISORDERS

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WILSON WONG

ABSTRACT

There is a large body of research showing that sleep disorders are becoming more prevalent, especially in developing children in the United States. The negative effects of sleep disorders are well researched in adults. One such negative effect is the connection between sleep disorders and mental health disorders. Though this connection is well researched in adults, less is known about the connection between sleep disorders and mental health in developing children. The primary purpose of this paper is to review existing literature on the negative effects of sleep disorders, the causes of sleep disorders in children, and how sleep disorders may affect the mental well-being of developing teenagers in their time of vulnerability.

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LIST OF ABBREVIATIONS

ADHD ..... Attention Deficit/Hyperactivity Disorder

DSWPD..... Delayed Sleep-Wake Phase Disorder

EDS .....Excessive Daytime Sleepiness

EEG.....Electroencephalogram

FOMO ..... Fear Of Missing Out

MFIS .....Modified Fatigue Impact Scale

NHIS ..... National Health Interview Survey

OSA.....Obstructive Sleep Apnea

PSQI.....Pittsburgh Sleep Quality Index

REM..... Rapid Eye Movement

SE.....Sleep Efficiency

SES.....Socioeconomic Status

SST.....School Start Times

TST .....Total Sleep Time

WHO.....World Health Organization

INTRODUCTION

Background

There is a growing body of research suggesting that sleep disorders are a prevalent and growing problem in the United States. Sleep disorders have wide-ranging effects, on both individuals and on society as a whole. In regards to the business world, sleep disturbance in employees has been shown to lower productivity and raise the number of mistakes made. Sleep deprived employees have been shown to select less difficult problems to tackle, and provide less creative solutions to problems that they do handle, thus lowering their efficiency. In medicine, new physicians are expected to work over 24 hour long shifts. Studies have shown these physicians will commit 460% more diagnostic mistakes, and 36% more serious medical errors as compared to well rested physicians.[1] Patients in hospitals are also affected by sleep disturbances, despite the fact that recovery from illnesses and injuries require adequate sleep.

Sleep disturbances have been linked to seven of the fifteen leading causes of death. Yet, the average sleep duration has been declining in the past 100 years.[1] As a growing public health epidemic, sleep disturbances need to be explored, especially in the context of vulnerable, developing adolescents (the WHO defines adolescents as developing persons between the ages of 10 and 19).

Sleep disorders include insomnia, parasomnia, sleep-related breathing disorders such as obstructive sleep apnea (OSA), central disorders of hyper somnolence, circadian rhythm sleep-wake disorders, and sleep-related movement disorders (see Figure 1).

Insomnia, whether it is difficulty falling asleep, intermittent awakening during the night, or waking too early, is a common problem in the United States, affecting as many as one-third of the population.[2]

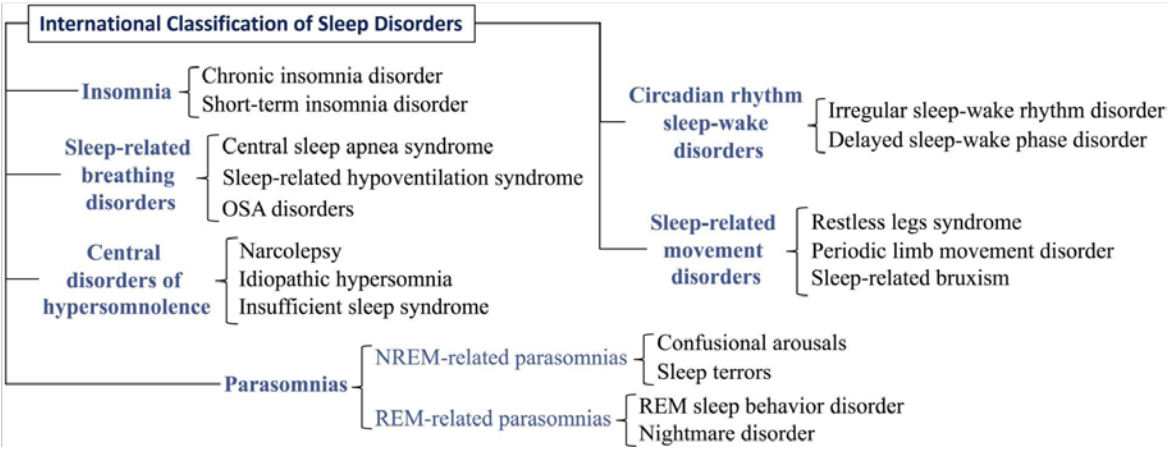


Figure 1: Classification of Sleep Disorders[3]

Sleep disorders are associated with negative physical and mental health consequences, such as increased risk for cardiovascular diseases, depression, anxiety, and suicide. A number of etiological causes have been speculated to increase the risk of sleep disturbances in individuals (see Appendix 1).

Sleep disturbances in adolescents and young adults has been a field of study in a number of countries, including Japan,[4] China,[5] Hong Kong,[6] and the United States.[7] A number of factors have been speculated to be the cause of this growing medical issue. Studies performed on adolescents in Japan implicated high caffeine usage, mobile phone use at night, electronic device usage at night, and the brightness of the room as notable factors that can contribute to sleep disturbances.[4]

In addition to these exogenous sources of sleep disturbances, a correlation has been discovered between the changing chronotypes of children growing into adolescence and sleep distrubances.[5] Chronotype is defined as the behavioral expression of the circadian rhythm, and is linked to daily activity patterns and sleep-wake cycles. Previous studies have shown that young children have a morningness chronotype that begins to shift into an eveningness chronotype as they transition into adolescence and adulthood. Complicating this change in chronotype is the expectation on these individuals to stay awake late into the night in their academic pursuits and to wake early to attend school.

Statement of Problem

Studies have shown that depression and anxiety disorders commonly occur together. Some evidence has come to light suggesting a direct causation model of anxiety causing depressive disorders.[7] The relationship between sleep disorders and mental health, however, is less well elucidated. There is a growing body of data showing that sleep disturbance is highly prevalent in individuals with depression and anxiety disorders. It has been suggested that individuals with anxiety disorders find it difficult to maintain a healthy sleep pattern, which further exacerbates their anxiety disorder and thus increases the individual's risk for developing chronic insomnia. This cycle of deepening anxiety disorder and chronic insomnia places these individuals at high risk for developing depression disorders.

In addition to the increased likelihood of developing depression and anxiety disorders, sleep disturbance sufferers are more likely to experience excessive daytime sleepiness (EDS). Excessive daytime sleepiness is estimated to affect 40% of adolescents.[5] Individuals suffering from excessive daytime sleepiness are associated with adverse consequences such as poor academic performance, poor mental health,[8] and increased rate of committing crime as an adult.[9]

Individuals suffering from sleep disturbances also suffer from increased perceived social loneliness and exclusion.[2] This is thought to be caused by the difficulty in regulating and processing negative emotions. Previous research has shown sleep to be an important factor in regulating emotion.

Adolescents, who are already at high risk of developing anxiety, are therefore prone to be shunted down a path of developing sleeping disorders, and therefore developing a plethora of mental health disorders that may well extend negative consequences well into their adult lives. Exacerbating this problem is the difficulty in getting these adolescents access to appropriate mental health care they require, as there is a tendency to downplay the seriousness of mental health disorders in adolescents.[10]

Sleep disturbance has also been linked physical health problems, especially in that of growing adolescent children. Developing children with sleep disturbances are at higher risk for obesity, diabetes, and cardiovascular disease. In addition to health issues, sleep disturbance causes daytime sleepiness, and this in combination with teenagers beginning to learn how to operate a motor vehicle causes an increase rate of traumatic injuries from motor vehicle accidents.[1]

Treatment of sleep disturbances early on is key to preventing poor social and mental health outcomes. Interventions in resolving sleep disturbances must take into account the cause of the sleep intervention, such as societal pressures, academic or extracurricular activities, or parental work schedules[11]. If the cause of the sleep disturbance is a physical one such as OSA, much consideration is required on which treatment plan is pursue, and the risk vs. the benefits that the treatment plan provides.

Hypothesis

The negative effects of sleep disturbances in young children and adolescents can cause long-lasting effects on physical and mental health that extends well into later adult life.

Specific Aims and Objectives

Improving sleep hygiene and health is now considered a goal in Healthy People Goals for 2020, specifically in increasing the number of adolescents that get adequate sufficient sleep, as defined by greater than 8 hours per night.[11] The aim of this thesis is to discuss the relation between the sleep disturbances and physical and mental health in adolescents, and the future health prospects as these adolescents progress into adulthood. To achieve this goal, this thesis will pool together the available literature on sleep disturbances in multiple countries, how these sleep disturbances affect young children and adolescents, and their long-lasting effects.

PUBLISHED STUDIES

Overview

Sleep disturbances have become a topic of concern in terms of a public health perspective.[12] It has been noted that in the past thirty years, sleep duration has gone down for both adults and adolescents. The study of sleep disturbance is not limited to the

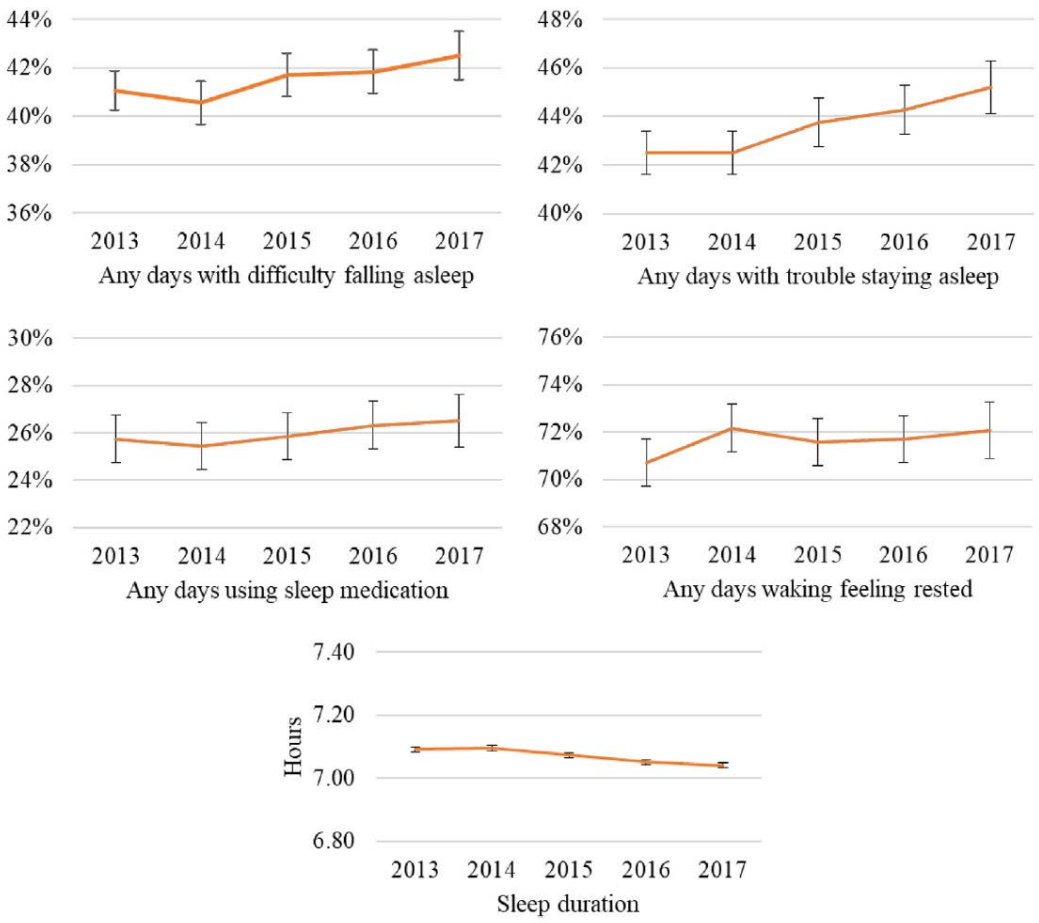


Figure 2: Trends of sleep quality components of 164,969 U.S. adults between 2013 and 2017, as recorded by questions found in the NHIS. [12]

United States. Other countries, including Sweden,[13] Japan,[4,14] Hong Kong,[6] and Australia[15] have begun studies on the effect of sleep disturbance and its adverse effects on individuals as well as on society as a whole.[1]

Methods to Measure Sleep Quality

Duration of sleep is not the only aspect of sleep that needs to be considered. Other aspects of sleep health, such as difficulty in falling asleep, difficulty in staying asleep, and how individuals feel upon waking, are all aspects that are equally, if not more important, than sleep duration. All of these aspects of sleep are considered while determining the quality of sleep individuals receive and the associated health benefits. Statistics on sleep health and hygiene are compiled in a number of different ways (see Appendix 2). Some are as simple as a participant filling out a questionnaire or keep a sleep diary. Others make use of technology such as smart phone apps or accelerometers attached to the waist or wrist. The most complicated methods require participants to go into a sleep laboratory to use sophisticated equipment under the supervision of medical personnel.

In an effort to study the trend of sleep habits in the United States, the National Center of Health Statistics introduced questions regarding sleep health into the National Health Interview Survey (NHIS) starting in 2013.[12] These questions asks participants the number of times per week they had trouble falling asleep, the number of times they had problems staying asleep, whether they took sleep medication, and how often they awoke

feeling rested. Analysis of the data acquired from 164,969 U.S. adults between 2013 and 2017 showed the troubling trajectory of increasingly poor sleep duration and increasing prevalence of sleep difficulties, such as difficulty initiating and maintaining sleep (see Figure 2).[12]

Table 1: Components measured by the Pittsburgh Sleep Quality Index[16]

Pittsburgh Sleep Quality Index Components
Sleep quality
Sleep latency
Sleep duration
Habitual sleep efficiency
Sleep disturbance
Use of sleeping medication
Daytime dysfunction

Another measure of sleep quality is the Pittsburgh Sleep Quality Index (PSQI).[16] This questionnaire is more specific and detailed, asking questions that would yield 7 subcategories about sleep quality (see Table 1 and Appendix 3). Each component is scored 0-3, with a lower score indicating a more healthy sleep component. A global PSQI score >5 is indicative of a "poor" sleeper. When the subject's studies were young children, typically the parents were involved in the data compilation. Parents would be asked to complete surveys on how the children slept, but this is typically seen to reduce the accuracy of the data. A Japanese version of the PSQI, called the PSQI-J, was created for use with Japanese subjects.[17]

For objective measures of sleep, polysomnography (PSG) and actigraphy are used. Polysomnography uses four electroencephalogram recordings to assess electrical brain activity, eye movement, and muscle tone while the individual is asleep. PSG is considered the gold standard for objective sleep measurements to assess for sleep-disordered breathing such as OSA, and is the only method that allows for study of sleep stages. As PSG requires the use of electroencephalogram (EEG) recordings, data acquired by PSG is limited by expense and the burden it places on the individual. Note that using data from a single night's PSG recordings are subject to a "first-night effects", as participants are not habituated to the sleep laboratory environment and the PSG equipment. Actigraphy is the measurement of movement using accelerometers attached to sleeping individual's wrist, and is used to differentiate an awake state from a sleeping state. Though actigraphy data correlates highly with PSG data, it is less reliable, and should be used in conjunction with a sleep diary in order to differentiate sleep from other times of stillness. The advantage, however, is that actigraphy is much less invasive than PSG, allowing researchers to gather multiple days of data rather than the typical one night's data PSG provides.

Association of Mental Health and Sleep Disturbances in Adolescents

Adolescence and young adulthood is a critical time for development, in a physical, emotional, and social sense. Puberty marks the onset of major physical and neurobiological changes.[18] Some of these changes include the development of higher

order cognitive and emotional functions. Around the age of the onset of puberty, many changes are occurring in the environment of the growing child. Adolescents and young adults begin pursuing their future career paths, creating a greater pressure to succeed in their academic life. There is also a switch from a relatively restricted and controlled environment of school and home to environments characterized by more freedom and independence.

Significant social developments also occur at this stage, as young people engage in more complex relationships with friends, families, peers, and potential intimate

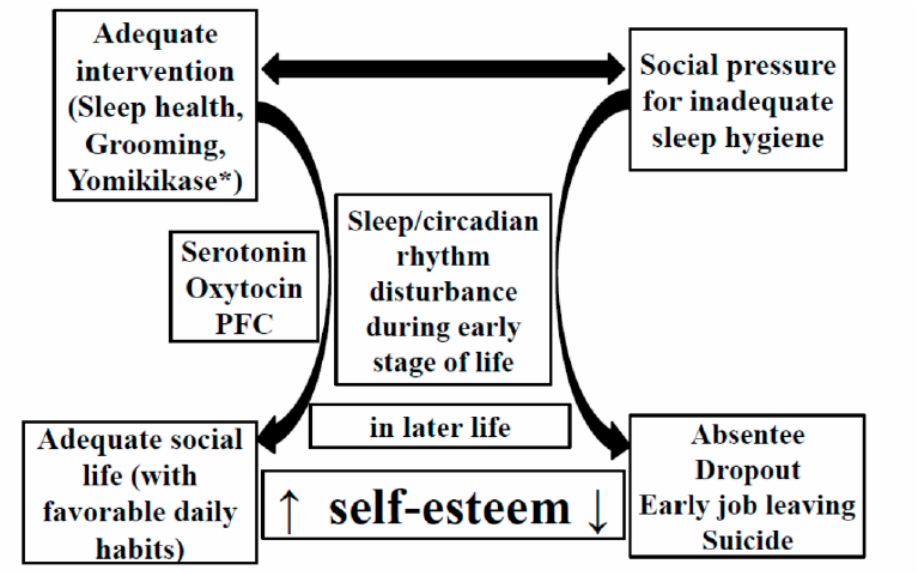


Figure 3: Relationship between sleep hygiene, daily habits, and self-esteem.[14]
***Yomikase is a Japanese term meaning to read a book to another person**

partners. Disruption of these developments can lead to the formation of mental disorders that can last a lifetime. Puberty, however, is a time of vulnerability, due not only to the mentioned neurobiological developments, but also psychosocial changes. The neurobiological change into an eveningness chronotype, the increased autonomy, and the

greater academic and social pressures results in adolescents that both can and want to stay up later all while being asked to maintain the same wake up time. This damage to a proper sleep-wake phase can send adolescents down a path of sleep/circadian rhythm disturbances, poor academic performance, lowered self-esteem, and consequently a poorer mental health outcome (see Figure 3). This contributes to the increased risk of developing and maintaining mental disorders (see Appendix 4). As such, interventions, such as increased health literacy on the effects of poor sleep hygiene[19] and/or change in public policy in regards to school start times, are required to protect our youths in one of the most vulnerable times of their lives.

Effects of Sleep Deprivation

The recommended sleep time of teenagers of age 13 to 18 years old is between 8 to 10 hours per day.[20] A systematic review and meta-analysis showed, however, that children age 15-18 years old had an average total sleep time (TST) of only 7.02 hours.[21] The suboptimal sleep time of adolescents can have negative effects on both the physical and mental health of adolescents.

In terms of physical health, sleep deprivation has been linked to increased pain perception,[22] reduced learning of motor skills,[23] increased risk of falls or accidental injuries, and increased fatigue. In terms of cognition, sleep deprivation on adolescents can lead to increased daytime sleepiness, lowered speed of processing information, lowered attention span, working memory, and executive function.

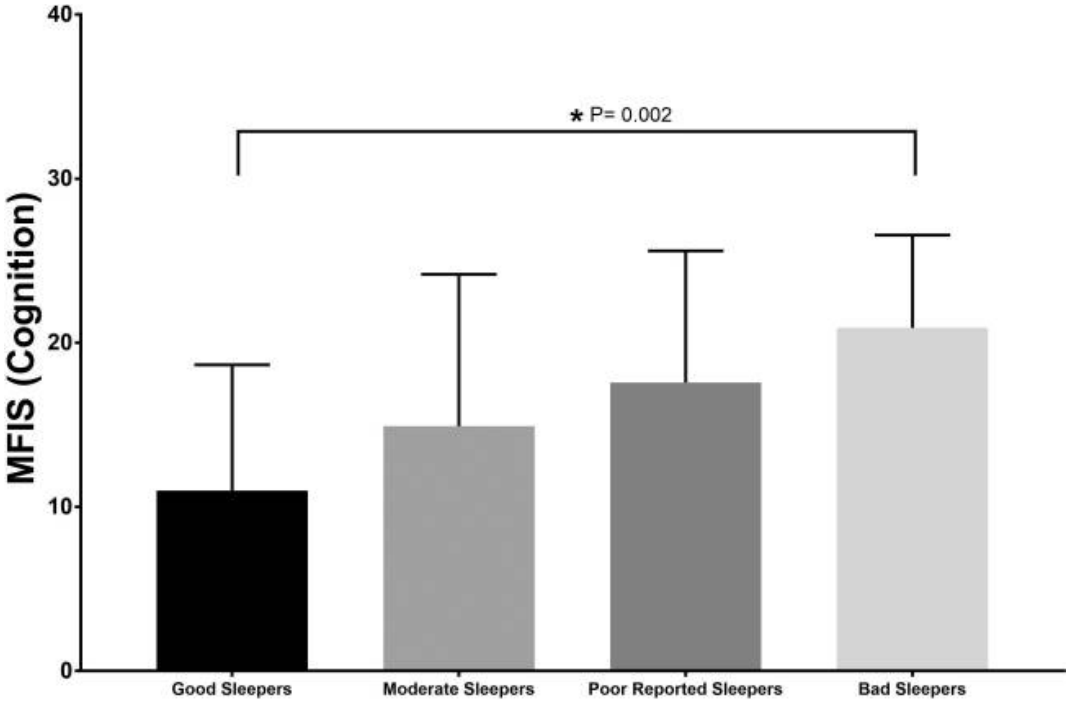


Figure 4: Impact of sleep on cognitive fatigue as measured by the MFIS[24]

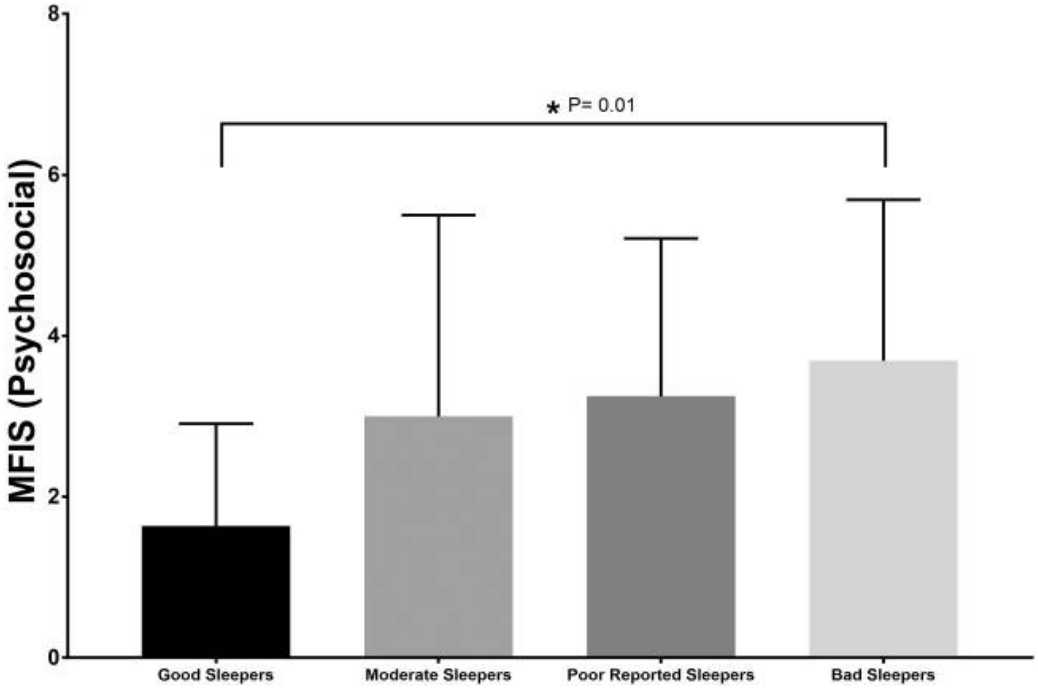


Figure 5: Impact of sleep on psychosocial function as measured by the MFIS[24]

A study of sleep data collected via actigraphy and the PSQI questionnaire of 66 individuals were split into good sleepers, moderate sleepers, poor reported sleepers, and bad sleepers. Participants were given the Modified Fatigue Impact Scale (MFIS), a 21-item scale split into 9 items for physical fatigue, 10 items for cognitive fatigue, and 2 items for psychosocial function status.[24] Though there were no significant difference between the groups in terms of physical fatigue, there were significant differences between the groups in terms of cognitive fatigue (see Figure 4) and psychosocial function (see Figure 5).

Excessive Daytime Sleepiness

One sign of inadequate sleep, whether it be short sleep duration or poor quality of sleep, is excessive daytime sleepiness (EDS). EDS has become a global health concern, and it is estimated that 40% of children and adolescents are afflicted.[6] Pediatric cases of EDS is strongly associated with mood and behavioral disorders, as well as an increased risk in substance abuse. Etiologically complex, EDS is associated with sleep disturbances as well as eveningness chronotype and lifestyle factors such as caffeine and/or electronic device use.

The high prevalence of EDS amongst developing children led researchers to determine if EDS onset is associated with pubertal development, and if they differ in males and females. EDS was studied in pubescent children rated on the Tanner scale, a scale used to describe the different stages 1-5 of the physical development of children

Table 2: Tanner scale of development

Tanner Scale of Development			
	Pubic Hair	Female breast	Male external genital
Stage 1	None	No glanduar tissue	testicular volume >1.5mL
Stage 2	Small amount; long, downy,	Breast bud forms	testicular volume 1.6-6mL; scrotum begins enlarging
Stage 3	extends laterally coarse, curly	Breast becomes elevated	testicular volume 6-12mL; penis begins to lengthen
Stage 4	extends across pubis adult-like quality	Increased breast sizing	testicular volume 12-20mL; penis lengthens further
Stage 5	extends to medial thighs	Breasts reach final adult size	tesituclar volume <20mL; adult scrotum and penis

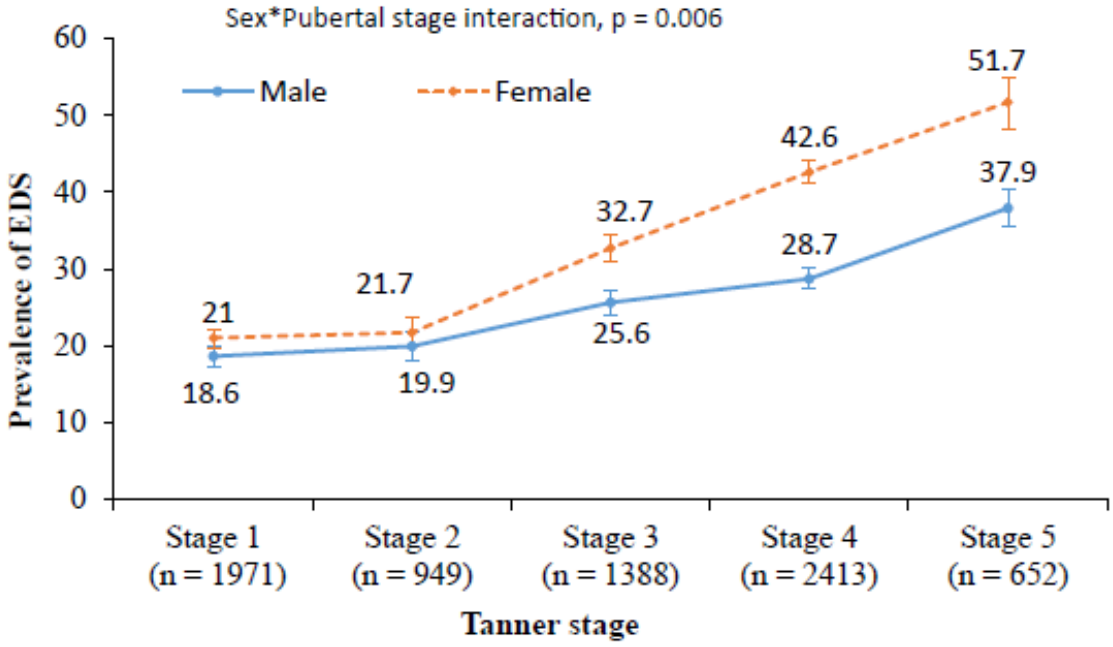


Figure 6: EDS prevalence difference between developing males and females along the Tanner stages[6]

based on secondary sex characteristics such as pubic hair growth, female breast development, and male external genitalia development (see Table 2). The study of 10,086 children age 6 to 18 years old showed an EDS prevalence of 29.2% (24.4% of males, 33.6% of females).[6] EDS prevalence was found to increase throughout puberty, with a female predominance emerging at Tanner stage 3 (see Figure 6).

Sleep Disturbance and Mental Health Disorders

Healthy sleep has been linked to clearance of metabolic waste in the brain and enhances cognitive function and memory consolidation.[25] Sleep and circadian rhythm disturbances, on the other hand, have been linked to a diverse range of adverse effects. Extensive research as shown that sleep disturbance is related to emotional dysregulation and increases negative emotions.[19] Sleep disturbance is present in many different anxiety and depression related disorders, each presenting with different deficiencies in sleep quality components. Those with generalized anxiety disorder exhibited decreased total sleep time, increased sleep onset latency, and increased waking after falling asleep. Individuals with obsessive-compulsive disorder (OCD) were found to have a significant decrease in total sleep time, as well as increased waking after falling asleep and decreased sleep efficiency. Interestingly, subjective sleep measurements from children with OCD were the same as the healthy group. This may be due to difference in the severity of the obsessive-compulsive symptoms, which is an indicator of how well individuals respond to cognitive behavioral treatment. Individuals with panic disorder

ranked poorly in multiple sleep quality components. Those with panic-disorder exhibited increased sleep-onset latency, decreased sleep efficiency and decreased total sleep time. There is evidence to suggest that treatment of the panic-disorder will not successfully treat the sleep disturbance, unlike in generalized anxiety disorder and OCD cases.[25]

There is evidence of a bidirectional relationship between sleep disturbance and mental health disorders, namely anxiety and depressive symptoms. Analysis of data collected in a longitudinal study in which both parents and child were given full psychiatric interviews strongly suggested comorbidity of sleep disturbance and generalized anxiety disorder as well as depression.[26] Between 27% and 77% of individuals with anxiety disorders meet the criteria for major depressive disorder.[7] Further research into this has shown that there is a longitudinal relationship between anxiety and depression, and is mediated by sleep disturbance. Characteristics of anxiety disorders such as catastrophic thinking and worrying contributes to sleep-related problems such as increased sleep-onset latency and sleep fragmentation. The resulting sleep disturbance then becomes a factor that increases the individuals risk for depressive symptoms.

Sleep Disturbance and Schizophrenia

Schizophrenia is a mental disorder in which afflicted individuals interpret reality abnormally, causing abnormal behavior. Individuals with schizophrenia have a life expectancy 20 years less than normal on top of the decrease in quality of life from the

myriad of mental health issues.[27] Schizophrenia symptoms are typically divided into positive and negative symptoms. Positive symptoms of schizophrenia refer to an excess or distortion of normal function, whereas negative symptoms are a decrease or absence of normal function (see Table 3). These symptoms are measured by the Positive and Negative Symptom Scale (PANSS).

Table 3: Positive and negative symptoms of schizophrenia

Symptoms of Schizophrenia	
Positive Symptoms	Negative Symptoms
Delusions	Social withdrawal
Hallucinations	Extreme apathy
Disordered thinking and speech	Lack of drive or initative
Disorganized behavior	Emotional flatness

Sleep disturbance and circadian dysregulation has been associated with schizophrenia. Two profiles of sleep disturbance were identified to be prevalent in schizophrenia cases.[28] The first sleep profile is characterized by delayed sleep-wake phase, sleep onset latency, increased total sleep time and subsequently decreased daytime activity. The second sleep profile is normal sleep-wake phase, but with sleep onset latency, and excessively increased but fragmented total sleep time. A cross-sectional study showed that delayed sleep-wake phase disorder (DSWPD) is comorbid in individuals diagnosed with schizophrenia. Individuals diagnosed with both schizophrenia and DSWPD showed significantly more severe symptoms of schizophrenia, especially with negative symptoms.

Schizophrenia patients are also found to be at a higher risk for OSA. 50-70% of patients with schizophrenia have symptoms of OSA.[29] One possible explanation suggested for this is that DSWPD and the associated increase in total sleep time in schizophrenic individual's results in increased daytime sleepiness and lower daytime activity. This in turn increases the risk of the individual for obesity, a factor that increases the risk of OSA. It has therefore been suggested that OSA become a regular part of the screening process when assessing individuals with schizophrenia.

Sleep Disturbance and Attention Deficit/Hyperactivity Disorder

Attention –deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder affecting 2.6-4.5% of children around the world.[30] ADHD is characterized by a set of core symptoms including inattention, hyperactivity, and difficulty controlling impulses. These symptoms range in severity, ranging from simple performance deficits to lowered mental capacities. Children diagnosed with ADHD also experience increase rates of sleep disturbance. Reports from caregivers show that 25-50% of such children suffer from sleep disturbances, particularly from sleep onset latency (see Figure 7).[31] If not addressed and treated, sleep disturbances in children with ADHD can lead to an increase in symptom severity and more emotional and behavioral problems.[32]

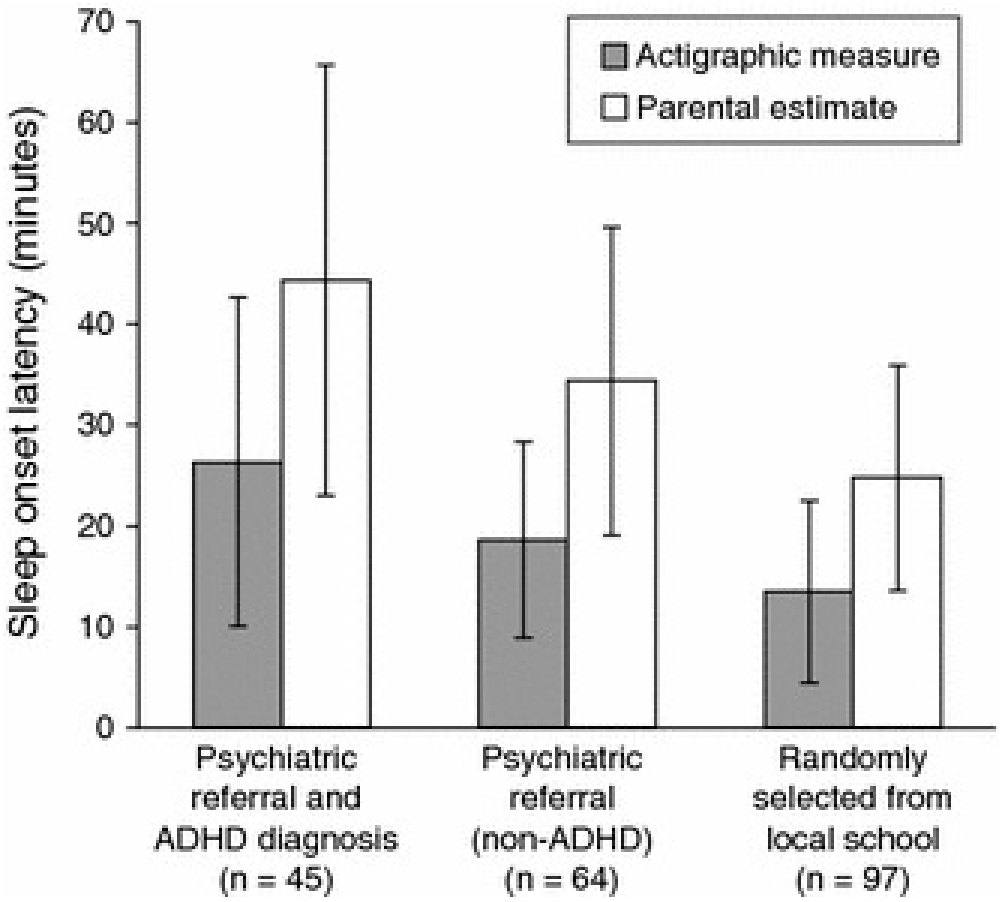


Figure 7: Comparison of sleep onset latency in children with a psychiatric referral and ADHD, non-ADHD psychiatric referral, and control population[33]

Sleep Disturbance and Emotional Regulation

Sleep has been shown to be associated with emotional regulation and processing (see Figure 8). In individuals with sleep deprivation, there is altered brain activation when viewing negative emotional stimuli, with greater amygdala activation and reduced functional connectivity between the amygdala and the medial prefrontal cortex.[34] The increased activity in the amygdala indicated greater emotional reactivity, which is

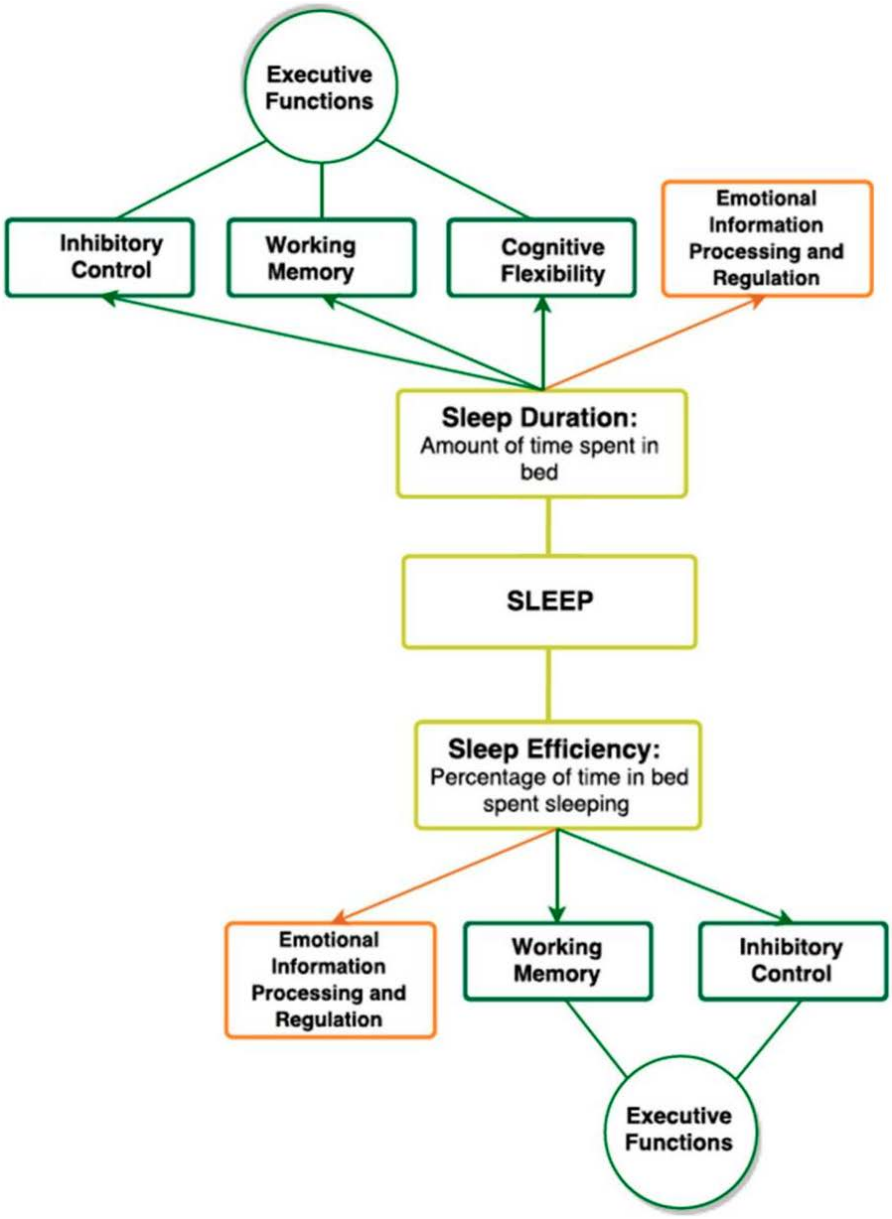


Figure 8: The connection between sleep components (efficiency and duration), emotional regulation, and memory processing.[34] Figure altered to enhance clarity

suggestive of a lowered ability to self-regulate emotional response. The functional connectivity between the amygdala and the medial prefrontal cortex is involved with top-

down modulation of emotional response, and reduction of this factor in sleep deprived individuals also suggests a weaker ability to self-regulate negative emotions.

Common Causes of Sleep Disturbances

A number of factors have been identified that increase the risk of sleep disturbances (see Table 4). These factors range from neurobiological changes that occur during puberty to environmental and social factors to even what and when food is consumed.

Table 4: Partial list of factors that affect sleep quality as measured by the PSQI[4]

Factors Affecting Sleep Quality Components
Eveningness Chronotype
Irregularity of time of last meal
Viewing electronic screen at night
Caffeine intake
Sunlight exposure in the morning
Brightness of the room at night
Waking before dawn

Studies have shown that beginning at puberty, adolescents develop as much as a 2 hour shift in their sleep-wake phase as compared to their childhood sleep patterns. This change is thought to be associated with changes in the circadian rhythm, which controls a number of key hormones and neurotransmitters (see Appendix 5). One such hormone is melatonin. Secretion and levels of melatonin play a role in sleep, and is connected to both the time of day and to the amount of ambient light. During puberty, changes in the

circadian rhythm, and in melatonin secretion times in particular, are shifted, causing this 2 hour shift in the sleep-wake phase. This shift is referred to as a switch from "morningness" chronotype to an "eveningness" chronotype.

This shift in the sleep-wake phase is not necessarily a problem on its own, but can become one when compounded with social stresses such as school start times (SST) and increased pressure to succeed academically. Though the switch from morningness chronotype to eveningness chronotype pushes back the bedtime of adolescents, SST either do not change, or are shifted to an even earlier time, resulting in a shorter sleep duration.

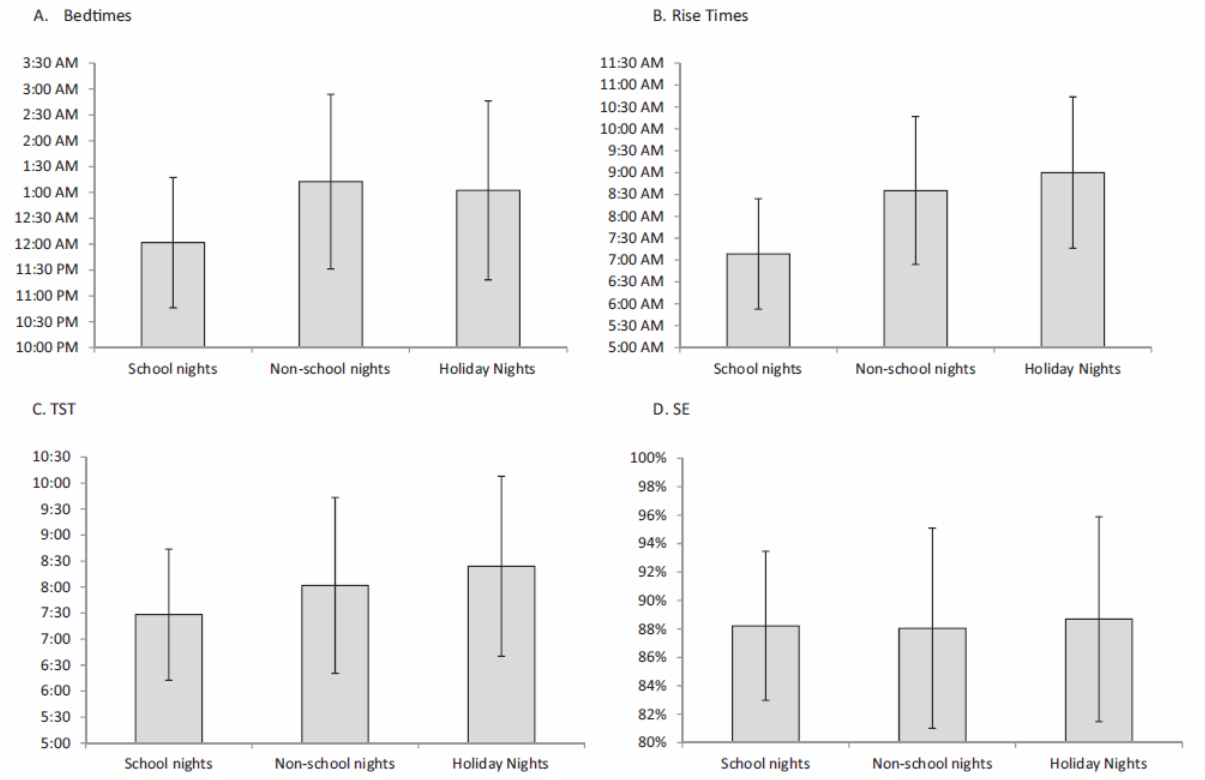


Figure 9: Variability in sleep quality measures as compared between school nights, non-school nights, and holiday nights. TST: Total Sleep Time SE: Sleep Efficiency[15]

Other environmental and societal pressures also play a role preventing adolescents from attaining the recommended 8 hours of sleep per night (see Figure 9). As mentioned, puberty is a period of turmoil for adolescents. As adolescents age, they become responsible for more things, such as academic success, extracurricular activities, and maintaining social relationships. These other responsibilities often interfere with the adolescents' ability to get a full night's sleep during the week.

The increase in fatigue that results from sleep deprivation is often met with increased usage of caffeinated foods and beverages (see Figure 10). Excess use of

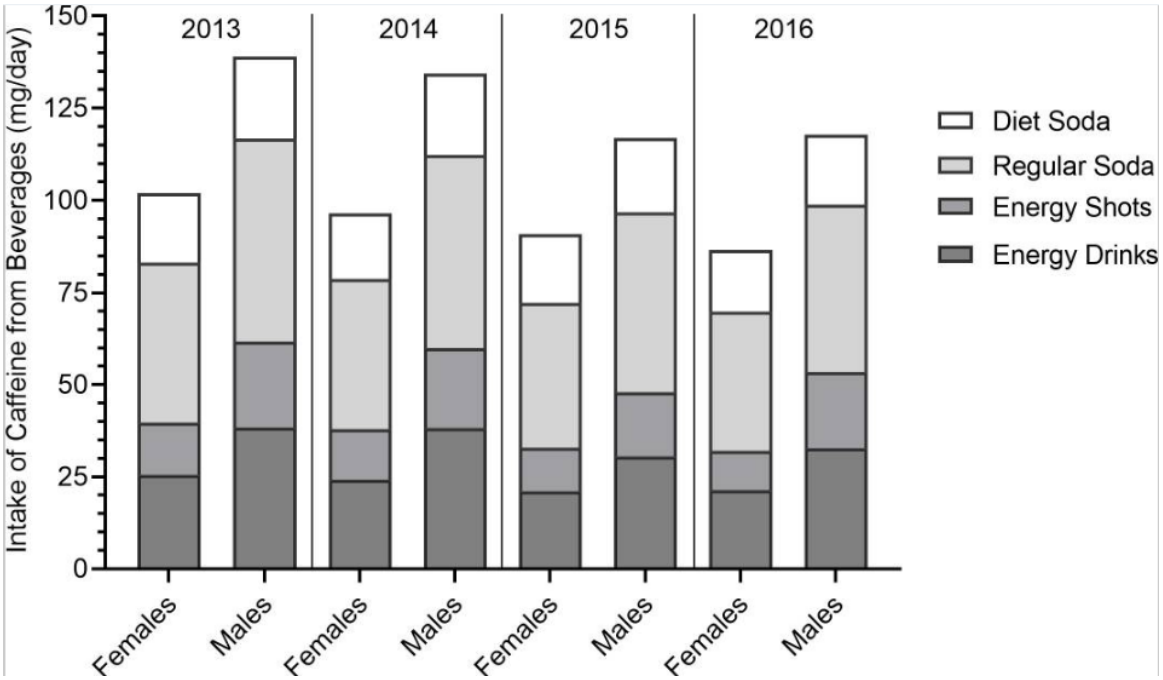


Figure 10: Average caffeine intake from various sources of US adolescents. Data collected from 32,418 students (48.8% in grade 8, 51.2% in grade 10)[35]

caffeine is associated with negative effects on sleep quality, such as shorter sleep duration, difficulty falling asleep, sleep fragmentation, and daytime sleepiness. Caffeine intake at night is also correlated to altered sleep biology, causing less time spent in rapid-eye movement (REM) sleep and slow-wave sleep. REM sleep and slow-wave sleep are both associated with learning and memory consolidation, and disruption of these areas of sleep can cause academic difficulties. Just as with oversleeping on weekends to make up for sleep debt, caffeine use perpetuates the disruption of a healthy sleep-wake phase.

A study done in Australia demonstrated that there was high variability in sleep patterns intraindividually.[15] Here, intraindividual sleep variation means the variability of sleep/wake schedule, sleep efficiency, and overall sleep quality over the course of a week. This variability is concerning because the sleep disturbance accrued over the weekday causes negative effects on academic performance, behavior, and mood. Students attempt to compensate for this sleep debt that is accrued over the weekdays by oversleeping in the weekends or by napping during the day, which perpetuates the disruption of a regular and sufficient sleep-wake phase.

Sleep Disturbance and Electronic Device Use

A more modern cause of sleep disruption is the prevalence of electronic devices, and their use just prior to sleep. The electronic devices in question include television, computers, smart phones, tablets, and video game consoles. Figure 11 shows the average amount of hours spent on electronic devices of various kinds. Note that multi-tasking, or

using more than one device at a time, is possible, so cumulative hours spent on electronics should be interpreted carefully. Use of technology before bedtime has been associated with lowered average total sleep time, as seen on Figure 12. The study showed that on average, children attained 30 minutes less sleep if they watched television or played video games before bed, and lost 60 minutes if they used smart phones or a computer before bed.[36]

Video games and social media are prominent causes of extensive screen time, especially in adolescents. A survey of 8 to 18-year old U.S. teenagers reported that 88% of the participants played video games regularly, though only 8% of these video game

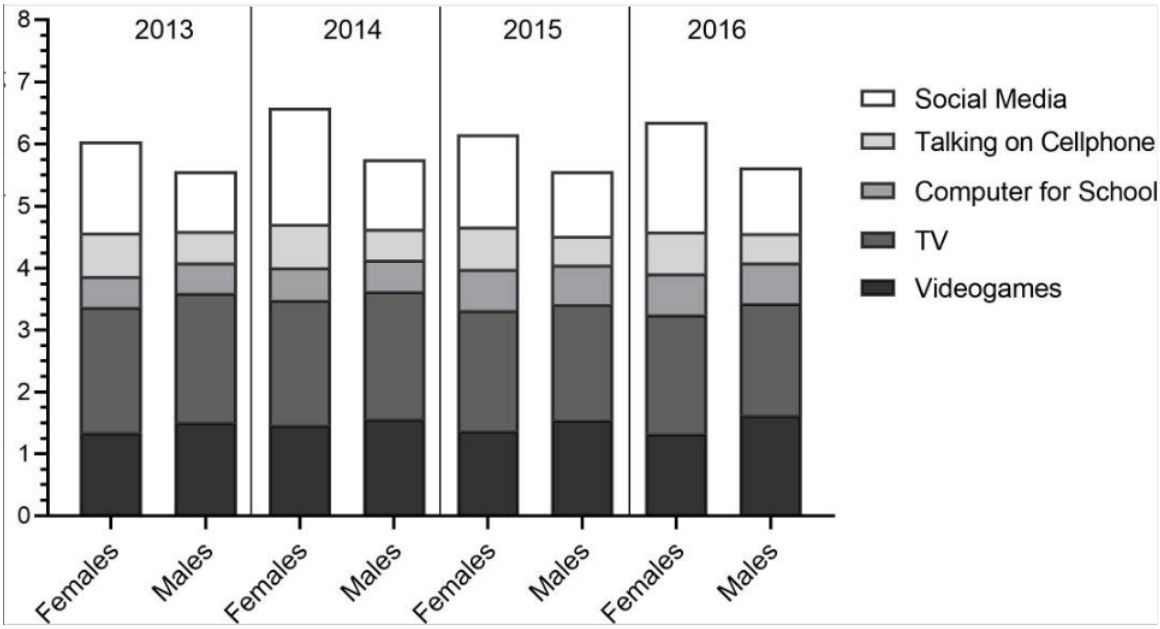


Figure 11: Average daily use, in hours per day, of electronic device use in US adolescents. Data collected from collected from 32,418 students (48.8% in grade 8, 51.2% in grade 10)[35]

players reported a pathological pattern.[37] In video game players, a positive correlation was found between high video game duration and intensity, and low sleep quality. Intensity in this context refers to the degree or magnitude of preoccupation on the video game. High intensity video gaming has also been correlated with a higher risk of developing maladaptive behavior patterns.

Social media has also become ubiquitous in the lives of adolescents. Recent research has shown that increased use of social media use has been linked to increases in anxiety and depressive symptoms. This is especially true in adolescents who are in a period of increased vulnerability in terms of self-esteem. A study of 467 children aged

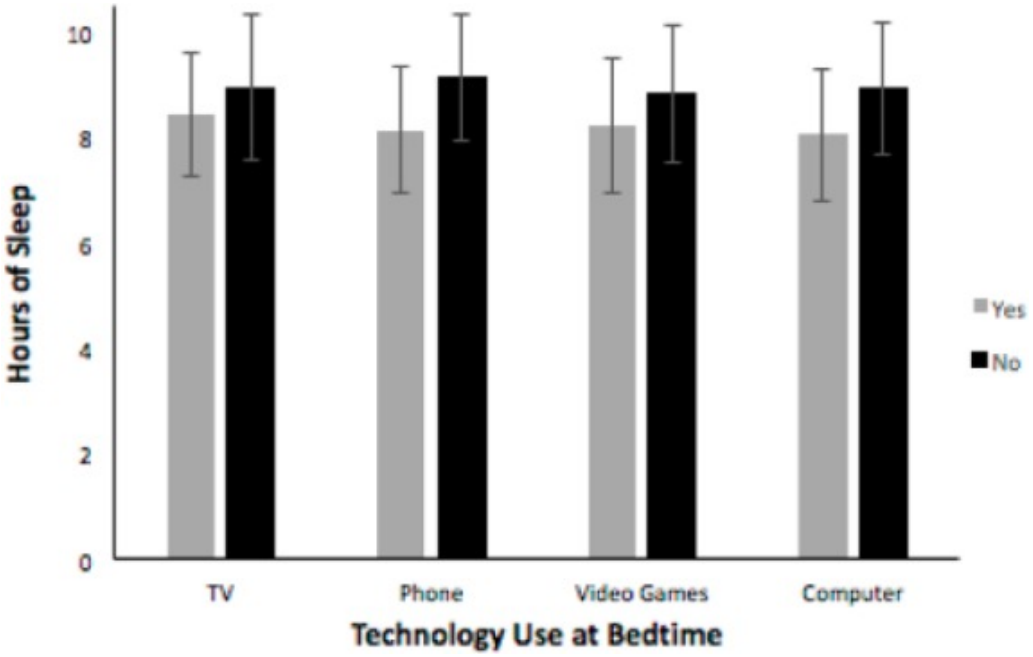


Figure 12: Average hours of sleep with and without use of technology at bedtime. Data collected from surveys filled by parents of 234 children of age 8-17 years[36]

11-17 reported that 97% of participants used social media. Nighttime use of social media is a strongly associated with poorer sleep quality, while overall use did not appear to significantly affect sleep quality. A possible reason for this is that electronic screen usage at night is the cause of the poor sleep quality. The emotional investment that raises pre-sleep cognitive arousal is another possible explanation for the poor sleep quality in late-night usage of social media.

Of particular note is the prevalence and extensive use of mobile phones and devices. Infants, toddlers, and young children all use phones; 75% of 0 to 8 year olds have used a mobile device, and over 89% of teenagers own a smart phone. A survey showed that more than 60 percent of adolescents kept their mobile phones with them as they went to bed, and 39% reported feeling that they were addicted to their phones.[38] The

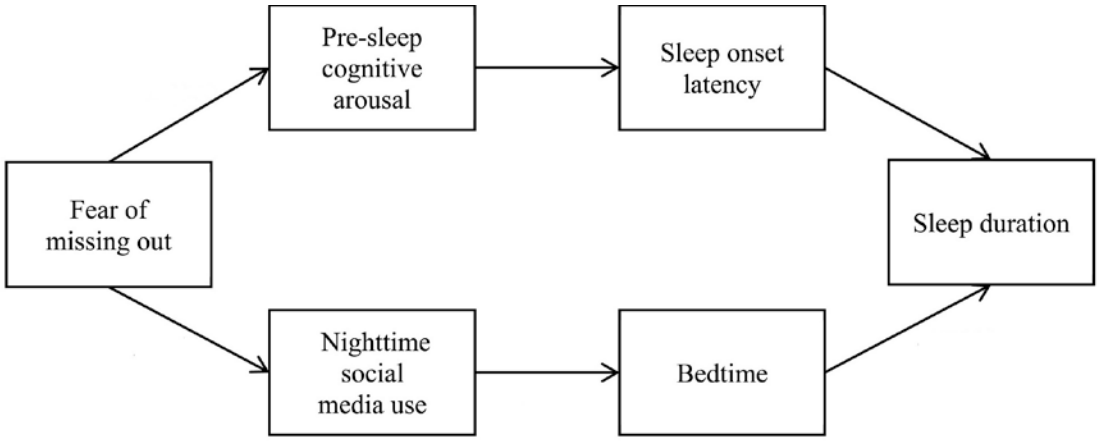


Figure 13: Model of how fear of missing out (FOMO) leads to sleep disruption[39]

bright light emitted from screens is thought to disrupt the natural circadian rhythm by disrupting melatonin secretion and thus causing sleep disruption. In addition, alerts that arrive during the night are sources of sleep interruption; a quarter of adolescents in a survey group of 268 reported sleep disturbances related to having a phone in bed with them during the night.[40] One theory as to why there is such substantive use of mobile devices in bed is the fear of missing out (FOMO). FOMO is a general state of anxiety in which individuals fear missing out on experiences. This state drives adolescents to check social media pages late into the night, causing sleep onset latency as well as higher levels of alertness in bed, a risk factor for higher levels of sleep disruption (see Figure 13).[39]

Obstructive Sleep Apnea: Causes and Treatments

Another cause of sleep disturbance is a range of sleep disordered breathing syndromes. These range from something as simple as snoring to OSA. OSA is defined as

Table 5: Signs and Symptoms of Obstructive Sleep Apnea

Signs and Symptoms of OSA	
Frequent Snoring	Laboured breathing during sleep
Gasping/snorting	Enuresis
Sleeping with seated position	Sleeping with neck hyperextended
Cynosis	Headaches upon awakening
Daytime sleepiness	ADHD
Learning difficulties	Underweight or overweight
Tonsillar hypertrophy	Adenoidal facies
Micrognathia/retrognathia	High-arched palate
Failiure to thrive	Hypertension

a complete or partial blockage of the airway during sleep, causing the patient to have interrupted sleep. It is thought that OSA is caused by a decrease in muscle tone that is a natural occurrence during normal sleep,[41] but other explanations include adenotonsillar hypertrophy and obesity. Onset of symptoms typically manifest between the 2- and 8-years of age, which coincides with peak tonsil growth.[42] OSA severity has a wide range. It can be a transient symptom caused by upper respiratory infections that causes swelling in the throat, or it can a more chronic symptom caused by genetics (see Table 5). The health detriments caused by OSA is often underestimated. OSA is a relatively common condition that affects 1.2% to 5.7% of the general pediatric population.[43] Individuals with OSA can have their sleep disrupted as much as 40 times in a single night, causing severe disruption of their sleep.[44] Untreated OSA in children has been linked to deficits in neurocognitive functioning, academic difficulties,[45] as well as external and internal behavior problems.[46] External behavior problems here refers to difficulty with behavioral regulation, compliance, aggression, impulsivity, and hyperactivity. Internal behavioral problems is related to anxiety, depression, and emotional regulation. It has been suggested that the behavioral issues that arise in children with OSA is caused by the cerebral hypoxic insult at a particularly vulnerable time in the child's brain development.[47]

Diagnosis of individuals with OSA involves an overnight polysomnography. Severity of OSA is determined by the number of obstructive apneas and hypopneas per hour of sleep. Overnight pulse oximetry can augment the data collected in aiding the diagnoses of OSA, but is not sufficient on its own.

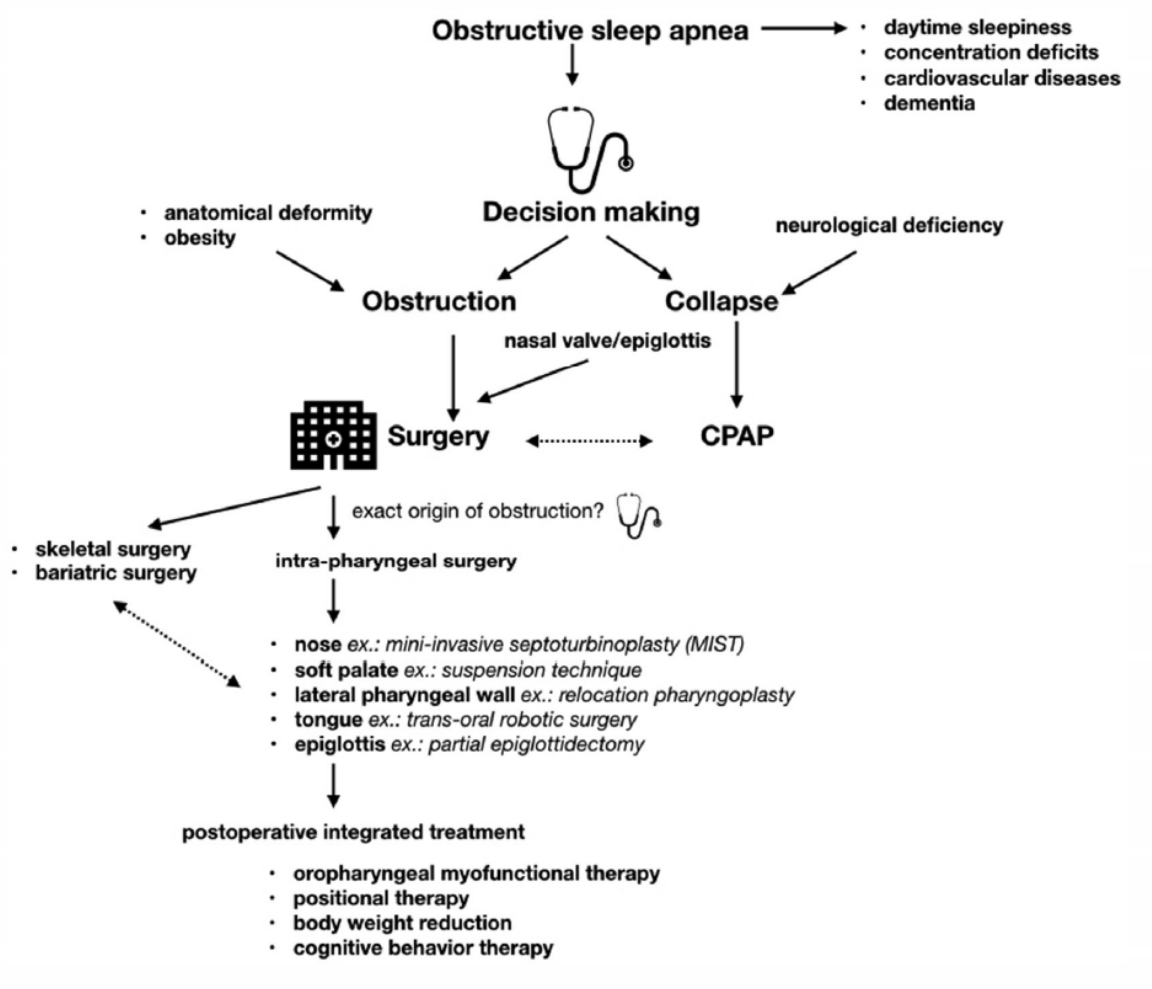


Figure 14: Flowchart detailing the effects and treatment of obstructive sleep apnea (OSA)[41]

A variety of treatment options are available for individuals suffering from OSA, depending on the cause (see Figure 14). Typically, first line treatment of OSA is with nightly use of continuous positive airway pressure, or CPAP. CPAP involves wearing a facemask at night that continuously applies a light air pressure to keep airways open. CPAP is not always effective for a number of reasons. One such reason is that though

CPAP treats the sleep apnea, the discomfort from wearing a facemask all night may cause sleep quality to decline in other ways, thus rendering the treatment obsolete.

Another reason is that CPAP may not be sufficient to correct the cause of the sleep apnea. If the OSA is of significant detriment to the individual, and CPAP is not sufficient to treat the symptoms, then surgery is the alternative treatment. A number of surgical, dental, and orthodontic treatments have been developed to combat OSA, including adenotonsillotomy (subtotal removal of the tonsils), mandibular advancement, and rapid maxillary expansion.[48] More invasive surgical techniques are available should first-line treatments fail to correct the OSA, but given the risks of such techniques, a thorough risk vs. benefits analysis should be done, especially when the patient is a young child. Given the complexities of human airways and the multifactorial causes of OSA, plans involving surgery also require significant postoperative integrated treatments. Such treatments involve strengthening the muscles using oropharyngeal myofunctional therapy.

Socioeconomic Status and Sleep Disturbance

Children from families with lower socioeconomic status (SES) are at higher risk for sleep disturbances and excessive daytime sleepiness.[49] Studies have shown that low SES families have shorter sleep duration when assessed objectively through use of actinography, as well as through self-reports. Findings from the National Sleep Foundation's 2006 survey showed that children in families from the lowest income

bracket reported greater difficulty falling asleep and staying asleep as compared with children from families with income in the highest bracket.[49]

A number of factors is believed to explain the disparity in sleep disturbance between children in families of different SES. The environmental conditions of families of lower SES is more disruptive, leading to greater variability in sleep schedule. Children in lower SES families were more likely to report pre-sleep worries, which is associated with night time awakening.

Over-indebtedness has also been studied in relation to sleep disturbance. Over-indebtedness, defined as being in a situation in which the household income is not sufficient to meet both living expenses as well as payment obligations, has been increasing steadily.[50] Recent studies have shown that over-indebtedness should be considered independently of SES when considered as a health index. It should be noted that over-indebtedness is not necessarily those of low SES, but rather affects individuals of all income, educational levels, and occupations. Associations of over-indebtedness and health, both mental and physical, include depression, obesity, diabetes, and back pain. In regards to sleep, over-indebtedness is seen to increase the risk of problems in both sleep onset and sleep maintenance. It is believed that the link between sleep disturbance and over-indebtedness is both the lack of material (i.e. substandard living conditions due inability to afford it) as well as psychosocial effects stemming from the persistent lack of financial resources needed to cover living costs and payment obligations.

Treatments for Sleep Disturbance

Sleep disturbances in adolescents has become a public health epidemic, and given its connection to mental health disorders, there is a need to curb the downward trend in sleep quality amongst adolescents in their time of vulnerability. One method would be to increase education on proper sleep hygiene and the negative effects of sleep deprivation.

Table 6: Components of good sleep hygiene[51]

Sleep Hygiene	
Not exercising withing 4 hours of bedtime	Regular sleep/wake times
Avoiding nicotine and caffeine 6 hours before bedtime	Avoiding heavy dinners
Avoid alcohol 4 hours before bedtime	Reduce fluid intake near bedtime
Avoid bedtime technology use	Avoid daytime napping

Practicing proper sleep hygiene will negate a lot of the contributing factors mentioned above to adolescent's poor sleep quality (see Table 6). One study revealed that health literacy (defined as the ability to obtain, understand, and use health information to make decisions on healthcare)[52] and sleep disturbance are associated with mental health problems. Low health literacy and sleep problems were found to increase the prevalence of sleep mental disorders. Increasing educational focus (see Appendix 6) on the importance of getting the proper amount of sleep, on how to practice good sleep hygiene, and how sleep deprivation can lead to poor mental health outcomes can reduce the number of cases of sleep disturbance in adolescents.

Another method to improve adolescent sleep quality is by changing public policies. School start times (SST) has become a topic of debate recently due to the rise in sleep disruption amongst young children and adolescents. The American Academy of Pediatrics recommended, in a statement published in 2014, that middle and high schools modify start times to no earlier than 8:30am.[53] At the time, the average SST throughout the nation was 8:03am, though with substantial variation by states (see Figure 15). Only 17.7% of public schools at a SST later than the recommended 8:30am.

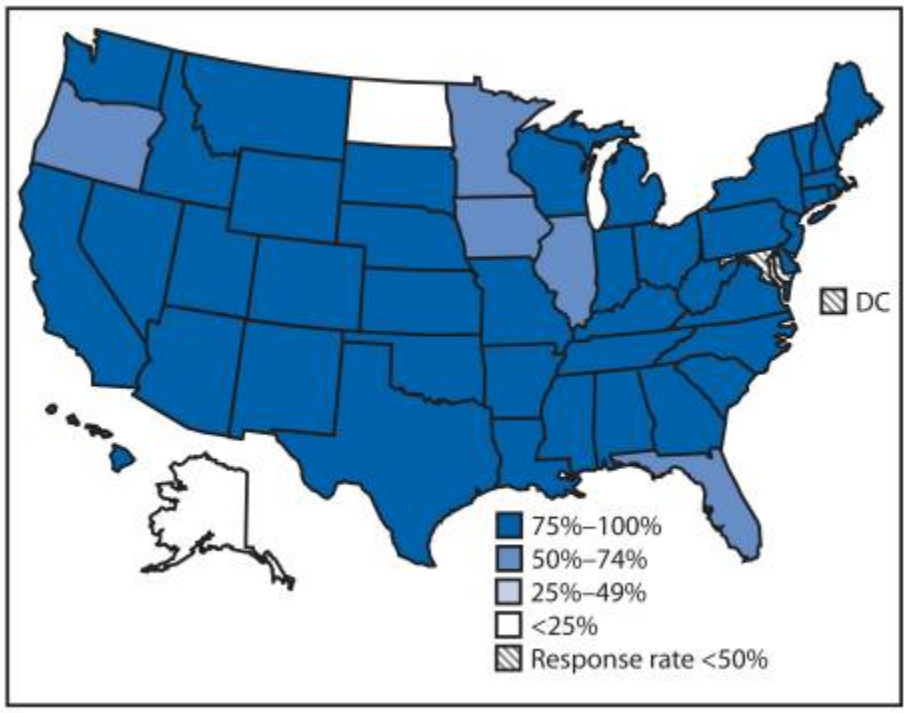


Figure 25: Percentage of public schools with SST before 8:30am, by state

Pilot programs and studies have been performed in the United States,[1,11] Hong Kong,[54] and Australia[55] on delaying SST on adolescent health, both mental and physical. All have agreed that early SST plays a major role in the epidemic of sleep deprivation, especially in adolescents. The natural delay in the sleep-wake phase driven by neurobiological changes that occurs during puberty conflicts with the need for students to wake early due to early SST. As little as a 15 minutes delay in school start times, from 7:45am to 8:00am resulted in a benefits to sleep quality, mental health, behaviors, and daytime functioning, as shown by self-reported surveys from the children as well as from surveys filled out by teachers of the students.

One unexpected benefit from delayed SST was that the life expectancy of adolescents increased. Delayed SST resulted in lower rates of daytime sleepiness, and in turn, a lowered rate of drowsy and distracted driving. In Teton County in Wyoming, a shift of SST from 7:35am to 8:55am resulted in a 70 percent decrease in traffic accidents involving sixteen to eighteen year-old drivers[1].

DISCUSSION

Sleep is essential in the maintenance of the health and function of the entire body. Despite it being a critical part of our lives, sleep duration and quality has trended downward in the past decades world-wide. A 1942 survey showed that the average adult slept 7 hours and 55 minutes. A more recent survey has found that number to have dropped to 6 hours and 31 minutes in the United States, and 6 hours and 22 minutes in Japan. Both of these are well below the recommended 8 hours of sleep as recommended by the World Health Organization (WHO). Sleep disturbances have become a world-wide issue, afflicting both adults and children. While sleep is often though of to affect individuals, there are societal repercussions of such wide spread sleep deprivation, in the economy, in education, and even in the medical field. Sleep deprivations causes a myriad of negative effects, both physical and mental, and these effects reflect on the effectiveness and productiveness of society.

Developing adolescents, undergoing puberty and all the difficulties that it entails, are especially vulnerable to the negative effects of sleep disturbances. Mental health disorders and sleeping disorders have a well-documented link in adults. Also known is the fact that a large number of mental health disorders begins during childhood, and extend well into adult life. This is worrying, as developing children are following the same downward trend in sleep duration and quality. Mental health disorders such as anxiety, depression, and suicidal ideation, are already one of society's most concerning public health challenges.

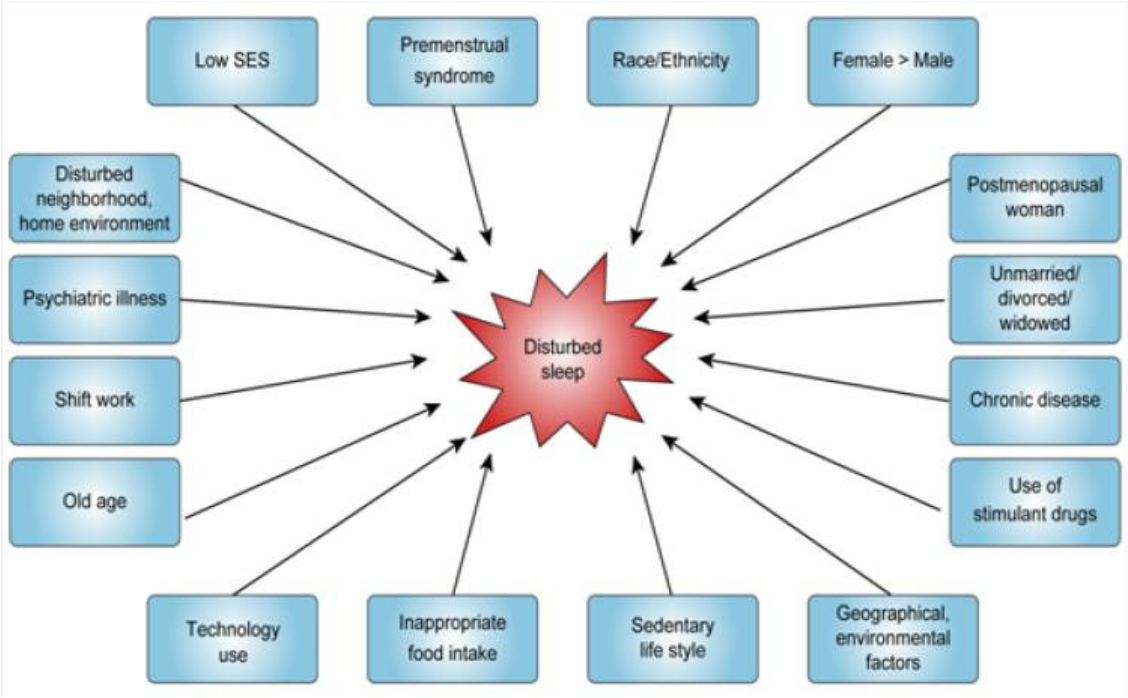
Treatment of sleep disturbance can be complicated, due to the multiple variables involved (see Appendix 7). In terms of a widespread societal treatment of sleep disturbances, a campaign to improve the sleep hygiene across the country is required. An increase in public education regarding proper sleep hygiene, the effects of sleep deprivation, and its connection to mental health disorders may turn the tide in the growing epidemic that is sleep-wake disorders. In terms of public policy, SST across the nation needs to be improved in order to meet the recommendations of the American Academy of Pediatrics. Diagnosis and treating the underlying causes of mental disorders is also required, due to the bidirectional link between sleep disturbances and anxiety, depression and other mental health disorders.

The lack of attention to the growing epidemic of sleep-wake disorders will only aggravate the spread of such disorders. Corrections to this trend need to be considered, on both a societal and individual level in order to curb the spread of sleep disturbance and mental health disorders.

APPENDIX 1

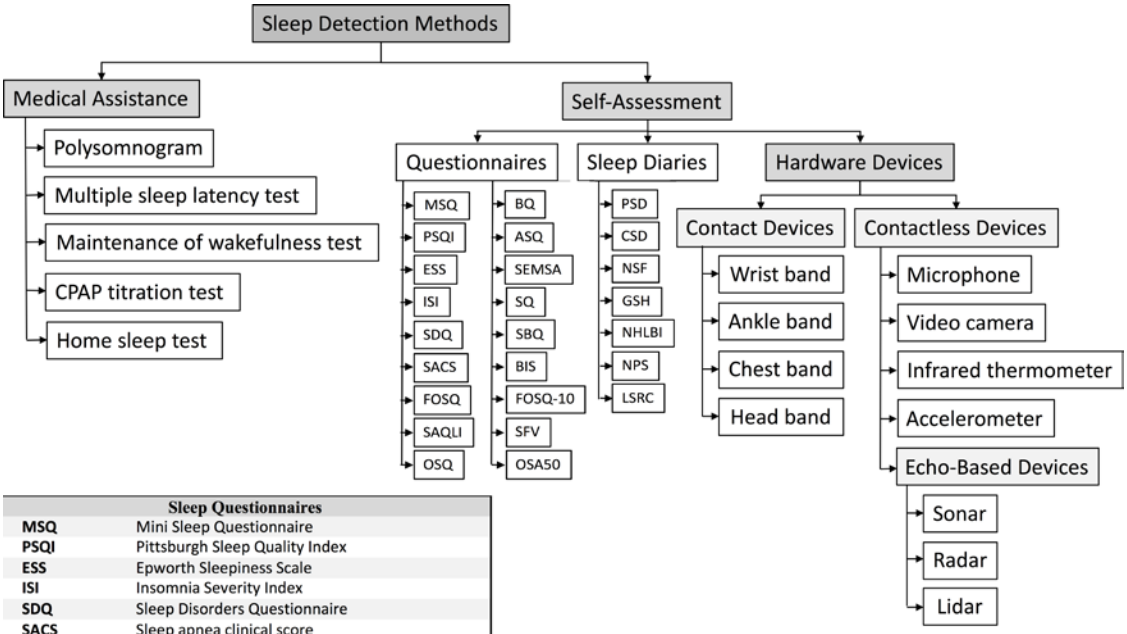
Partial list of etiological factors associated with sleep disturbance[56]

SES – Socioeconomic Status



APPENDIX 2

Taxonomy of sleep detection methods[3]



Sleep Questionnaires	
MSQ	Mini Sleep Questionnaire
PSQI	Pittsburgh Sleep Quality Index
ESS	Epworth Sleepiness Scale
ISI	Insomnia Severity Index
SDQ	Sleep Disorders Questionnaire
SACS	Sleep apnea clinical score
FOSQ	Functional Outcomes of Sleep Questionnaire
SAQLI	Calgary Sleep Apnea Quality of Life Index
OSQ	Oviedo Sleep Questionnaire
BQ	Berlin Questionnaire
ASQ	Athens Sleep Questionnaire
SEMSA	Self-Efficacy Measure for Sleep Apnea
SQ	STOP Questionnaire
SBQ	STOP-BANG Questionnaire
BIS	Bergen Insomnia Scale
FOSQ-10	Functional Outcomes of Sleep Questionnaire - 10
SFV	Simple Four Variables
OSA50	Obesity, Snoring, Apneas, aged over 50

Sleep Diaries	
PSD	Pittsburgh Sleep Diary
CSD	Consensus Sleep Diary
NSF	National Sleep Foundation
GSH	Get Self Help Sleep Diary
NHLBI	National Heart, Lung, and Blood Institute
NPS	NPS MedicineWise Sleep Diary
LSRC	Loughborough Sleep Research Center

APPENDIX 3

The Pittsburgh Sleep Quality Index (PSQI)[16]

The Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions. During the past month,

1. When have you usually gone to bed? _____
2. How long (in minutes) has it taken you to fall asleep each night? _____
3. When have you usually gotten up in the morning? _____
4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed) _____

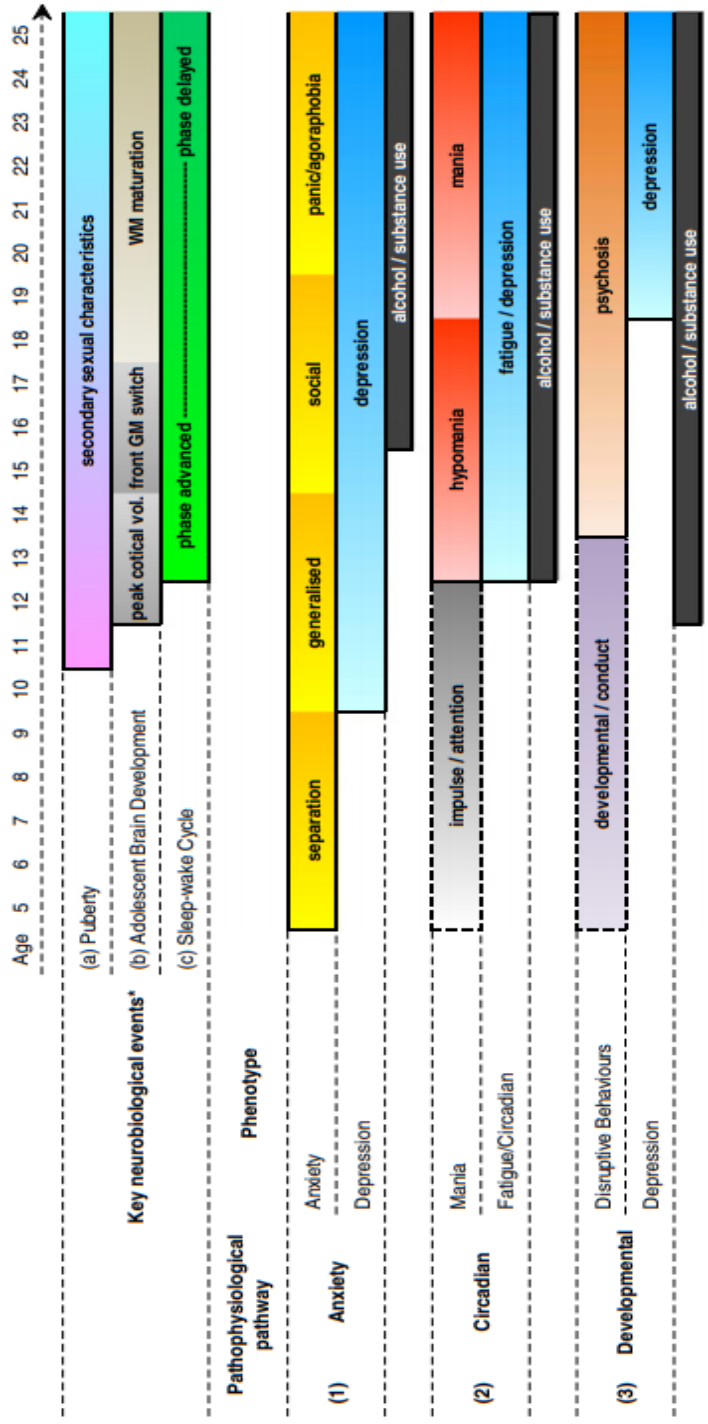
5. During the past month, how often have you had trouble sleeping because you…	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times week (3)
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s):				
6. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)
9. During the past month, how would you rate your sleep quality overall?				

Component 1	#9 Score	C1_____
Component 2	#2 Score (≤15min=0; 16-30 min=1; 31-60 min=2, >60 min=3) + #5a Score (if sum is equal 0=0; 1-2=1; 3-4=2; 5-6=3)	C2_____
Component 3	#4 Score (>7=0; 6-7=1; 5-6=2; <5=3)	C3_____
Component 4	(total # of hours asleep)/(total # of hours in bed) x 100 >85%=0, 75%-84%=1, 65%-74%=2, <65%=3	C4_____
Component 5	Sum of Scores #5b to #5j (0=0; 1-9=1; 10-18=2; 19-27=3)	C5_____
Component 6	#6 Score	C6_____
Component 7	#7 Score + #8 Score (0=0; 1-2=1; 3-4=2; 5-6=3)	C7_____

Add the seven component scores together _____ **Global PSQI Score** _____

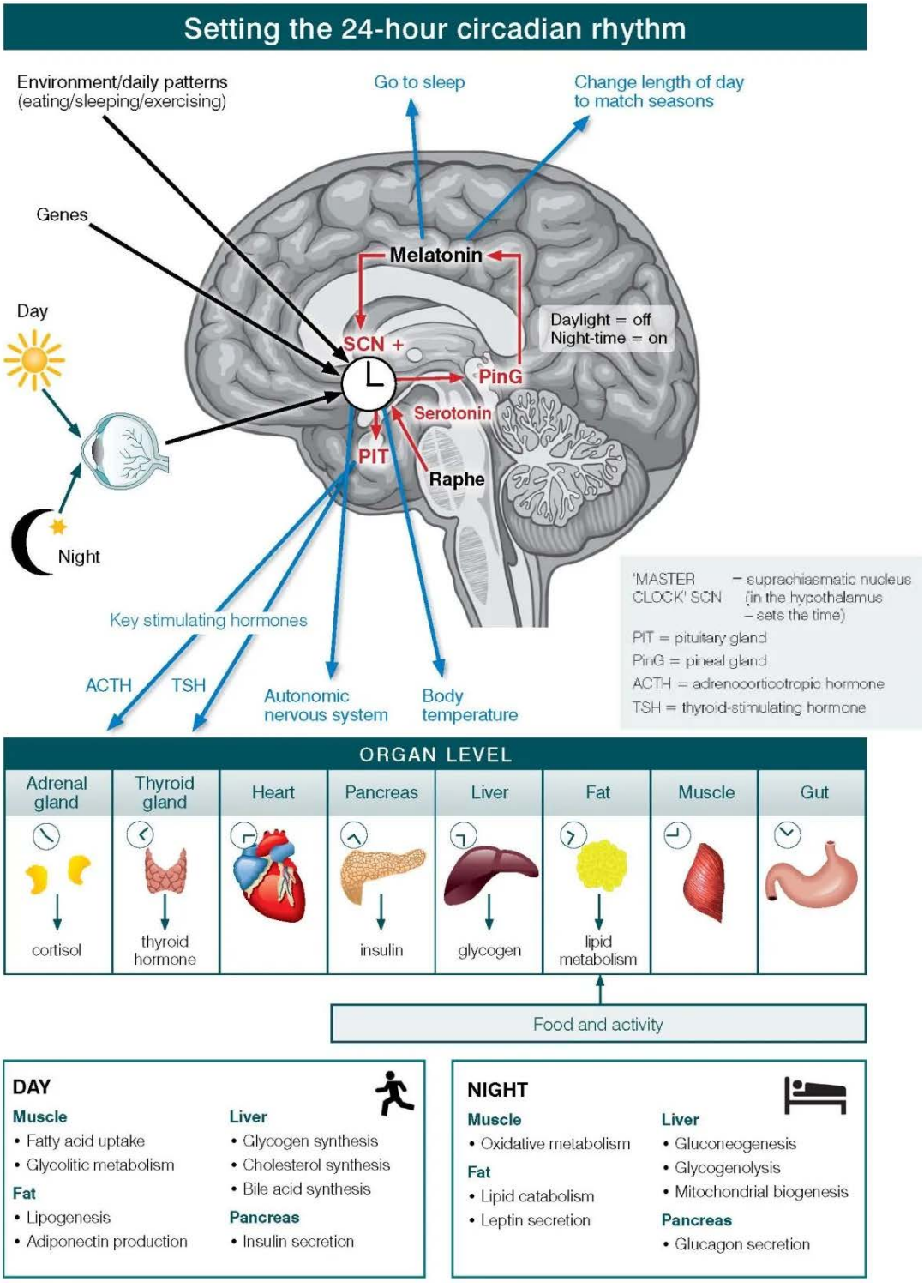
APPENDIX 4

The three common pathways that lead to mental health disorders in adolescents undergoing puberty[57].



APPENDIX 5

The effect of the circadian rhythm in human beings[57].



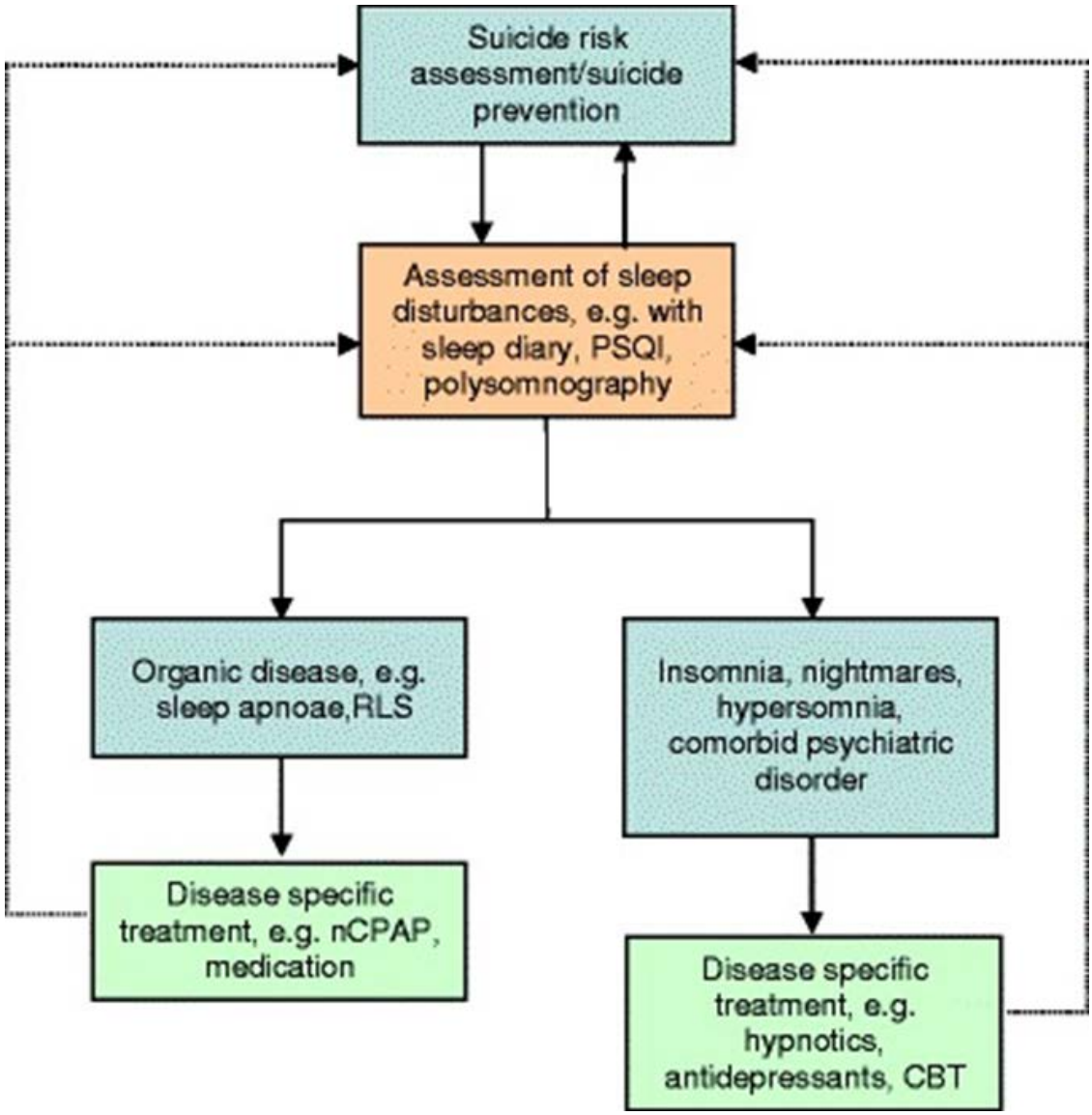
APPENDIX 6

Flyer from Stanford on tips to prevent neuropsychiatric disorders[58]

APPENDIX 7

Assessment and treatment of sleep disturbances in suicide prevention[59]

PSQI – Pittsburgh sleep quality index
RLS – Restless leg syndrome
nCPAP – Nasal continuous positive airway pressure
CBT – Cognitive behavior therapy



LIST OF JOURNAL ABBREVIATIONS

Am J Forensic Med Pathol	American Journal of Forensic Medicine and Pathology
Atten Deficit Hyperact Disord	Attention Deficit and Hyperactivity Disorders
Biomed J	Biomedical Journal
BMC Med	BMC Medicine
Curr Prob Pediatr Adolesc Health Care	Current Problems in Pediatric and Adolescent Health Care
Depress Anxiety	Depression and Anxiety
EPMA J	The EPMA Journal
Eur J Pain	European Journal of Pain
Glob Pediatr Health	Global Pediatric Health
Int J Environ Res Public Health	International Journal of Environmental Research and Public Health
Int J Paediatr Dent	International Journal of Paediatric Dentistry
Int J Pediatr Otorhinolaryngol	International Journal of Pediatric Otorhinolaryngology
J Adolesc	Journal of Adolescence
J Affect Disord	Journal of Affective Disorders
J Am Acad Child Adolesc Psychiatry	Journal of the American Academy of Child and Adolescent Psychiatry
J Anxiety Disord	Journal of Anxiety Disorders
J Behav Med	Journal of Behavioral Medicine
J Child Psychol Psychiatry	Journal of Child Psychology and Psychiatry and Allied Disciplines
J Clin Sleep Med	Journal of Clinical Sleep Medicine

J Sch Nurs	Journal of School Nursing
Med J Aust	Medical Journal of Australia
Med Sci Basel Switz	Medical Sciences (Basel, Switzerland)
MMWR Morb Mortal Wkly Rep	MMWR: Morbidity and Mortality Weekly Report
Mult Scler J – Exp Transl Clin	Multiple Sclerosis Journal – Experimental, Translational and Clinical
Neuropsychiatr Dis Treat	Neuropsychiatric Disease and Treatment
Nurs Health Sci	Nursing & Health Sciences
Nurs Outlook	Nursing Outlook
Pediatr Ann	Pediatric Annals
Pediatr Int	Pediatrics International
Psychiatry Res	Psychiatry Research
Res Dev Disabil	Research in Developmental Disabilities
Schizophr Res	Schizophrenia Research
Sleep Med	Sleep Medicine
Sleep Med Disord Int J	Sleep Medicine and Disorders: International Journal

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