

Review Article

Sleep Disturbances in Adolescents: A Narrative Review

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Abstract

This narrative review is based on a literature search on PsycINFO and PubMed that involved entering the terms adolescent sleep disturbances. Following exclusion criteria, 71 papers could be classified as adolescent sleep disturbance studies including research on the prevalence, the effects and the risk factors for sleep disturbances. Most of the studies have been conducted in other countries where the prevalence of adolescent sleep disturbances has widely ranged from 2% to 77%. The effects of sleep disturbances have included academic problems, pain conditions, physical health, behavioral and emotional problems. The predictor or risk variables have included family problems, stress, sedentary behavior, excessive use of social media, attention deficits, headaches and emotional problems. Several cognitive behavioral therapy studies as well as some interventions with multiple components have shown reduced sleep disturbances. Like other literature on adolescent problems, this research is limited by primarily being derived from self-report and parent report and by the absence of longitudinal data that could help inform prevention/intervention research by further profiling those at risk for sleep disturbances.

This narrative review is based on a literature search on PsycINFO and PubMed that involved entering the terms adolescent sleep disturbances. The inclusion criteria were peer reviewed empirical studies. Exclusion criteria were case studies and non-English papers. Following these criteria, 71 papers could be classified as adolescent sleep disturbance studies including research on the prevalence, the effects and the risk factors for sleep disturbances. Most of the studies have been conducted in other countries where the prevalence of adolescent sleep disturbances has widely ranged from 2% to 77%. The effects of sleep disturbances have included academic problems, pain conditions, physical health, behavioral and emotional problems. The predictor or risk variables have included family problems, stress, sedentary behavior, excessive use of social media, attention deficits, headaches and emotional problems. Several cognitive behavior therapy studies as well as some interventions with multiple components have shown reduced sleep disturbances. Like other literature on adolescent problems, this research is limited by primarily deriving from self-report and parent report and by the absence of longitudinal data that could help inform prevention/intervention research by further profiling those at risk for sleep disturbances. This narrative review is accordingly divided into sections on the prevalence of adolescent sleep disturbances, the scales that have been used to assess those differences, the effects of sleep problems, the risk factors for sleep disturbances, interventions and methodological limitations and future directions.

PREVALENCE OF SLEEP DISTURBANCES IN ADOLESCENTS

The prevalence of sleep disturbances has varied widely

from 2-77% across countries. This variability may be culturally determined or related to methodological differences in data collection including age and age range of adolescents, recruiting and assessment methods (e.g. national survey or school questionnaire) and sleep measures used.

In a study on 30,002 11-15 year old adolescents in Denmark, the prevalence of difficulty falling asleep was 13% [1]. This was a significant increase from the prevalence of 7% in 1991. Greater prevalence was noted among girls, younger adolescents and those with lower socioeconomic status. In a sample of 16,781 Dutch adolescents, approximately 20% reported sleep disturbances in the previous month [2]. The sleep disturbances in this study were related to psychosocial problems, suicidality and health risk behaviors including cannabis use and compulsive multimedia use. In a study on 937 ninth grade Swedish adolescents, 11% had sleeping difficulties but as many as 55% of the adolescents slept less than the recommended eight hours per night [3]. The use of technology and school stress were associated with short sleep duration and these problems were greater for girls than boys.

Another example of sleep disturbances being related to addictive use of the Internet comes from a sample of 631 adolescents from middle and high schools who completed self-report questionnaires [4]. In this sample, 42% reported sleep disturbances, 30% Internet addiction, 27% depression and 23% suicidal ideation. Those who expressed suicidal ideation had greater rates of these problems. In a confirmatory path analysis, the effect of sleep disturbance on suicidal ideation was moderated by Internet addiction and mediated by the sleep effects on depressive symptoms. This study highlights the comorbidity of these adolescent problems.

Other measures of sleep problems include sleep apnea and excessive daytime sleepiness. In a study on sleep apnea, 746 fifth and seventh graders completed self-report questionnaires [5]. Thirty-three percent reported suspecting sleep apnea and 9% reported suicidal ideation. Although suspected sleep apnea was associated with suicidal ideation, that relationship was attenuated by depression and stress. Surprisingly, the screening criterion for sleep apnea was daytime sleepiness. In another study on sleep apnea, the adolescents were assigned to high risk (N=202) and low risk (N=591) groups [6]. The high risk adolescents with obstructive sleep apnea had more severe anxiety symptoms, lower self-esteem, insomnia, excessive daytime sleepiness and higher BMI. In a study that focused specifically on excessive daytime sleepiness, the overall prevalence of excessive daytime sleepiness was 29% in a sample of 10,086 Hong Kong adolescents [7]. Excessive daytime sleepiness was, in turn, correlated with short weekday time in bed, eveningness, chronotype and insomnia symptoms.

The prevalence of sleep problems is even greater in a sample of adolescents with attention - deficit/hyperactivity disorder [8]. In this study, 63% of 81 adolescents (13-17-years- old) reported less than eight hours of sleep on school nights, although the prevalence was even greater (at 77%) for parent-reported sleep duration. This lack of agreement highlights the question of reliability of adolescent report (or of parent report). As in many other studies on adolescent sleep problems, nighttime media use was associated with shorter sleep duration and greater sleep problems. Media use was also related to greater anxiety and depression and to evening circadian preference as well as greater daytime sleepiness. The adolescents and parents also differed on the type of anxiety being reported, with adolescents suggesting that they were having panic symptoms and parents reporting that their adolescents were showing generalized anxiety disorder symptoms.

MEASURES OF SLEEP DISTURBANCES IN ADOLESCENTS

Although several sleep researchers have used less than eight hours as a criterion for sleep disturbances in adolescents, others have used scales that address several aspects of sleep disturbances. Some of these are scales that had been developed for adult sleep problems and the research was then conducted to validate the measure for adolescents. For example, in a study on Australian adolescents (N=889), the Pittsburgh Sleep Quality Index was assessed by exploratory factor analysis and confirmatory factor analysis as well as by convergent validity with the Center for Epidemiological Studies-Depression scale and the Spence Children's Anxiety Scale [9]. These findings validated the use of this sleep scale for adolescents and highlighted the covariation between poor sleep duration, efficiency and latency and showed good convergent validity with depression and anxiety scores.

The Chronic Sleep Reduction Questionnaire is another scale that has been validated as a measure of prolonged and insufficient sleep in a sample of 298 healthy adolescents versus a sample of 290 adolescents with insomnia/delayed sleep-wake phase disorder [10]. A third adult sleep scale that has been validated

for adolescents is the Patient Reported Outcomes Measurement Information System (PROMIS) including sleep disturbance and sleep-related impairment items [11]. In this study on 1046 Dutch-Flemish adolescents, confirmatory and exploratory factor analyses validated this sleep measure by reducing the items for both sleep disturbance and sleep-related impairment. The researchers suggested that these findings needed to be replicated in a larger and more diverse sample.

The Sleep Disorder Self-Report was developed in a cross-sectional study on 2310 Chilean adolescents based on duration, alterations, breathing problems, fatigue and stimulant use [12]. Reliability was based on internal consistency which suggested that this measure for sleep disorders in adolescents is valid and reliable. The Sleep Health Composite is a more expansive assessment that included a seven-day sleep diary as well as self-report rating scales [13]. Greater sleep health on this measure was correlated with fewer physical symptoms, and a reduced risk for obesity and mood or anxiety disorders.

In a more exploratory study, adolescents who were referred to residential care facilities for neglect, abuse and family problems were compared with adolescents living at home using self-report, actigraphy and a more qualitative measure of self-figure drawings and accompanying narratives [14]. The adolescents in residential care were given an earlier sleep schedule which allowed for longer sleep duration than those living at home. Their sleep duration and sleep latency were longer based on actigraphy, and they drew themselves in a closed space with monochromatic colors. Their narratives revealed their wanting to avoid anxiety-provoking experiences.

EFFECTS OF SLEEP DISTURBANCES

Several negative effects have been reported for sleep disturbances and adolescents. These include school problems, pain syndromes, physical health, behavioral and emotional problems. It is not clear if these are truly effects or risk factors or reciprocal/comorbid problems given that most of the studies are cross-sectional as opposed to longitudinal, making it impossible to determine causality or directionality. Typically, the researchers have referred to comorbid problems as correlates or they have arbitrarily designated a comorbid problem as a predictor or an outcome variable in a regression analysis. Unfortunately, longitudinal studies are both costly and have compliance problems. Cross-sectional data, nonetheless, can inform intervention efforts.

SCHOOL PROBLEMS

School problems that have appeared in this recent adolescent sleep disturbances literature include cognitive problems, attention and learning problems as well as connectedness. In a

Table 1: Prevalence rates in different countries and first authors.

Prevalence	First authors
Denmark- 13%	Holstein
Holland- 20%	Verkooijen
Sweden- 55%	Jakobssen
Hong Kong- 29%	Liu

study exploring the relationship between sleep and cognitive problems, 163 adolescents with an evening circadian preference were studied [15]. Earlier dim light melatonin onset when combined with later bedtime and a shorter total sleep time predicted greater risk in the cognitive domain. In a study that involved teacher report on 172 adolescents, findings from path models suggested that daytime sleepiness as well as bullying and victimization were associated with attention and learning problems [16]. The association between victimization/bullying and attention/learning problems was attenuated as daytime sleepiness increased. In a two-wave cross-legged panel analysis, the relationship between adolescents' sleep problems and school connectedness was explored [17]. Sleep problems that occurred at the beginning of the school year significantly and negatively predicted school connectedness at the end of the school year, but school connectedness at the beginning of the year did not predict sleep problems at the end of the year. This two-wave cross-legged panel analysis would seem to be a good model for identifying effects of and risks for sleep disturbances in adolescents.

PAIN SYNDROMES

Pain syndromes might be expected effects of sleep problems given that insufficient deep sleep leads to the release of substance P which causes pain [18]. Another potential mechanism is a reduction in serotonin (the anti-pain neurotransmitter) following sleep deprivation. Several pain conditions have been noted following sleep disturbances in adolescents including headaches, stomach aches, backaches and musculoskeletal problems.

In a study on 29,470 adolescents in Canada, chronotype was estimated using the midpoint of sleep on weekends and its relationship to physical health and health behaviors [19]. The results suggested that each one hour delay in chronotype was associated with a greater number of headaches, backaches and stomachaches. The same delay was related to unhealthy behaviors including daily soft drink consumption, smoking and screen time. In a study on adolescents from the UK, electronic medical records were searched from a primary care database [20]. Adolescents who had consulted primary care physicians for sleep problems had significantly increased risk of consultation for musculoskeletal pain. Once again pain could relate to insufficient restorative sleep and the increased levels of substance P that causes pain. Substance P could easily be assayed from saliva samples, and together with sleep activity levels from actigraphy, that potential underlying mechanism could be assessed.

PHYSICAL HEALTH

Surprisingly few studies have focused on sleep effects on physical health in adolescents in this recent literature. An earlier

literature may have documented health problems following chronic sleep disturbances. In this recent literature, a large cohort of adolescents (N=3104) reported sleep problems and poor health in a longitudinal repeated measures study [21]. The results of multivariate logistic regressions suggested that chronic sleep disturbance (defined as difficulty falling asleep or staying asleep) led to twice the odds of reporting sub-optimal health at their one-year follow-up. In a cross-sectional study on adolescents from Bogotá (N=2779), metabolic abnormalities were assessed including hyperglycemia, hypertriglyceridemia, low high-density lipoprotein cholesterol (HDL-c), hypertension and increased waist circumference [22]. Logistic regression analysis suggested that increased glucose levels were noted in boys who had short sleep duration. And, excessive sleepiness during the day was related to low HDL-c levels in boys and high triglyceride levels in girls. The girls who had irregular sleep patterns had decreased HDL-c levels. These metabolic abnormalities may have contributed to the poor general health conditions noted in the previous study [21].

BEHAVIOR PROBLEMS

Several different behavior problems have been noted as negative effects of sleep disturbances on adolescents, but only in a few studies in the recent literature. These include internalizing behavior, aggression, academic failure, drug use and sexual behavior. In a study on adolescents from small towns and semi-rural communities in Alabama (N=235), sleep duration was measured by actigraphy for one week, and adolescents completed reports on sleep quality and internalizing/externalizing behaviors [23]. Adolescents who had both poor sleep quality and short sleep duration had higher levels of internalizing symptoms, as well as aggressive and rule-breaking behavior. The highest levels of these negative behaviors were noted in adolescents from low-income homes. Family income has been entered as a potential covariate in several adolescent sleep studies but, surprisingly, it has rarely been a significant risk factor.

In a large sample survey on students from Virginia (21,360 10th grade and 20,330 12th grade), sleep duration was measured by self-report as the average number of hours of sleep per school night [24]. The adolescents also self-reported 7 risk behaviors including drug use (alcohol, cigarette, illicit drugs and inappropriate prescription drug use), risky sexual behavior, deviant behavior and academic failure. Adolescents who slept less than the recommended eight hours per week day were significantly more likely to have a greater number of risk behaviors. Protective factors were also reported in this study, but, surprisingly, these were not significantly related to sleep duration for either grade.

EMOTIONAL PROBLEMS

Emotional problems have also been rarely researched as outcome variables/effects of sleep disturbances in adolescents. However, they have frequently been assessed as risk factors for sleep disturbances in adolescents. The treatment of emotional problems as effects or risk factors has been an arbitrary decision by researchers in these most typical cross-sectional studies that cannot result in causality conclusions. In this section on emotional problems as effects, the emotional problems have been

Table 2: Scales for assessing sleep disturbances and first authors.

Scale	First author
Pittsburg Sleep Quality Index	Raniti
Chronic Sleep Reduction Questionnaire	Dewald- Kaufmann
PROMIS	Van Kooten
Sleep Disorder Self-Report	Gomez-Campos
Sleep Health Composite	Dong

rated on questionnaires such as the Strengths and Difficulties Questionnaire or they have been listed as depression or anxiety symptoms. And, as in the studies on physical and behavior problems, different measures of sleep have been recorded including eveningness, insomnia, mid-sleep (chronotype) and sleep quality.

In a study on Chinese adolescents (N=4,948), insomnia was assessed by the Insomnia Severity Index, chronotype preference by the Morningness-Eveningness Questionnaire and emotional and behavioral problems by the Strengths and Difficulties Questionnaire [25]. As might be expected, insomnia symptoms were prevalent in the evening-type adolescents. As has typically occurred, both types of insomnia were reported including difficulty initiating sleep and difficulty maintaining sleep. Both types were independently related to emotional and behavioral problems as well as poor mental health.

In a similar study on chronotype entitled "Teenage night owls or early birds?", Canadian students were surveyed (N=2014) [26]. An hour delay in mid-sleep time (chronotype) was associated with more emotional problems, less emotional well-being, more behavior problems and fewer prosocial behaviors independent of sleep duration. The data from these two studies highlight the validity of measuring chronotype as well as insomnia and duration of sleep.

In a study on Norwegian adolescents whose parents were the informants, sleep problems were assessed by three questions including the adolescents' sleep quality, sleep sufficiency and daytime sleepiness [27]. Sleep quality problems were related to

emotional and hyperactivity-inattention problems and daytime sleepiness problems were related to hyperactivity-inattention. The variable sufficient sleep was not related to emotional problems. These results highlight the importance of examining specific sleep problems. The study would have been stronger with the addition of the adolescents' self-report to assess parent-adolescent agreement on these measures.

In a longitudinal study on Dutch adolescents (N=2230), sleep problems and anxiety symptoms were measured by the Youth Self-Report [28]. Significant associations between sleep problems and anxiety symptoms were noted at all four assessment waves, and poor sleep predicted greater anxiety symptoms between the first and second and between the third and fourth assessment waves. These are among the stronger data because of the longitudinal design that suggests that poor sleep especially during early and mid-adolescence preceded anxiety symptoms. And, anxiety may be reduced by alleviating sleep problems. In a similar study but one that addressed the association between sleep problems and depression in Chinese adolescents (N=8,998), a regression analysis suggested that sleep duration related to depression at all grades [29]. The preference for going to bed late related to both adolescent depression and behavior problems at all grades, although it was a greater risk for students in the higher grades.

Non-suicidal self-harm, suicidal ideation and suicidal attempts are among the worst effects of sleep disturbances, although once again they may be reciprocal as they have been reported in cross-sectional not longitudinal studies in this recent adolescent sleep disturbance literature. As an exception, in a longitudinal study in the UK, a group of adolescents reported non-suicidal self-harm

Table 3: Effects of sleep disturbances and first authors.

Effects	First authors
<u>School Problems</u>	
Cognitive problems	Dolsen
Attention and learning problems	Rubens
School connectedness	Bao
<u>Pain Syndromes</u>	
Headaches, backaches & stomach aches	Gariepy
Musculoskeletal pain	Andreucci
<u>Physical Health</u>	
Sub-optimal health	Conklin
Metabolic abnormalities	Pulido-Arjona
<u>Behavior Problems</u>	
Internalizing/ Externalizing	El-Sheikh
Risk behaviors	Ordway
<u>Emotional Problems</u>	
Emotional problems	Li, Gariepy
Hyperactivity/ inattention	Hestetun
Anxiety symptoms	Narmandakh
Depression symptoms	Wang/ Boafo
Non-suicidal self-harm	Mars
Suicidal attempts	Yildiz

at two time periods (N=569) [30]. The strongest predictors of non-suicidal self-harm were sleep problems including waking in the night and insufficient sleep. However, other predictors were cannabis use, other illicit drug use and lower levels of extraversion. In a comparison between suicidal adolescents with major depression (N= 17) and a group of non-depressed adolescents (N=17), the suicidal adolescents had a longer sleep onset latency, longer REM latency, higher percentage of non-REM sleep and higher REM density, suggesting shallower sleep [31]. In another study that compared adolescents who attempted suicide (N= 103) and healthy adolescents (N= 59), the adolescents who attempted suicide had poor sleep quality [32]. But the adolescents who attempted suicide also had other problems including a lower rate of school attendance, less academic achievement, socializing problems, a greater rate of smoking, and appetite changes, thus confounding the poor sleep quality effect.

RISK FACTORS/PREDICTORS

A number of risk factors/predictors have been the focus of several studies in the recent literature on adolescent sleep disturbances. They can be classified as family variables (child maltreatment and intra-family conflict), stress (bicultural stress and sexual minority stress), sedentary time, excessive use of technology (screen time, Internet use, phone awakenings, smart phone and Facebook intrusion), attention deficits (attention deficit/hyperactivity disorder and autistic traits), headaches, and emotional problems (anxiety, depression and suicidality). As in the development of a literature on a medical condition, the effects were studied first followed by the risk factors resulting in a greater number of recent publications appearing on risk factors as compared to the effects of sleep disturbances. In the recent literature on risk factors for sleep disturbances in adolescents, the majority of publications have, not surprisingly, focused on excessive use of telecommunications. This is followed by emotional problems, although once again these variables are probably bidirectional or reciprocal, as it is unknown in these cross-sectional studies whether the emotional disturbance preceded the sleep disturbance or whether the sleep disturbance contributed to the emotional problems.

FAMILY VARIABLES

Surprisingly, only three studies could be found on family variables in this recent literature on sleep disturbances in adolescents. They include a history of child maltreatment, conflict within the family and less parental monitoring of sleep time. In the study on child maltreatment (defined as sexual abuse, physical abuse and exposure to intimate partner violence), adolescents from Ontario Canada (N=2910) participated in a survey on these problems and their relationships to sleep variables [33]. The results suggested that all three types of child maltreatment had increased the odds of taking more than 10 minutes to fall asleep, of having more frequent night wakings, of sleeping fewer hours on weekdays and on weekends. The study on intra-family conflict involved a survey of Chinese adolescents (N=11,831) [34]. Structural equation modeling was used to measure the mediating effects of sleep disturbance on the relationship between family conflict and attention, internalizing and externalizing problems. And, sleep disturbance significantly mediated the relationship

between intra-family conflict and mental health problems. The survey on parental supervision of bedtime included adolescents from Singapore (N=2346) [35]. In this study, the barriers to healthy sleep included less parental supervision of bedtime but also later preferred sleep timing, longer study time and earlier school start time. The shorter sleep time was related to several problems including poor health, overweight, depression, difficulty concentrating, anxiety and thoughts of self-harm/suicide.

STRESS

Although all of the risk factors for sleep disturbances in adolescents could be considered stressors, the term stress is rarely used in the titles of the studies and stress per se is not typically measured. An exception is a study on bicultural stress and sleep. The other two studies included in this section are on being a sexual minority as a risk factor. These studies do not address stress specifically, but they might be considered stressful risk factors. In the study on bicultural stress (defined as the challenge arising from living in two cultural contexts), the participants included Latino adolescents (N=209) who completed daily diaries for a week while wearing actigraphy watches and a questionnaire on sleep problems [36,37]. A greater number of daily bicultural stressors on a given day predicted several problems that night including longer sleep onset latency, earlier sleep midpoint and shorter sleep duration. These effects especially applied to male adolescents attending higher Latino-enrollment schools.

Sexual minorities have been noted to experience increased discrimination and minority stress, so it is perhaps not surprising that they have more sleep disturbances as reported in two recent studies. In a large cross-sectional survey of Chinese adolescents (N=150,822), only 27% of sexual minority students slept eight or more hours per day which was significantly less than their heterosexual peers (36%) [38]. The reports on sleep quality also suggested a greater prevalence of sexual minority than heterosexual students (33% versus 22%). That these students were experiencing stress was probably exacerbated by school bullying victimization which may have mediated the relationship between sexual minority status and sleep quality. In a longitudinal two-wave study (11th grade and four years post high school) on a sample of U.S. adolescents (N=1,946, 6% sexual minorities), sexual minority females had a greater odds of snoring/stopping breathing and daytime sleepiness [39]. Mediation analysis indicated that 44% of this relationship was mediated by overweight status and 71% was mediated by depressive symptoms.

SEDENTARY BEHAVIOR

The Global School-Based Student Health Survey from 67 countries (N= 181,093) included data on sleep disturbance and sedentary behavior [40]. In this sample, 8% of adolescents had anxiety-induced sleep disturbance and 4% had sedentary behavior exceeding eight hours per day. When those who had less than one hour sedentary behavior per day were compared to those who had more than eight hours sedentary behavior per day, there was a two times greater odds for anxiety-induced sleep disturbance for the latter group. This association was the

Table 4: Risk factors/predictors and first authors.

<u>Risk factors</u>	<u>First authors</u>
<u>Family Variables</u>	
Child maltreatment	Turner
Family conflict	Zhang
Parental supervision	Yeo
<u>Stress</u>	
Bicultural stress	Sladek
Sexual minorities	Li, Luk
<u>Sedentary Behavior</u>	
>8 hours per day	Vancampfort
Sedentary time	Choi
Obesity	MacLean
<u>Telecommunication</u>	
>Screen time after bedtime	Widome, Lissak, Cabre-Riera
Problematic internet use	Park, Kawabe
Smart phone use	Chung, Dewi, Bauducco, Forester
Facebook intrusion	Przepiorka
<u>Emotional Problems</u>	
Loneliness	Eccles
Headaches	Lateef
Evening negative effect	Dolsen
Anxiety	Geng, Li
Depression	Gupta
PTSD & depression	Schneiderman

same for both sexes, and only a small difference was noted across countries. In a smaller sample of Korean adolescents (N=80) that used actigraphy to measure both sedentary time and sleep duration for a period of five days, data analysis revealed a similar negative correlation between sedentary time and sleep duration [41, 37].

Sedentary time may be a risk factor for obesity which, in turn, is related to sleep problems. In a study on adolescents whose body mass index was greater than the 95th percentile (N=210), polysomnography revealed multiple sleep problems including obstructive sleep apnea which was noted in 44% of the adolescents [42].

TELECOMMUNICATION

Telecommunication effects on sleep in adolescents have included screen time, Internet use, phone awakenings, smartphone use and Facebook “intrusion”. In a cohort of Minnesota adolescents (N=2,134), shorter self-reported sleep duration was related to greater computer/screen time as well as screen use after bedtime [43]. Shorter sleep duration was also associated with all other sleep-wake problems as well as depressive symptoms. In a study on Indonesian adolescents (N=180), insomnia was associated with duration of social network site use (SNS) and academic stress [44].

In a review of the literature, excessive screen time was associated with poor sleep which, in turn, was related to

internalizing and externalizing behavior as well as depressive symptoms and suicidal ideation [45]. In contrast, in a systematic review of reviews there was only weak evidence for the association between screen time and poor sleep [46]. However, this review of 13 reviews included only one high quality review paper. And, when actigraphy has been used, the use of screen devices has been related to poor sleep quality [47]. In this cross-sectional study on adolescents from Menorca (N=226), actigraphy was used to record sleep activity for seven nights. Greater use was associated with lower sleep efficiency and longer latency to sleep, and problematic mobile phone use was associated with lower sleep quality.

In a study on South Korean adolescents, those with problematic Internet use (N=152) were compared with adolescents with normal Internet use (N=614) [6]. Those with problematic use had greater insomnia and excessive daytime sleepiness, and that group included more evening types. When depression was entered as a moderating variable, problematic Internet use had greater effects on insomnia and excessive daytime sleepiness. The relationship between Internet addiction and sleep habits has also been explored in Japanese adolescents (N= 853) [48]. In this study, Young’s Internet Addiction Test was used to divide the sample into addicted, possibly-addicted and non-addicted groups. The total scores from the Child and Adolescent Sleep Checklist were higher in the addicted and possibly-addicted groups and the total night sleep time was

significantly shorter and the bedtime was significantly delayed on both weekdays and weekends in the addicted group.

The use of smart phones has also been tied to sleep problems in at least four studies in the current literature on adolescent sleep disturbances. In one study from South Korea, analyses were performed on a sample of adolescents using smart phones (N=1796) of which 15% of boys and 24% of girls were at-risk smart phone users [49]. This at-risk group had higher daytime sleepiness scale scores. Other risk factors were female gender, alcohol consumption, poor health, initiating sleep after midnight, taking more time to fall asleep and night sleep duration less than six hours.

In a sample from Indonesia (N=714), the use of smart phones at night was positively correlated with sleep disturbance as well as depression symptoms [50]. And, in a cross-sectional survey of Swedish adolescents (N=2,767), 12% of the younger adolescents and 18% of the older adolescents slept less than the recommended seven hours [51]. Those adolescents who reported bedtime arousal and use of information and communication technology in bed were the most likely to report less than seven hours sleep. Additional predictors of less than 7 hours sleep were stress at home and school performance stress. And those adolescents sleeping less than the recommended seven hours also reported more behavior problems as well as more depression, anxiety and anger.

Even one nocturnal awakening per month from a mobile phone has been associated with restless sleep and problems falling asleep in Swiss adolescents [52]. The authors interpreted their data cautiously, suggesting that the natural changes in circadian rhythms during adolescence may be confounding the effects of mobile phone and media use on sleep. Adolescents who may be experiencing more extreme circadian rhythm changes in sleep may be those who are engaging in greater media use. Facebook intrusion has also contributed to sleep problems in a sample of 426 adolescents [53]. These results were based on the Facebook Intrusion Questionnaire and the Medical Outcomes Study Sleep Scale.

ATTENTION PROBLEMS

Excessive use of technology has also reduced school-night sleep duration especially in adolescents with attention-deficit/hyperactivity disorder (N=162 with ADHD and 140 without ADHD) [54]. ADHD in itself has been related to problematic sleep in adolescents presenting at a behavioral sleep medicine clinic (N=376) [55]. In another study on adolescents with ADHD (N=80), greater evening preference reported by both parents and adolescents was associated with sleep problems and daytime sleepiness [56]. Autistic traits have also been associated with shorter weekday sleep duration in a sample of 157 adolescents [57]. These adolescents were likely high functioning on the autism spectrum inasmuch as they completed assessments of anxiety, depression and ADHD, and sleep was both self-reported and measured by actigraphy.

EMOTIONAL PROBLEMS

Emotional problems have been the focus of many studies in the recent literature on sleep disturbances in adolescents. They

include loneliness, negative affect, anxiety and depression. In a study on adolescents from Denmark (N=3,305), loneliness was associated with greater sleep disturbance, difficulties sleeping and more frequent sleepiness in the morning [58]. Associations were also reported between sleep disturbances and more frequent headaches, stomachaches and backaches. Headaches in themselves have been associated with shorter duration sleep as compared to those adolescents without headaches in a sample from the U.S. (N= 10,123) [59]. This was especially true for adolescents with migraine with aura who more often reported difficulty maintaining sleep, early morning awakening, daytime fatigue and persistent insomnia symptoms. These, in turn, were associated with comorbid anxiety and mood disorders.

Eveningness or an evening circadian preference has been associated with dim light melatonin onset [60]. In this study, adolescents (N=94 of 163) who had greater evening negative affect had an evening circadian preference and later dim light melatonin onset.

In a longitudinal study on the relationship between different types of anxiety and sleep problems, the adolescents (N=1,573) were seen four times over a period of 2.5 years [61]. Bidirectional relationships were reported between sleep problems and anxiety symptoms. Short sleep duration was predicted by generalized anxiety disorder whereas panic disorder symptoms increased difficulty falling asleep. Poor sleep quality was predicted by school phobia and symptoms of generalized anxiety disorder. Short sleep duration, in turn, predicted symptoms of panic disorder, generalized anxiety disorder and school phobia. And, difficulty falling asleep predicted generalized anxiety disorder symptoms while poor sleep quality predicted school phobia symptoms. These results highlight the importance of longitudinal studies and assessing both the sleep and emotional problems at each point of the study. Although many problems associated with sleep may be bidirectional, as in this study, researchers of cross-sectional studies have often arbitrarily designated the sleep problem as either an effect or a risk factor.

Given that anxiety is typically comorbid with depression, those two types of mood are often measured together. In another longitudinal study, anxiety was thought to precede the development of depression and therefore was entered as a risk factor in a structural equation model [62]. In this nationally representative sample of adolescents (N=20,745), anxiety was related to subsequent depression and mediated by insomnia and restless sleep. The problem here is that while depression was measured at wave one and four of the study, anxiety was only measured at wave one and sleep problems were only measured at wave two, so the design of the study would predictably lead to these results.

When depressed adolescents were compared to healthy controls in another study, all sleep measures were compromised [63]. In this study, 31 depressed adolescents and 32 health

Table 5: Interventions for sleep problems and first authors.

Interventions	First authors
Cognitive behavior therapy	McMakin, Blake, Aslund
CBT for insomnia	McMakin

controls were compared on three scales including the Adolescent Sleep-Wake Scale, the Adolescent Sleep Hygiene Scale and the School Sleep Habits Survey. Those adolescents who were depressed had significantly worse sleep quality, longer sleep onset latency and shorter sleep duration.

The reciprocal relationship between sleep problems and mental health symptoms has also been assessed in a longitudinal study on adolescents who had been maltreated as children (N=247) and comparison adolescents (N=138) [64]. A path model was used to assess cross-lagged effects between mental health symptoms (posttraumatic stress disorder and depression) and sleep disturbances. The results suggested that depressive and PTSD symptoms predicted later sleep disturbances and sleep disturbances also predicted depressive and PTSD symptoms. The only maltreatment effect was that those adolescents who were maltreated reported longer sleep duration than comparison adolescents. These results highlight the need for intervention for both mental health symptoms and sleep problems.

Psychiatric symptoms and neurocognitive function have also been associated with sleep problems. In a study on these neuropsychiatric relationships, four groups were formed including a normative group (24% of the sample), a nonspecific mental health symptoms group (27%), a lower neurocognitive function group (24%) and a comorbid psychiatric symptoms and lower neurocognitive function group (25%) [65]. The results of a multivariate latent regression model suggested that the mental health symptoms group and the comorbid psychiatric symptoms and neurocognitive function group had more sleep problems including a longer sleep latency and more sleep arousals per night.

INTERVENTIONS

Several intervention studies have appeared in the recent literature on sleep disturbances in adolescents. Although the interventions have been given different names, they have been described as cognitive behavioral therapies and mindfulness based therapies. The techniques have included bedtime shifts (sleep restriction), stimulus control, thought challenging, psychoeducation and relaxation techniques [65].

In one of the recent papers, two studies were reported [66]. In the first study, cognitive behavioral treatment (CBT) was provided for adolescents with generalized, social or separation anxiety, and small reductions were noted in sleep problems (parent and child report) and sleep patterns (sleep diaries) (N=133). The authors did not consider these outcomes clinically significant. For the second study, those adolescents who continued reporting sleep-related problems (N=50) were given an intervention called sleeping TIGERS, which was a six-eight session cognitive behavior therapy for insomnia with a focus on sleep problems including sleep habits, sleep regularity, media use at night and rumination. In this round of treatment, clinically significant reductions in sleep problems and improvements in sleep patterns were noted. The sleep improvements seemed to have resulted from the cognitive behavior therapy directed specifically at insomnia. Or. They could have resulted from the addition of several intervention sessions for those who had experienced small reductions in sleep problems following the initial CBT protocol. In

another cognitive behavioral and mindfulness-based group sleep intervention called Sleep SENSE, sleep education, sleep hygiene, stimulus control, cognitive restructuring, anxiety - reducing, mindfulness and motivational interviewing were included [67]. In a secondary analysis of this randomized controlled trial on 123 adolescents, sleep quality following the intervention significantly improved for those adolescents who had moderately high levels of anxiety and depressive symptoms. It would be difficult to conclude, however which of these aspects of the multi-faceted intervention were effective. In a study specifically on adolescents with major depressive disorder (N=465), 92% of the adolescents had clinically significant sleep difficulties [68]. Sleep difficulties decreased from baseline to post-treatment (36 weeks) and at one year followup (86 weeks) and this decrease did not differ between psychological treatments.

In a systematic review and meta-analysis on six randomized controlled trials on cognitive and behavioral sleep interventions with four or more treatment sessions (N=528), surprisingly, positive effects were seen on actigraphy but not on self-reported total sleep time [69]. In contrast, the sleep onset latency decreased in the intervention group as measured both by sleep diary and actigraphy. Time that it takes to fall asleep may be more salient to adolescents than total sleep time. The authors also cautioned that the treatment protocols were heterogeneous and were also at-risk for bias, suggesting that they were inconclusive.

METHODOLOGICAL LIMITATIONS OF THE LITERATURE AND FUTURE DIRECTIONS

The prevalence of sleep disturbances has varied widely from 2-77% across countries. This variability may be culturally determined or related to methodological differences in data collection including age and age range of adolescents, recruiting and assessment methods (e.g. national survey or school questionnaire), sample sizes and sleep measures used. Only one meta-analysis was found in this recent literature. That was a meta-analysis on six randomized controlled trials on cognitive behavior therapy interventions for sleep disturbances [69]. The paucity of meta-analyses likely relates to the variability of sleep measures used, suggesting too much heterogeneity across samples. Although several sleep researchers have used less than eight hours as a criterion for sleep disturbances in adolescents, others have used scales that address several aspects of sleep disturbances. Not only have several scales been used but also several measures including eveningness, insomnia, mid-sleep (chronotype), sleep quality, sleep apnea, daytime sleepiness and dim light melatonin onset. With samples as large as the epidemiological studies, these measures could have been taken together. And both types of insomnia including difficulty initiating and difficulty maintaining sleep need to be measured as they appear to be independently related to emotional and behavior problems [6].

As in the literature on other adolescent problems, most of this research has relied on self-report and parent report. Some findings were based on parent report alone. In studies that have used both parent and adolescent report, parents have reported that their adolescents had greater sleep problems than the adolescents themselves reported. And, for example in an intervention study, the adolescents reported improved sleep

but the parents did not [70]. This lack of agreement questions the reliability not only of self-report but also the reliability of the scales and other sleep measures. The use of both parent and adolescent report has probably related to the need for parental consent and adolescent assent in the research process. The lack of agreement is perhaps not surprising given that parents are not typically monitoring their adolescents' sleep behaviors. Given that daytime sleepiness is a significant problem for academic performance, it's surprising that teacher report has not appeared in these studies. In addition, more diary and actigraphy studies are needed. Given that sleep recording is now available on many devices including watches and cell phones, they could be used as recording devices.

Longitudinal data could help inform prevention/intervention research by further profiling risk factors for sleep disturbances. Although researchers have arbitrarily designated sleep problems as risk factors or effects of other risk factors, it is not clear whether these are truly effects or risk factors or reciprocal problems given that most of the studies are cross-sectional as opposed to longitudinal, making it impossible to determine causality or directionality. Unfortunately, longitudinal studies are both costly and have compliance problems. Cross-sectional data, nonetheless, can inform intervention efforts.

In most cases sleep problems and other problems have been bidirectional or reciprocal. For example, reciprocal longitudinal associations have been reported between adolescents' media consumption and their sleep-related problems including insomnia and daytime sleepiness [71]. Typically, the researchers have referred to comorbid problems as correlates or they have arbitrarily designated a comorbid problem as a predictor or an outcome variable in a regression analysis. The amount of variance explained by sleep problems may depend on the severity of the outcome variable. For example, school attendance and achievement, smoking, drugs and socializing problems may be less predictive of sleep problems than suicidal ideation and attempts [32]. Or, in more complex models, researchers have labeled them mediators as in mediation and structural equations analysis. Some researchers have included comorbidities such as excessive media use, stress, anxiety and depression in their data analyses.

Most of the literature derives from epidemiological studies that are informative about effects and risk factors, although they don't address potential underlying mechanisms. Surprisingly no fMRI studies were found and no hormonal/neurotransmitter studies. As was noted, the pain syndromes that result from sleep disturbances could relate to insufficient restorative sleep and the increased levels of substance P which could easily be assayed from saliva samples [18]. Along with activity levels from actigraphy, that mechanism could be assessed. Only one study addressed a potential underlying mechanism. In this study (N=80), a negative relationship was noted between video baseline heart rate variability and sleep related problems [72].

Despite the multiple methodological limitations of this recent research, the effects and the risks/predictor variables that have been identified will help inform future prevention/intervention research. The comorbid problems associated with sleep disturbances in adolescents highlight the need for research

on potential underlying mechanisms. The widespread prevalence of adolescent sleep problems across cultures further suggests the need for underlying mechanism research that might also inform programs to prevent sleep disturbances in adolescents.

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