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Review

Sleep Disturbances in Child and Adolescent Mental Health Disorders: A Review of the Variability of Objective Sleep Markers

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Abstract: Sleep disturbances are often observed in child and adolescent mental health disorders. Although previous research has identified consistent subjective reports of sleep disturbances, specific objective sleep markers have not yet been identified. We evaluated the current research on subjective and objective sleep markers in relation to attention deficit hyperactivity disorders, autism spectrum disorders, anxiety and depressive disorders. Subjective sleep markers are more consistent than objective markers of actigraphy, polysomnography, and circadian measures. We discuss the causes of variability in objective sleep findings and suggest future directions for research.

Keywords: sleep; mental health; electroencephalography (EEG); children; adolescents; Attention Deficit Hyperactivity Disorder (ADHD); anxiety; autism; arousal

1. Introduction

Significant neurobiological, physiological, and social changes occur during childhood and adolescence [1,2], including changes in circadian and sleep systems that regulate sleep duration and timing [3]. The duration of sleep decreases as development progresses, from about 14.5 h at 6 months of age to 8 h at age 16 years [4]. Other macrostructural changes, including changes in sleep stages, sleep architecture, and sleep efficiency, occur during childhood and adolescence [5]. Also, circadian changes, such as a shift toward later circadian chronotype and evening-type sleep patterns, emerge in adolescence [6]. These changes in sleep patterns across development, especially in the context of mental health problems, can be difficult for some youth.

Along with changes in sleep patterns, many youth develop mental health disorders in childhood and adolescence [7]. Attention Deficit Hyperactivity Disorder (ADHD) (8.6%), mood disorders (3.7%) [8], and autism spectrum disorders (0.7%) (ASD) [9] are common mental health problems in children that show an onset in early childhood [10]. In adolescents, common mental health issues include anxiety disorders (31.9%), behavior disorders (19.1%), mood disorders (14.3%), and substance use disorders (11.4%) [11]. Further, child and adolescent mental health disorders are characterized by significant comorbidity with a wide range of severity [8,11,12].

Sleep difficulties in youth with mental health problems are common, including increased sleep latency, nocturnal awakenings, nightmares, snoring, restless sleep, excessive daytime sleepiness, bedtime struggles, and fear of dark [13]. Sleep problems are known to have complex bidirectional relationships with childhood psychiatric disorders [14]. Historically, the evidence linking subjective sleep reports with reliable objective sleep markers in youth with mental health disorders has been

inconsistent. Although youth with anxiety, depression, ADHD, or ASD often report subjective sleep disturbances [15–17], there is a paucity of evidence on reliable objective markers of sleep in pediatric mental health disorders [17,18]. An earlier meta-analysis of children with ADHD identified sleep onset difficulties, bedtime resistance and difficulty with waking up in morning on subjective reports, high sleep onset latency and true sleep on actigraphy, and low sleep efficiency on polysomnography [19]. However, a recent meta-analysis only identified high percentage of stage 1 sleep as the significant finding in children with ADHD [20]. In major depressive disorder (MDD), a systematic analysis identified decreased sleep onset latency and rapid eye movement (REM) abnormalities as reliable sleep findings [21]. Objective sleep markers such as REM abnormalities, prolonged sleep onset latency, sleep fragmentation, and reduced sleep efficiency were identified in some studies of pediatric mental health disorders. However, several other studies have not shown any differences in objective sleep markers between children with mental health disturbances and healthy controls [22].

Herein, we review the literature on objective markers of sleep disturbances in the context of youth mental health disorders. We focused on current research studies and literature predominantly published during the last decade which includes objective measurements of sleep (polysomnography (PSG) or actigraphy) or circadian rhythms. Specifically, we examined studies in children and adolescents with anxiety disorders, depressive disorders, ADHD, and ASD diagnosed by diagnostic and statistical manual of mental disorders (DSM) criteria. We excluded studies of children with primary sleep disorders. From the selected studies, we identified objective sleep markers and their associations with subjective reports of sleep disturbances.

2. Objective and Subjective Markers of Sleep Disturbances

Objective markers of sleep disturbances include measurements by PSG, actigraphy, and measures of circadian biology. Polysomnography, the most widely used and validated standard for the evaluation of sleep, is a multi-modal instrument which assesses a range of physiological changes in electroencephalography (EEG), respiration, and heart rate [23], with an established scoring method to identify macrostructural sleep characteristics [24,25]. Actigraphy, a wrist-based instrument that measures movement by an accelerometer, is another reliable tool for measuring sleep and wake rhythms [23,26]. Circadian rhythms are assessed using laboratory-based protocols [27], including assessment of melatonin and cortisol [28]. Arousals from sleep, defined as behavioral awakenings, an abrupt shift in the EEG frequency and desynchronization of EEG [29], have been examined in research studies as markers of sleep instability. Brief arousals from sleep, referred to as microarousals and cyclic alternating patterns, are used as markers of sleep disturbances [30,31] whereas subjective sleep patterns are assessed from several instruments including Children's Sleep Habits Questionnaire [32], Adolescent Sleep-Wake Scale, Sleep Disturbances Scale for Children, Sleep Self-report, School Sleep Habits Survey [33], and sleep diaries.

2.1. Sleep in Anxiety and Depressive Disorders

Subjectively, parents of children with generalized anxiety disorder (GAD) report resistance to bedtime, delay in sleep onset, short sleep duration, high anxiety before sleep, and daytime sleepiness [34]. Similarly, adolescents with anxiety have high bedtime worries/fears, insomnia symptoms, daytime sleepiness on self-reports and high sleep onset latency, total sleep time and wake after sleep onset duration, and low sleep efficiency on sleep diaries [35]. In depression, children and adolescents typically report insomnia and, in some cases, hypersomnia, with severe depression associated with comorbid insomnia and hypersomnia [15]. In MDD, sleep diaries indicate subjective sleep complaints such as long sleep latency, a high number of awakenings, and high wake after sleep onset, although, these subjective reports are less common than in anxious children and adolescents [36]. Gender differences emerged in depression with females showing greater numbers of sleep complaints than males [15].

Recent actigraphy studies did not reveal any differences between children with GAD and healthy controls, despite reported subjective sleep disturbances [34]. However, a recent study in adolescents with GAD showed long sleep onset latencies, but unexpectedly greater sleep duration, compared to typically developing children [35]. Few studies have examined sleep patterns of children and adolescents with depression using actigraphy. Adolescent males with depression showed a shift toward later circadian phases from weekdays to weekends [37]. Short sleep duration and lower sleep efficiency were identified in adolescents with the seasonal affective disorder, a variant of depressive disorder [38].

Polysomnography in anxiety disorders showed reduced latency to REM [39], high sleep onset latency in children [36,39], low sleep efficiency and a high number of sleep arousals compared to controls. In multiple night PSG, youth with an anxiety disorder had greater sleep onset latency on the first night compared to the second night [36]. At-home PSG, in contrast to in-lab PSG, showed children with GAD had high sleep efficiency and fewer REM periods. The authors explained that children with anxiety had high bedtime resistance at home and went to bed later, which led to high sleep efficiency (from decreased sleep onset latency and decreased wake after sleep onset) [40]. In depression, low sleep efficiency, low proportion of slow wave sleep, and a high number of arousals have been observed [41] along with decreased total sleep time [42]. Interestingly, the dissipation of slow wave activity was slower and flatter [42], suggesting differences in the homeostatic dissipation of sleep pressure in children with depression. However, in the PSG study by Forbes et al., no differences were observed in depression when compared to healthy controls [36].

Lower nighttime cortisol, a marker of circadian and arousal differences, was observed in prepubertal children with anxiety [43], but no differences were observed in adolescents [44] or MDD [43]. However, adolescents with depression show higher peri sleep onset cortisol than healthy controls [44]. Additionally, arousal assessed in anxiety disorders showed pre-sleep arousal levels correlated with objective sleep findings—with pre-sleep somatic and cognitive arousal negatively correlated with REM sleep and total sleep time, respectively [40].

Eveningness chronotype assessed by chronotype questionnaires was consistently high in children with depression [45] and adolescent males [37] and was associated with the earlier development of depression symptoms [46] and circadian phase delay [47]. Later chronotype and social jetlag were observed in adolescent females with the seasonal affective disorder [38]. Circadian period, as measured by actigraphy, was found to be high in male and low in female children and adolescents with depression, in combination with low circadian amplitude [48].

2.2. *Summary of Sleep in Anxiety and Depressive Disorders*

In summary, children and adolescents with anxiety disorders show reliable subjective reports of greater sleep onset latency, bedtime fears, and greater wake after sleep onset duration [34,36]. Interestingly, findings on actigraphy do not show differences in sleep in children [34] but show high sleep onset latency and high sleep duration in adolescents with anxiety when compared to healthy controls [35]. PSG results corresponded with the findings of increased sleep onset latency, low sleep efficiency, and low slow wave sleep in anxiety and depression [36,41]. However, in a comparative study, sleep findings on PSG (sleep onset latency, sleep duration, sleep efficiency) were significantly greater in anxiety than depression and healthy controls, but similar in youth with depression and healthy controls [36]. Sleep efficiency was also inconsistent when assessed by PSG conducted at home versus the laboratory [34,40]. Cortisol level separated in some studies but not in others [43,44]. Chronotype differences, such as evening chronotype, phase delay, and social jet lag were consistently present in children and adolescents with depression [37,45,46]. The sleep findings of individual anxiety and depressive disorder studies are presented in Table A1 (Appendix A).

2.2.1. Sleep in Attention Deficit Hyperactivity Disorder

In children with ADHD, subjective reports indicate a wide range of sleep problems, including difficulty with sleep onset, daytime sleepiness [49–56], anxiety prior to sleep [50,53,55,57], high severity of

insomnia [50,53,55,56], high awakenings at night [50,51,53,56], difficulty waking up, less refreshing sleep [54], insufficient sleep [57], resistance to bedtime [51], and restless sleep [55]. However, a study by Mullin et al. identified no differences in subjective reports of sleep on sleep diary measures [58].

On actigraphy, children with ADHD have been identified to take longer to fall asleep [52,53,59], have lower sleep efficiency, lower sleep time [53,54], greater sleep fragmentation [59], and a high wake after sleep onset duration [59]. Greater day-to-day variability in sleep onset is present in youth with ADHD when compared to children with other psychiatric disorders and healthy controls [52]. However, sleep findings in actigraphy were not significantly different in other studies comparing children [60] and adolescents [58] with ADHD to healthy controls.

In-home PSG has shown that children with ADHD have short sleep duration, short REM sleep, a smaller percentage of REM sleep, and longer sleep onset latency [57]. However, in-lab studies of children with ADHD compared to healthy controls show greater REM duration [56,61], sleep period [61], and REM latency [49], as well as shorter total sleep time and less sleep in stage 1 and stage 3 [56]. These contrasting results are worth considering as no significant differences were present in other studies measuring overnight PSG [50,55,62] or Multiple Sleep Latency Test (MSLT—an objective assessment of sleepiness conducted with multiple naps during the day using EEG) [55]. High microarousals with increased motor activity during light and REM sleep was present in children with ADHD [63]. Cyclic alternating patterns, a marker of sleep instability and arousal, were found to be lower in children with ADHD, suggesting a state of hypoarousal in ADHD [49,64]. However, others have reported no differences in cyclic alternating patterns [62].

Cortisol levels vary across the day in children with ADHD, being lower in the morning and higher in the evening [65]. One study showed high urinary melatonin levels in children with ADHD [66], whereas another study did not show any differences in the melatonin levels in children with ADHD compared to typically developing children [67]. However, later melatonin onset at bedtime and earlier melatonin offset were present in children with ADHD [67]. Evening chronotype in children with ADHD was associated with resistance to bedtime [68] and delayed melatonin onset [69].

2.2.2. Summary of Sleep in Attention Deficit Hyperactivity Disorder

Overall, children with ADHD subjectively report sleep onset difficulties, daytime sleepiness, anxiety before sleep, and awakenings at night [50,53,55,57], corroborated on actigraphy by increased sleep onset latency, lower sleep time, and lower sleep efficiency [52,53,59]. However, at least one study did not find any differences between ADHD and typically developing children on actigraphy [58]. In PSG, longer sleep onset latency and shorter sleep duration were observed along with REM abnormalities in youth with ADHD [49,51,57]. In-lab vs. home PSG produced variable REM findings [57,61], whereas multiple studies did not identify objective sleep differences in PSG between youth with ADHD and healthy controls [50,55,62]. High melatonin and cortisol were identified [65,66], but the differences were not replicated in other studies [67]. Evening chronotype was common in ADHD and associated with resistance to bedtime [68,70]. The sleep findings of ADHD studies are presented in Table A2 (Appendix A).

2.3. Sleep in Autism Spectrum Disorders

Subjective reports of sleep in children with ASD include long mean sleep latency [71–73], short sleep duration, high nighttime awakenings, anxiety before sleep, and bedtime resistance [73]. Low functioning children with ASD are reported to have more severe sleep disturbances, including more frequent night awakenings, greater bedtime resistance, delay in sleep onset, later bedtimes and wake times, and less sleep than high functioning children with ASD [74]. However, a recent study did not find differences between typically developing children and children with ASD in subjective reports of sleep [72].

On actigraphy, preschool, school-aged children, and adolescents with ASD confirmed the subjective sleep findings, with long sleep latency, decreased sleep duration, and increased wake

after sleep onset duration [73,75]. Other findings include low sleep efficiency in children [71,73,76] and adolescents [77] with ASD. Recent work also showed greater night-to-night variability in wake time, wake after sleep onset periods, and sleep efficiency in children with ASD [78], whereas greater variability in sleep onset latency has been reported in high functioning adolescents with ASD [76].

Polysomnography findings show short total sleep time, short REM latency [79], long sleep onset latency, less slow-wave sleep, low microarousals, and more sleep-wake transitions in children with ASD compared to typically developing children [72]. Low proportion of slow wave sleep and light sleep (high arousals) have been associated with high repetitive behaviors and poor social behaviors and intellectual measures [72]. Severe autism was linked to more pronounced sleep abnormalities with high sleep onset latency, high wake after sleep onset duration, low total sleep time, low slow wave sleep, and prolonged REM latency. Cyclic alternating patterns, the marker of arousal and sleep instability measured by visual inspection of sleep EEG, are greater among children with regressive autism compared to non-regressed children with autism and typically developing children [74]. Poor sleepers in autism have more affective problems, fewer social interactions, and longer sleep latency [80]. Moreover, youth with ASD also show low sleep efficiency, low sleep duration, and high variability in sleep latency from night 1 to 2 [80].

High salivary cortisol and overall blunted cortisol rhythms were identified in children with autism, with higher cortisol levels associated with severe symptoms of autism [81]. Melatonin secretion rate has been found to decrease in prepubertal children with autism [82], but not in adolescents [77]. Other studies did not identify differences in measures of cortisol or melatonin in children [83] or adolescents with autism [77].

2.4. Summary of Sleep in Autism Spectrum Disorders

Collectively, children and adolescents with autism commonly have reports of longer sleep latency, short sleep duration, and high resistance to bedtime on subjective measures [71,73]. Actigraphy validates the subjective findings of long sleep latency and short sleep time along with low sleep efficiency [71,73,77]. The PSG findings consisted of short total sleep time, short REM latency, low sleep efficiency, and low slow wave sleep [72,74,79], with severe autism associated with more severe sleep abnormalities as well as cyclic alternating patterns [72,74]. Melatonin and cortisol abnormalities were identified in children with autism but were not identified in adolescents [77,81,82]. The findings in actigraphy, PSG, and circadian measures were not consistently identified across studies. The sleep findings of autism spectrum disorder studies are presented in Table A3 (Appendix A).

3. Discussion

The goal of this review was to identify objective sleep characteristics associated with mental health disorders in children and adolescents. Collectively, the findings highlight that subjective reports of sleep problems are common in mental health disorders but do not necessarily coincide with reliable objective markers of sleep disturbances measured by actigraphy and PSG. High sleep onset latency, short sleep duration, and resistance to bedtime were commonly present in subjective measures of anxiety, ADHD, and ASD across diagnostic categories [34,35,49,57,72,73]. Although actigraphy showed high sleep onset latency [35,53,59], low sleep efficiency, and shorter sleep duration in ADHD and autism [71,73,75], these findings were not specific for a single disorder. Similarly, PSG showed long sleep onset latency, low sleep efficiency and low slow wave sleep as the common objective findings in autism [72,74,79], ADHD [56,57], anxiety, and depression [36,41], but were not specific for individual disorders and also varied across studies. However, severe autism was associated with more abnormal sleep findings [72,74,80]. The location of the study (at home vs. in-lab PSG) also produced variable findings in anxiety [34,40] and ADHD [57,61], and sleep findings also varied on multi-night PSG assessments [36,55]. Overall, specific macrostructural findings in mental health disorders were not identified. Nonspecificity of objective sleep findings in child and adolescent mental health disorders have been documented in the literature [13,14].

The overlapping objective sleep findings observed across child and adolescent mental health disorders suggest possible common sleep mechanisms. Child and adolescent mental health disorders often present with high rates of comorbidity [8,11]. When controlling for comorbid psychiatric symptoms, objective sleep markers show little differentiation in a study of sleep markers in ADHD [53]. In another study comparing diagnostic categories, child and adolescent psychiatric symptoms did not vary in sleep and cortisol measures [84], highlighting possible common pathways to objective sleep markers. However, severe mental health symptoms [72,74] and the presence of multiple comorbid mental health disorders have been associated with greater objective sleep disturbances [41]. Also, mental health symptoms, especially anxiety, present as temporary state and stable trait characteristics [85], both of which are known to affect sleep and cortisol measures [78,83] differentially. Delineating state and trait characteristics in mental health may be important for identifying sleep pathology. Considering the heterogeneity of state-trait characteristics and common sleep findings across diagnostic categories, identifying specific biobehavioral phenotypes based on biological phenotypes (such as attention, arousal, motivation) could assist with mapping reliable objective sleep markers across disorders and diagnostic categories [86,87].

Reliable macrostructural sleep findings have consistently eluded child and adolescent mental health disorders. Technical and methodological characteristics of actigraphy and PSG should be acknowledged when evaluating the findings of objective sleep markers. Actigraphy may overestimate sleep [88] during periods of inactivity. In actigraphy, greater night-to-night variability is found in ADHD [52,89] and autism [76,78], hence, an extended duration of measurement is needed to identify reliable results. Similarly, night-to-night variability is identified in PSG studies [90]. Therefore, single night PSG, commonly used in research studies [49,50,56,72,91], may be insufficient for identifying objective findings because of "first night effect". Sleep findings often are different on the first night of sleep in the lab because of novel sleeping environment. "First night effect", associated with high sleep latency, has been identified in children with ADHD [55,92] and autism [80] on multi-night studies. Given that sleep efficiency increases and wake after sleep onset decreases on the second night [93], multiple nights of PSG may be necessary to identify reliable objective differences in sleep [94]. The location of the sleep study (home vs. in-lab PSG) produces varying sleep findings in youth with anxiety [39,40] and ADHD [49,57], suggesting sleep environment moderates sleep phenotypes. The macrostructural characteristics of sleep identified with EEG have not revealed reliable differences in past studies of child and adolescent mental health disorders [13,14]. Macrostructural characteristics of sleep are assessed by visual scoring with rules that were originally established in 1968 [25]. Manual sleep scoring [24,25] can be problematic as it has low correspondence for delineating electrophysiological activity and does not take into account the temporal and spatial resolution or autonomic changes [95] during sleep. Examining the microarchitectural characteristics of sleep at greater temporal resolution using spectral methods [96] may help identify specific sleep findings in child and adolescent psychiatric disorders [97].

Arousals from sleep are an integral part of the sleep process [98] and are associated with measurable changes in the EEG [29]. Arousals associated with awakenings, microarousals (less than 3 s), and cyclic alternating patterns (CAP) that reflect sleep stage instability have been evaluated as objective markers of poor sleep [30,31]. High awakenings at night are common in anxiety [34,36], ADHD [50,55,57], and autism from subjective reports whereas arousals, microarousals and CAP are assessed by PSG and include EEG, behavioral, and autonomic components [30]. Frequent PSG arousals from sleep are identified in children with depression [41] and ADHD [63] and low microarousals in autism [72]. High cyclic alternating pattern, the marker of sleep instability and arousal [99], was reported in a regressive form of autism [74] with no differences in another study [79]. Low CAP in ADHD [49,64] is in line with evidence of a hypoarousal state in ADHD; however, other studies have failed to replicate this finding [62]. It is worth noting that microarousals and CAPs are manually scored, which likely contributes to their low reliability across studies. Computer-assisted techniques to

identify EEG, respiratory and autonomic arousals during sleep in children and adolescents are likely to enhance the reliability of objective findings of sleep disruption [100].

Generalized CNS arousal, defined as optimal sensory, motor, and affective drive, is necessary for survival and interaction with the environment [101,102], and is, therefore, a critical biological process operating during sleep, wakefulness, and affective modulation. Hypothalamic-pituitary-adrenal (HPA) axis and the locus coeruleus-norepinephrine system are essential for the optimal functioning of the arousal system [103]. Dysregulation of arousal systems along with the HPA axis has been proposed in the pathophysiology of depression [104], autism [105] and ADHD [106]. Cortisol is an essential hormone of the HPA axis and was examined in several studies. High daytime cortisol has been reported in anxiety [43] and autism [81], and low daytime cortisol in ADHD [65], suggesting neuroendocrinal differences in sleep-wake systems. However, other studies have not corroborated these findings [43,44,77]. Methodological differences in measuring cortisol are present across studies which likely contributes to the inconsistent findings [107]. Heart-rate variability, a measure of autonomic arousal, has been observed to be higher in children with autism [91] and ADHD [108]. Research on arousal using reliable cortical and autonomic measures and methods in youth [109] are needed to identify more stable objective markers of sleep disturbances, particularly those that emphasize measurement reliability.

4. Future Directions

We conducted this review to identify objective sleep markers associated with mental health disorders in children and adolescents. Several subjective sleep markers were found to be more consistent and common across child mental health disorders than objective sleep markers, which were not specific and varied across studies. A gap exists in identifying the pathophysiology of sleep disturbances and their links to mental health disorders in youth. Future research should focus on these links to clarify objective markers of sleep and their association with subjective reports and mental health symptoms. Also, mental health symptoms are heterogeneous and cross existing boundaries of syndromes, hence using biobehavioral phenotypes based on pathophysiology may help identify reliable objective markers of sleep [110]. It is essential to control for circadian, homeostatic, and environmental factors (light, physical activity) [111] that impact objective findings of sleep. Multimethod assessments using actigraphy, PSG, EEG, and subjective measures are needed [88] as single measurement methods identify specific markers unique to the method. Detailed analysis of EEG using spectral analysis may also reveal subtle findings not identified by manual scoring methods. Lastly, examining dysregulation and variability of arousal patterns within biobehavioral phenotypes across sleep and mental health may identify specific treatments and help advance the mission of precision medicine [86].

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Appendix A

Table A1. Subjective and objective sleep patterns in anxiety and depressive disorders.

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Alfano et al., 2010 [16]	Cross-sectional study of children's subjective sleep patterns and arousal in anxiety disorders.	Generalized Anxiety disorder = 16 Seasonal Affective Disorder = 10 Social Phobia = 13 Age = 7–14 years	Children's Sleep Habits Questionnaire (CSHQ)	Children with GAD had higher difficulty sleeping when compared to other anxiety disorders.	Higher latino children than other ethnicities were present in the study.
			Pre-sleep Arousal Scale for Children	Pre-sleep cognitive and somatic arousal higher in children with generalized anxiety disorder.	
Alfano et al., 2015 [34]	Cross-sectional study of subjective and objective sleep patterns of children with generalized anxiety disorder (GAD).	GAD (M:F) = 19:20 Age = 8.6 ± 1.5 years Control (M:F) = 17:19 Age = 8.8 ± 1.3 years	CSHQ Sleep Self Report	High bedtime resistance, high sleep onset latency, high sleep anxiety, daytime sleepiness, parasomnias, and low sleep duration in children with GAD.	Parent reports and child reports show weak correlation. Anxiety Disorder Interview Schedule used for diagnosing anxiety disorder.
			Actigraphy for 7 days	No significant differences in any of the actigraphy measured sleep variables.	
Alfano et al., 2013 [39]	Cross-sectional study of objective sleep patterns (PSG) of children with GAD.	GAD (M:F) = 6:9 Age = 8.5 ± 1.5 years Control (M:F) = 6:9 Age = 8.9 ± 1.3 years Age range = 7–11 years	Polysomnography (PSG)	High sleep latency and low REM latency observed in GAD. Total recording time higher in Generalized Anxiety Disorder.	Anxiety Diagnostic Interview Schedule used for diagnosing anxiety disorder. Sample size was small in the study.
Patriquin et al., 2014 [40]	Cross-sectional study of objective sleep patterns of children with GAD using in-home PSG.	GAD (M:F) = 8:8 Age = 8.8 ± 1.3 years Control (M:F) = 8:8 Age = 8.4 ± 1.3 years	In-home PSG for one night	Children with GAD had higher sleep efficiency and fewer REM periods than controls. No difference in pre-sleep cognitive and somatic arousal.	
Mullin et al., 2017 [35]	Cross-sectional study of subjective and objective sleep patterns of children and adolescents with GAD.	GAD = 26 Age = 15.1 ± 1.9 years Control = 17 Age = 15.5 ± 1.5 years	Sleep Diary Chidren's Report of Sleep Problems	High bedtime worries, insomnia symptoms, high sleep onset latency, high wake after sleep onset duration, and low sleep efficiency in self reports of adolescents with GAD. High sleep onset latency, poor sleep quality and high waketime anxiety reported by adolescents with GAD on sleep diaries.	77% of the adolescents with GAD were taking psychiatric medications.
			Actigraphy for 7 days	High sleep onset latency and longer sleep time in adolescents with GAD.	

Table A1. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Forbes et al., 2008 [36]	Cross-sectional study of subjective and objective findings of sleep in MDD, Anxiety Disorder and healthy controls.	MDD = 128, Age = 12.0 ± 2.3 years Anxiety Disorder = 24, Age = 12.2 ± 3.1 years Control = 101, Age = 10.9 ± 2.2 years	Sleep logs	No significant difference in the sleep logs.	
			PSG for 3 nights	For anxiety, significant high number of awakenings, long sleep latency, high stage 1 and stage 2 sleep, low sleep efficiency and high number of arousals observed in children with anxiety disorder. No differences between MDD and controls on PSG measures.	
Forbes et al., 2006 [44]	Cross-sectional study of cortisol levels in children and adolescents with affective disorders.	MDD Children = 76, Age = 10.49 ± 1.42 years Adolescents = 40, Age = 13.98 ± 1.36 years Anxiety Children = 18, Age = 10.49 ± 1.38 years Adolescents = 14, Age = 13.38 ± 1.99 years Healthy controls Children = 44, Age = 10.36 ± 1.43 years Adolescents = 32, Age = 13.44 ± 1.61 years	Plasma cortisol sampled every 20 min	Children with anxiety had higher peri sleep onset cortisol than children with depression or control children. Adolescents with depression had higher peri sleep onset cortisol than children with depression and control adolescents.	
Feder et al., 2004 [43]	Cross-sectional in-lab study of cortisol in children with anxiety and depression.	MDD = 76 Age = 9.3 ± 1.5 years Anxious = 31 Age = 8.7 + 1.7 years Healthy controls = 17 Age = 9.2 + 1.2 years	24 h blood cortisol sampling	Children with anxiety had lower nighttime cortisol than depression and sluggish rise in the cortisol. Depressed children did not show cortisol differences from healthy children.	
Armitage et al., 2004 [48]	Cross-sectional study of objective sleep patterns of children and adolescents with depression and healthy controls.	MDD (M:F) = 31:28 Age = 12.3 ± 2.9 years Healthy controls (M:F) = 20:21 Age = 12.4 ± 2.8 years	Actigraphy for five days	Adolescents with Major depressive disorders had lower activity levels, dampened circadian amplitude, lower light exposure and spent less time in bright light than healthy controls. Preteen girls with Major depressive disorder had low light exposure, spent less time in bright light, and had lower circadian amplitude.	More than half of the sample had comorbid psychiatric disorders.
Shahid et al., 2012 [41]	PSG study of children and adolescents in the inpatient unit.	Number (M:F) = 56:50 Age = 13.4 ± 1.7 years	Polysomnography	High levels of insomnia, low sleep efficiency, high arousals from slow wave sleep were present in all disorders. High number of diagnoses (4–7) than low number of diagnoses (1–3) were associated with low slow wave sleep, high arousals from slow wave sleep, and decreased REM sleep.	Majority of the medications were on psychotropic medications.

Table A1. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Santangeli et al., 2017 [42]	Cross-sectional study of subjective and objective sleep patterns in adolescents with depression and healthy controls.	Depressive Disorder (M:F) = 8:0 Age = 16.9 ± 1.0 years Healthy controls (M:F) = 10:0 Age = 16.2 ± 0.7 years	Overnight polysomnography	Decreased total sleep time and slower dissipation of slow wave sleep pressure and happening later on in the night in adolescents with depression. Negative correlation of severity of depression and slow wave dissipation and depression observed in the frontal area.	
de Souza et al., 2014 [47]	Cross-sectional study of chronotype and social jet lag in children and adolescents.	*N* = 351 Age = 12–21 years	Munich Chronotype Questionnaire	Sleep phase delay was associated with higher levels of depression. No differences in social jetlag findings.	
Borisenkov et al., 2015 [38]	Cross-sectional study of chronotype and sleep in adolescents with depression.	Number (M:F) = 1517:1918 Age = 14.8 ± 2.6 years	Munich Chronotype Questionnaire and Seasonal Pattern Assessment Questionnaire	Later bedtimes and waketimes, longer sleep onset latency, low sleep efficiency, and more sleep inertia observed in Seasonal Affective Disorder. Circadian phase delay, and social jetlag observed in females with Seasonal affective disorder. Depressed boys were more prone to eveningness than healthy controls.	Female gender, increased age, and latitude increased likelihood of Seasonal affective disorder.
Chiu et al., 2017 [45]	Cross-sectional study of chronotype in depression.	2139 students (grades 1–7) 1708 parents	Questionnaires for subjective sleep quality, and Morningness Eveningness Questionnaire	Eveningness chronotype associated with depression after controlling for sleep quality. Eveningness chronotype associated with parental report of emotional and behavioral problems.	
Haraden et al., 2017 [46]	Longitudinal study of chronotype in adolescents with depression and healthy controls.	Male = 111, Age = 14.8 ± 2.28 years Female = 144, Age = 15.1 ± 2.33 years	Morningness Eveningness Scale	Evening chronotype associated with the earlier onset of depression symptoms.	
Merikanto et al., 2017 [37]	Cross-sectional study of chronotype and sleep in adolescents with depression and healthy controls.	Depressive Disorder (M:F) = 9:0 Age = 14.5–17.5 years Healthy controls (M:F) = 8:0 Age = 14.5–17.5 years	Horne Ostberg Morningness Eveningness Questionnaire Actigraphy for 25 days (25 to 44 days)	Evening chronotype was high in adolescent males with depression. Earlier circadian phase on school days and greater shift to later circadian phase was observed in depressed boys.	

M: Male; F: female; REM: rapid eye movement; ADHD: Attention Deficit Hyperactivity Disorder; MDD: major depressive disorder.

Table A2. Subjective and objective sleep parameters in attention deficit hyperactivity disorder.

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Hvolby et al., 2008 [52]	Cross-sectional evaluation of objective sleep in children with ADHD, psychiatric disorders and healthy controls.	ADHD (M:F) = 37:8 Age = 5 years 9 months–10 years 11 months Psychiatric control (M:F) = 55:9 Age = 6 years 2 months–12 years 4 months Healthy Controls, (M:F) = 61:36 Age = 6 years–11 years 1 months	Actigraphy	Long sleep onset latency, greater day to day variability in sleep onset latency in children with ADHD when compared to healthy children and psychiatric controls.	
Owens et al., 2009 [54]	Cross-sectional evaluation of subjective and objective sleep patterns of children with ADHD and healthy controls.	ADHD (M:F) = 82:25 Age 10.2 ± 2.0 years Control (M:F) = 23:23 Age = 10.3 ± 2.6 years	Electronic sleep diaries	Children with ADHD report less sleep, more difficulty waking up in the morning, and more daytime sleepiness. Parental reports suggest more reports of sleep difficulties such as difficulty getting out of bed, difficulty getting ready for bed, and difficulty falling asleep than healthy children.	
			Actigraphy	Lower sleep efficiency, shorter total sleep time in children with ADHD.	
Mullin et al., 2011 [58]	Cross-sectional study of children and adolescents with ADHD, Bipolar disorder and healthy controls.	ADHD combined (M:F) = 11:3 Age = 15.1 ± 2.1 years Bipolar Disorder (M:F) = 6:7 Age = 14.4 ± 2.1 years Healthy controls (M:F) = 11:10 Age = 14.1 ± 2.0 years	Sleep diary	Children with ADHD did not differ from the controls in any of the subjective sleep parameters.	Children with ADHD on medication.
			actigraphy	No differences in sleep between adolescents with ADHD and controls.	
Moreau et al., 2014 [53]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD	ADHD (M:F) = 24:17 Age = 9.7 ± 1.6 years Healthy controls (M:F) = 24:17 Age = 9.5 ± 1.6 years	Children's Sleep Habits Questionnaire Insomnia severity index and Sleep Diary	Sleep onset delay, sleep anxiety, daytime sleepiness and high insomnia score in children with ADHD	Three fourths of the children with ADHD children were taking stimulants. Having a medication on board or comorbidity was not associated with differences in sleep disturbances in ADHD.
			Actigraphy for 5 days	Total sleep time, and sleep efficiency were lower and sleep onset latency significantly higher in children with ADHD. Mean activity was higher in children with ADHD. Higher deviation of sleep onset latency and higher deviation In mean activity in children with ADHD than controls.	
Jeong et al., 2014 [59]	Cross-sectional study of objective sleep patterns in children with ADHD and healthy controls	ADHD (M:F) = 37:0 Age = 8.7 ± 2.1 years Healthy controls (M:F) = 32:0 Age = 9.3 ± 1.9 years	Actigraphy for 3 days	Children with ADHD had longer sleep latency, wake after sleep and greater sleep fragmentation than healthy controls.	
Bergwerff et al., 2016 [60]	Cross-sectional study of objective sleep patterns in children with ADHD and healthy controls	ADHD (M:F) = 47:16 Age = 9.7 ± 1.6 years Healthy controls (M:F) = 32:29 Age = 10.1 ± 1.6 years	Actigraphy	No differences of measured sleep patterns in children with ADHD and controls. No significant night-to-night variability in children with ADHD when compared to controls.	Long duration in bed, high nocturnal activity, and high average wake bout duration in children with ADHD but did not reach significance.

Table A2. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Gruber et al., 2009 [57]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD and healthy controls	ADHD (M:F) = 10:5 Age = 8.93± 1.39 years Healthy controls (M:F) = 13:10 Age = 8.61 ± 1.27 years	Children's Sleep Habits Questionnaire	Parents of children with ADHD report lower sleep time, high sleep anxiety, daytime sleepiness, sleep onset difficulties and high awakenings at night	No medication in the past seven days. Children with ADHD scored high on the internalizing symptoms than healthy controls.
			In home olysomnography one night	Children with ADHD had shorter sleep duration and shorter Rem sleep duration, total sleep time, and smaller percentage of REM sleep.	
Kirov et al., 2004 [61]	Cross-sectional study of objective sleep findings in children with ADHD and healthy controls.	ADHD = 17 Age = 11.2 ± 2.0 years Control = 17 Age = 11.2 ± 2.3 years	Polysomnography	Greater REM sleep duration, high sleep period time identified in children with ADHD. High movements in light sleep stages and high movement related epochs in children with ADHD.	
Miano et al., 2006 [64]	Cross-sectional study of objective sleep patterns in children with ADHD and healthy controls.	ADHD (M:F) = 18:2, Age range = 6–13 years Healthy Controls (M:F) = 11:9, Age range = 6–13 years	Two-night polysomnography	Children with ADHD have increased sleep period, total sleep time and high sleep stage shifts. Low cyclic alternating patterns in stage 2 sleep observed in ADHD.	
Kirov et al., 2007 [63]	Cross-sectional study of objective sleep patterns in children with co-morbid ADHD and controls.	ADHD and Tic Disorder (M:F) = 18:1 Age 11.0 ± 2.2 years Control (M:F) = 17:2 Age = 11.0 ± 2.2 years	Polysomnography	High sleep period time, short REM latency and high REM sleep in children with ADHD. High microarousals, increased motor activity during light and REM sleep also observed in children with ADHD.	
Prihodova et al., 2010 [55]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD and healthy controls.	ADHD (M:F) = 26:5 Age = 9.3± 1.7 years Healthy controls (M:F) = 22:4 Age = 9.2 ± 1.5 years	Pediatric sleep questionnaire	Children with ADHD had restless sleep, difficulty with falling asleep and high leg movements	
			Two-night polysomnography	Children with ADHD had increased wakefulness, reduced sleep efficiency, and prolonged sleep onset latency on first when compared to second night. No night to night variability in control subjects. Multiple sleep latency test did not show differences.	
Choi et al., 2010 [50]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD and healthy controls.	ADHD (M:F) = 24:3 Age = 9.0 ± 2.1 years Healthy controls (M:F) = 23:3 Age = 8.4 ± 1.5 years	Children's Sleep Habits Questionnaire	Children with ADHD have more difficulty with sleep onset, less sleep duration, more awakenings at night, more daytime sleepiness, and more parasomnias. Total sleep disturbance scores higher in children with ADHD.	High internalizing, externalizing and affective problems in children with ADHD.
			Overnight Polysomnography	No significant differences in the PSG sleep characteristics of children with ADHD and controls.	

Table A2. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Gruber et al., 2012 [51]	In home study of children with ADHD using polysomnography.	ADHD (M:F) = 17:9 Age = 8.46 ± 1.5 years Healthy controls (M:F) = 30:19 Age = 8.6 ± 1.2 years	Children's Sleep Habits Questionnaire	High sleep onset latency, high sleep anxiety, daytime sleepiness, awakenings at night, resistance to bedtime and low total sleep time in children with ADHD.	
			In home Polysomnography	No significant differences on PSG measures in children with ADHD and healthy controls.	
Imeraj et al., 2012 [65]	Cross-sectional study of cortisol patterns in children with ADHD and healthy controls.	ADHD (M:F) = 9:2 Age = 8.8 ± 1.5 years ADHD + ODD (M:F) = 17:5 Age = 9.0 ± 1.5 years Healthy controls (M:F) = 26:7 Age = 8.8 ± 1.6 years	Salivary cortisol measured five times a day for five days	Cortisol lower in the morning and higher in the evening.	
Prihodova et al., 2012 [62]	Cross-sectional study of subjective and objective sleep of children with ADHD using polysomnography.	ADHD (M:F) = 12:2 Age = 9.6± 1.6 years Healthy controls (M:F) = 8:4 Age = 9.0 ± 1.6 years	Two-night polysomnography	No significant changes in macro and microstructural differences among ADHD and controls.	Recruited from the clinic by the DSM criteria. Children with ADHD had high internalizing symptoms than healthy controls.
Akinci et al., 2015 [49]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD and healthy controls.	ADHD (M:F) = 20:8 Age = 8–12 years Healthy controls (M:F) = 9:6 Age = 9–13 years	Pittsburgh Sleep Quality Index (PSQI)	On PSQI, low sleep quality, high sleep latency and low sleep efficiency were present in children with ADHD.	Children were free of medication use.
			Laboratory polysomnography	High REM latency and high REM sleep percentage was present in children with ADHD. Low oxygen saturation at night and awake period and increased leg movements in ADHD. Cyclical alternating patterns (CAP) were low in ADHD.	
Virring et al., 2016 [56]	Cross-sectional study of subjective and objective sleep patterns in children with ADHD and healthy controls.	ADHD *n* = 76 Age = 9.6 ± 1.8 years, 74% male Controls = 25 Age = 9.4 ± 1.5 years 68% male.	Sleep Diary Children's Sleep Habits Survey	Children with ADHD differed from healthy controls in all the measures on the Children's Sleep Habits Questionnaire Scale Children with ADHD had longer sleep onset latency than the control group on sleep diaries.	Sleep measures did not differ among the different ADHD subtypes. Children diagnosed with ADHD with and without comorbidity did not differ in sleep measures.
			Polysomnography	Sleep latency, number of sleep cycles, and REM sleep higher, and total sleep time, Stage 3 and stage 1 sleep lower in children with ADHD than controls.	
Van der Heijden et al., 2005 [69]	Cross-sectional study of objective sleep patterns in children with ADHD and healthy controls.	ADHD with sleep onset insomnia (M:F) = 66:21, Age = 8.8 ± 1.7 years ADHD without sleep onset insomnia (M:F) = 26:7, Age = 8.2 ± 2.0 years	Actigraphy and melatonin	Children with ADHD and sleep onset insomnia had significantly longer sleep onset latency, later bedtime and waketime. Melatonin onset significantly later in children with ADHD and sleep onset insomnia.	
Buber et al., 2016 [66]	Cross-sectional study of urinary melatonin in children with ADHD and healthy controls.	ADHD (M:F) = 23:4 Age = 9.3 ± 2.6 years Healthy controls (M:F) = 21:7 Age = 10.5 ± 2.7 years	24 h urinary melatonin levels measured in the morning and evening	High urinary melatonin levels present daytime, nighttime and 24 h levels in children with ADHD.	

Table A2. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Novakova et al., 2011 [67]	Cross-sectional study of salivary melatonin in children with ADHD and healthy controls.	ADHD (M:F) = 30:4 Age = 6–12 years Healthy controls (M:F) = 26:17 Age = 6–12 years	24 h salivary melatonin	No differences in salivary melatonin levels between ADHD and control subjects.	Duration of the melatonin signal was shortened in 10–12 year old sub sample with ADHD.
Doi et al., 2015 [70]	Cross-sectional study of chronotype in children with behavioral problems.	Number (M:F) = 342: 312 Age = 4–6 years	Munich Chronotype Questionnaire	Chronotype was associated with inattention/hyperactivity problems.	

M: Male; F: female; REM: rapid eye movement; ADHD: Attention Deficit Hyperactivity Disorder.

Table A3. Subjective and objective sleep findings in autism spectrum disorders (ASD).

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Allik et al., 2006 [71]	Cross-sectional study of subjective and objectively measured sleep in ASD, high functioning autism and Healthy Controls.	ASD (M:F) = 17:2 High functioning autism (M:F) = 11:2 Control (M:F) = 28:4 Age = 8.5–12.8 years	Sleep Diary for one week	High sleep onset latency, poor sleep efficiency and low sleep quality observed in autism and high functioning autism on sleep diaries.	
			Actigraphy for one week	No differences in sleep on actigraphy between autism spectrum and healthy controls.	
Goodlin-Jones et al., 2008 [75]	Cross-sectional study of subjective and objective sleep characteristics in preschool children with autism, children with developmental delay, and healthy controls.	Autism Spectrum Disorder = 68 Age = 2.3–5.6 years Developmental Disability = 57 Age = 2.0–5.7 years Healthy Controls = 69 Age = 2.0–5.1 years	Children's Sleep Habits Questionnaire and daily sleep diary	Sleep diary and actigraphy measures were concordant with each other for start of sleep, sleep duration, sleep onset latency, number of naps, nap duration, wake after sleep onset duration, and 24 h sleep duration.	
			Actigraphy	Children with Autism had significantly shorter 24 h sleep duration, shorter naps, less time in bed than children with developmental disability and healthy children. Developmentally disabled children had more fragmented sleep, with high number and duration of awakenings than autism and healthy controls.	
Souders et al., 2009 [73]	Cross-sectional study of subjective and objectively measured sleep in Autism Spectrum Disorder and Healthy Controls.	Autism Spectrum (M:F) = 44:15 Control (M:F) = 26:14	Children's Sleep Habits Questionnaire	Longer sleep onset latency, high sleep anxiety, bedtime resistance, and parasomnias, and short sleep duration in Autism.	
			Actigraphy for 10 days	Longer Sleep latency, short sleep duration, increased wake after sleep onset duration, and low sleep efficiency in children with Autism.	

Table A3. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Goldman et al., 2017 [77]	Cross-sectional study of subjective and objective sleep patterns of children with autism spectrum disorders and healthy controls.	Autism spectrum disorder (M:F) = 20:8 Age = 15.6 ± 2.8 years Typically developing children = (M:F) = 6:7 Age = 15.6 ± 2.1 years	Adolescent Sleep Wake Scale	More difficulty going to bed and falling asleep on self-reports of children with autism spectrum disorder.	
			Actigraphy	Sleep latency was longer and sleep efficiency lower in autism spectrum disorder. Cortisol and dim light melatonin onset not significantly different between children with autism and healthy controls.	
Baker et al., 2013 [76]	Longitudinal study of subjective and objectively measured sleep in High Functioning Autism and healthy controls.	High Functioning Autism (M:F) = 22:5 Control (M:F) = 26:14 Age = 15.5 ± 1.3 years	Sleep Diary for 7 days, and modified School Sleep Habits Survey	Difficulties with falling asleep and high daytime fatigue in adolescents with high functioning autism.	Night to night variability of sleep latency, sleep onset time, sleep offset time and sleep period higher at follow up.
			Actigraphy	High sleep onset latency and low sleep efficiency that are both variable in Autism than healthy controls.	
Fletcher et al., 2017 [78]	Longitudinal study of subjective and objectively measured sleep in Autism and healthy controls	Autism (M:F) = 17:5 Control (M:F) = 14:15 Age = 6–13 years At follow up 7–14 year	Children's Sleep Habits Questionnaire	Higher global scores on Children's sleep habits questionnaire in children with Autism at baseline and follow up	Significant difference in IQ between children with Autism and typically developing children.
			Actigraphy	Low sleep efficiency, highly variable sleep efficiency in Autism. High variability in wake time and wake after sleep onset in Autism.	
Malow et al., 2006 [80]	Cross-sectional study of subjective and objective sleep in children with ASD and healthy controls.	ASD = 21 Healthy Controls = 10 Age = 4–10 years	Children's Sleep Habits Questionnaire	High bedtime resistance, sleep onset delay, low sleep duration, high sleep anxiety in children with autism when compared to healthy controls.	
			Two-night polysomnography	Low sleep efficiency, high sleep latency observed in children with Autism.	
Miano et al., 2007 [79]	Cross-sectional study of subjective and objective sleep in children with ASD and healthy controls.	ASD (M:F) = 16 Age = 9.4 ± 4.5 years Controls (M:F) = 9:9 Age = 10.2 ± 2.9 years	Sleep Questionnaires	Difficulty initiating sleep and maintaining sleep, and daytime sleepiness in ASD.	
			Polysomnography	Short total sleep time, short REM latency, reduced time in bed in ASD than healthy controls.	

Table A3. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Giannotti et al., 2011 [74]	Cross-sectional study of subjective and objectively measured sleep in Autism (regressed and non-regressed) and Healthy Controls.	Autism (regressed) M:F = 16:6 Age = 5.5 ± 2.1 years Autism (non-regressed) M:F = 14:4 Age = 5.1 ± 3.9 years Healthy Children M:F = 9:3 Age = 5.8 ± 2.4 years	Children's Sleep Habits Questionnaire	Shorter total sleep time, later bedtimes and later waketimes in the regressed and non-regressed children High number of awakenings at night, bedtime resistance, sleep onset delay, later bedtimes and waketimes that are severe in regressed than non-regressed children with Autism.	Autism children had mild mental retardation and borderline intellectual functioning.
			Polysomnography for two consecutive nights	Total sleep time, sleep efficiency less in regressed and non-regressed Autism than typically developing children. Awakenings per hour, REM sleep less in regressed than non-regressed children than typically developing children. Slow wave sleep, REM percentage less in regressed autism than typically developing children. Stage 2 sleep high in regressed autism than typically developing children.	
Lambert et al., 2016 [72]	Cross-sectional study of subjective and objective measures of sleep in children with autism and healthy controls.	Autism = 11 Age = 6–13 years Control = 13 Age = 7–12 years	Children's Sleep Habits Questionnaire	No differences in subjective measures of children with Autism and healthy controls.	Low slow wave sleep and light sleep associated with high repetitive behaviors. The groups differed significantly in anxiety, affective and attentional problems.
			Polysomnography	Longer sleep latency, low slow wave sleep, low sleep spindles and K complexes in Autism Higher stage transitions from stage 1 to wake and low microarousals per hour of sleep in Autism.	
Harder et al., 2016 [91]	Cross-sectional study of objective sleep patterns in ASD and Healthy Controls.	Autism Disorder (M:F) = 21:0 Age = 4–10 years Typically Developing Children (M:F) = 18:5 Age = 4–10 years	Polysomnography	Low stage 3 sleep in children with Autism than healthy controls.	
			Heart rate variability	Children with ASD had higher HR during N2, and REM sleep. ASD children had higher values of normalized Low Frequency (Heart rate variability) in REM and normalized lower High Frequency heart rate variability in REM. Higher Low Frequency to High Frequency ratio in REM.	

Table A3. *Cont.*

Author	Description of Study	Demographics	Measures	Significant Results	Additional Comments
Tordjman et al., 2005 [82]	Cross-sectional study of circadian measures of sleep in ASD and healthy controls.	Autism Disorder (M:F) = 33:17 Age = 11.5 ± 4.5 years Typically Developing Children (M:F) = 49:39 Age = 11.0 ± 4.4 years	Urinary melatonin	Nocturnal melatonin secretion rate lower in autism, specifically in prepubertal children, marked in males. Melatonin levels negatively correlated with impairment in verbal communication and play.	Children diagnosed by Autism Diagnostic Observation Schedule. Twenty children taking medication.
Corbett et al., 2014 [83]	Cross-sectional study of objective measures of sleep in children with autism and healthy controls.	ASD = 46 Age = 10.3 ± 1.7 years Typically developing children = 48 Age = 9.9 ± 1.6 years	Salivary cortisol	No differences in Cortisol Awakening Response between children with autism and typically developing children.	
Tordjman et al., 2014 [81]	Cross-sectional study of circadian measures of sleep in ASD and healthy controls.	Autism Disorder (M:F) = 36:19 Age = 11.3 ± 4.1 years Typically Developing Children (M:F) = 22:10 Age = 11.7 ± 4.9 years	Salivary cortisol collected five times a day	Salivary cortisol measured high in Autism and flat cortisol daytime and night slopes in children and adolescents with Autism. Higher cortisol levels in children with severe impairments in social interaction.	Children diagnosed by Autism Diagnostic Observation Schedule.

M: Male; F: female; ASD: Autism Spectrum Disorder; IQ: intelligence quotient; HR: heart rate; REM: rapid eye movement.

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