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Review

Relationship between sleep and measures of attention, executive functions, and processing speed in children with autism spectrum disorder: A systematic review

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ABSTRACT

Sleep disorders represent a common comorbidity among children and adolescents with autism spectrum disorder with prevalence ranging from 50 to 80%. Poor quality sleep has a negative impact on individuals' cognitive functions such as self-regulation, attention, executive functions, memory, and speed of processing. The aim of this literature review was to examine the correlation between sleep and measures of attention, executive functions, and processing speed among children with autism. This review included research articles published between 2012 and May 2022 in PubMed and Scopus databases, using the keywords "sleep" AND "attention" OR "executive functions" OR "processing speed" AND "autism" AND "children". These keywords were accompanied by synonyms, close-related, or underlying terms using the Boolean connector OR. 1226 results were yielded but the total number of original papers was reduced to 90 after checking for duplicate publications and title/abstract screening. 68 out of the 90 articles were excluded as irrelevant to the scope of the present study, after reading the full text. As a result, 22 studies were included in the present review, which was compiled by the PRISMA protocol. Exclusion criteria were papers published in any language other than English, non-research articles and studies in typically developing and/or adult populations. Regarding the measurement of sleep quality, most studies used subjective measures, such as questionnaires with reports and parental observations of participants' sleep habits and behaviors. Most studies used subjective rather than objective instruments to measure the under examination cognitive functions. In the case of attention, most studies tested it as a unitary construct by using questionnaires. Contrary, regarding Executive Functions, the majority of studies examined specific aspects, such inhibition, shifting and working memory, rather than executive functions as a unitary construct. Results showed a strong correlation between sleep and measures of attention, whereas results for executive functions and processing speed are less clear. Early and accurate diagnosis of sleep disorders could prove to be crucial in the regulation of these cognitive functions in children with autism, as it implies early and targeted intervention. Conclusively, further research on sleep quality improvement interventions is needed in autism individuals.

KEYWORDS: Sleep, attention, executive functions, processing speed, autism, children.

Introduction

Autism Spectrum Disorder (ASD) is a neuro-developmental disorder characterized by deficits in social communication and interaction, as well as by restricted and repetitive behaviors, actions, and interests. ASD is a condition with high heterogeneity of characteristics. Some individuals encounter co-existing language difficulties and/or mental retardation.[1]

One of the most influential interpretive frameworks of ASD is the Executive Dysfunction Hypothesis.[2] According to this, ASD individuals face deficits in Executive Functions which largely explain some of their distinct

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behavioral characteristics.[2,3] Furthermore, research suggests that people with autism tackle difficulties in other cognitive functions, such as attention[4,5] and processing speed.[6,7]

The term Executive Functions (EF) refers to a set of cognitive skills which support individuals flexibly adapting their thoughts, actions, and emotions while solving a problem.[8] Although there is no consensus on the specific nature of these functions and the way they are organized as a set, some of the most widely accepted are: (1) inhibition, (2) shifting (or cognitive flexibility), (3) working memory (or working memory updating), (4) initiation, (5) planning (or organizing), (6) problem-solving, and (7) monitoring.[8–10] EF are activated when a task is demanding and imports novel unpredictable conditions or information, which demand one's attention. Hence EF are closely related to attention.[9] Similar to EF, attention is divided into distinct yet close-related functions, such as: (1) focused/-sustained attention, (2) selective attention, and (3) divided attention.[11,12] Cognitive functioning is not only determined in terms of accuracy on problem-solving -for which attention and EF are crucial-, but also in terms of how much time is needed for the problem to be solved. Thus, processing speed is a distinct cognitive function that is generally defined as the time an individual spends to successfully process information and complete a task.[13,14]

Research has suggested that children and adolescents with ASD seem to cope with sleep disorders (SD) more often than individuals with no developmental disabilities.[15–18] SD such as insomnia symptoms (difficulty falling and staying asleep), restless sleep, short sleep duration, and early morning waking are the most common parent-reported symptoms in children with ASD.[19] In a recently published study, Lai and colleagues reported that the prevalence of sleep disorders was significantly higher in ASD population (13%) in comparison to the typical population (3,7%).[15] Other studies refer to a prevalence as high as 50–86%, which is two to three times greater than typically developing (TD) children.[17–18] Until today, a great number of research has confirmed executive dysfunction in children, adolescents, and adults with ASD, regardless of control factors such as intelligence quote, gender, depression, or ADHD comorbidity.[15,20] On the same page, sleep disorders seem to have negative effects on the cognitive functions of ASD individuals, such as attention, memory, and self-regulation of mood and behavior.[17,21,22]

There is a paucity of research regarding the relationship between SD and cognitive functioning in ASD individuals. Improving sleep quality is likely to improve attention, EF, and processing speed. These cognitive functions are involved in many important areas of activity and development of children, such as school success, social behavior and adaptation, language development, and mathematical skills.[23–25] Thus, improving them through achieving better sleep quality in children with ASD, is likely to lead to multiple benefits in all of the above areas. Considering the high prevalence of SD and cognitive dysfunction in ASD, the scope of the present literature review was to examine the association between sleep and cognitive measures of attention, EF, and processing speed in ASD.

Material and Method

The present review was performed following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol.[26]

Search strategy and inclusion criteria

Two independent researchers searched Medline and Scopus using the key terms: "sleep" AND "attention" OR "executive functions" OR "processing speed" AND "autism" AND "children". These four key words were accompanied by synonyms, close-related, or underlying terms using the Boolean connector OR (see the Supplementary material for the exhaustive list of terms). A time restriction between 2012 and 2022 (May) was set. The initial resulting papers were screened on their titles and abstracts as a first step to evaluate their relevance to the scope of the current review. As a second step, the remaining articles were read in their full texts by which their relevance to the theme was further tested according to inclusion/exclusion criteria. At this point, the articles were also checked for duplicate publications. Inclusion criteria were the following: research articles, English language, Autism Spectrum Disorder population, and children. Exclusion criteria were case studies, reviews, brief reports, and letters to editors; any other language rather than English, typically developing population, adults.

Data synthesis and outcome measures

From each article, the following data were extracted: article ID, publication time, number of subjects, age of subjects, sleep quality measures, attention/ executive functioning/ processing speed measures. Sleep quality measures were the independent variable. The outcome was attention/ executive functions/ processing speed.

Results

The searches on PubMed and Scopus yielded 1226 results. The total number of initial papers was reduced

after checking for duplicate publications and title/abstract/keywords screening to 90. Out of the remaining 90 articles, 68 of them were excluded after reading their full texts as irrelevant to the scope of the present study. As a result, 22 studies were included in the current review. Figure 1 depicts the PRISMA flow diagram for the present investigation. The 22 included studies were evaluated for risk of bias using the Appraisal tool for Cross-Sectional Studies (AXIS) (see supplementary material).

Cognitive measures

In regards to the measurement of attention, EF, and processing speed, two distinct categories were extracted: (1) subjective measures such as parent-reported questionnaires which are based on participant's daytime behavior, and (2) objective measures which evaluate participants' cognitive performance in specific problem-solving experimental tasks.

Seventeen out of the twenty-two under review studies (17/22, 77%) used exclusively subjective measures.[27–44] Three out of them (3/22, 14%) utilized solely objective measures.[44–46] The remaining two (2/22, 9%) granted both types of measures.[33,47]

Sleep quality measures

As far as sleep quality measurement is concerned, two categories were extracted: (1) subjective measures such as parent-reported questionnaires which are based on observations about participants' sleep habits and behaviors, and (2) objective measures such as actigraphy (wrists) and neuroimaging (polysomnography) by which sleep indicators are recorded during participants' sleep.

Fifteen out of the twenty-two under review studies (15/22, 68%) used exclusively subjective measures of sleep quality.[27,29–31,34–39,41,43,44,47,48] On the other hand, three studies (3/22, 14%) utilized solely objective measures.[28,32,46] The remaining four studies (4/22, 18%) granted both subjective and objective measures.[33,40,42,45] More details about the research tools that were used for assessing sleep and EF are provided in table 1.

Relationship between sleep and attention

Attention was examined by sixteen studies (16/22, 73%).[29,30,32–43,46,48] Eleven of them (11/16, 69%) found significant correlations between sleep and attention measures.[29,30,32,34–37,41–43,48] One of them (1/16, 6%) reported no significant correlation between the two variables.[39] All of these twelve studies which mainly reported positive results (11/12, 92%) can be categorized as using exclusively subjective measures for both sleep and attention (12/12, 100%).[30,32,34–37,39,41–43,48] Results of that category of studies indicate a strong relationship between sleep and attention.

The remaining four of the studies that assessed attention (4/16, 25%) reported mixed results[33,38,40,46] depending on which type of measurement was used[33,40] and on which attention tools/functions were used/tested.[38,46] In particular, two out of the four studies (2/4, 50%) found mixed results used both subjective and objective measures.[33,40] Lambert[40] found that CBCL sleep problems subscale was significantly associated with CBCL attention problems subscale, whereas PSG REM sleep variables were not significantly correlated with CBCL attention problems subscale. Loring[33] found that, after sleep quality improvement through sleep education, an inattention indicator (commission errors) measured by an objective measure (C-CPT) was significantly improved. In contrast, sleep improvement was not significantly correlated with the attention problems subscale of a subjective measure (BASC-2). These two studies demonstrate that when different types of measurement (subjective vs objective) are used in the same study, results become contradicting. The two remaining studies (2/4, 50%) used different tools of exclusively one type of measurement, either subjective or objective.[38,46] More specifically, Heinrich,[38] by using subjective measures, found no associations between sleep parameters extracted by clinical interviews and CBCL attention problems subscale, among ASD and ASD+ADHD groups. Contrarily, they found that

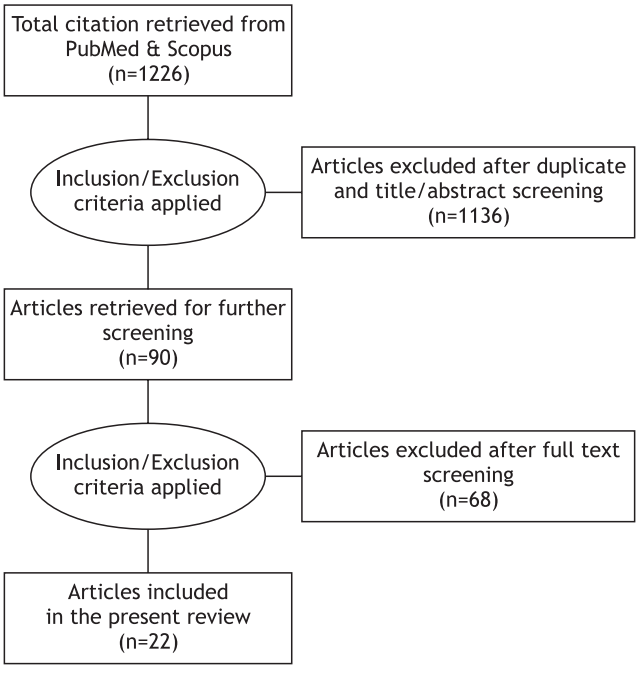

Figure 1. PRISMA flow diagram.

Table 1. Summary of studies that investigated relationships between sleep and measures of attention, executive functions, and processing speed in children with autism spectrum disorder.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
1	Gisbert Gustemps et al,[27] 2021, Spain	44 ASD children/ adolescents	10.5±2.8 (8-13 years)	The Sleep Disturbance Scale for Children (SDSC)	Behavioral Rating Inventory of Executive Function – Second Edition (BRIEF-2) (Only EF composite score was tested)		Univariate linear regression analysis showed that none of the sleep variables of the Sleep Disturbance Scale for Children (SDSC) reached significance in predicting the BRIEF Executive Function composite score.
2	Smidt et al,[28] 2021, USA	31 ASD children	4–17 years	Actimetry (wrists)	Behavior Rating Inventory of Executive Function (BRIEF) (Only EF composite score was tested)	Decreased executive function performance (BRIEF total score) was significantly associated with decreased levels of two sleep-parameters (earlier start of physical activity, strength of the circadian rhythm) as measured by actigraphy through wrists, in univariate linear regression analysis.	When adjusted for multiple factors by multivariate analysis these associations did not remain significant, likely due to the small sample size.
3	Zaidman-Zait et al,[29] 2020, Canada	281 ASD children	4-5 years	Children's Sleep Habits Questionnaire (CSHQ)	Child Behavior Checklist 1.5–5: "Attention problems" subscale (11 items)	Children with high levels of difficulties related to sleep onset, sleep duration and sleep-disordered breathing (CSHQ) had higher levels of attention problems (CBCL attention subscale), as indicated by hierarchical multiple regression analysis.	
4	Tyagi et al,[30] 2018, India	57 ASD vs 121 TD controls	3–12 years 6–12 years	The Sleep Disturbance Scale for Children (SDSC)	Sensory Profile 2: Attentional Responses (Attentional responses associated with sensory processing)	Univariate linear regression analysis showed that sleep problems total score as measured by the Sleep Disturbance Scale for Children (SDSC) was significantly associated with attentional responses during sensory processing (attention subscale) as evaluated by the Sensory Profile 2.	However, this correlation was found to be insignificant on the multivariate regression analysis, probably due to the small sample size.
5	Tesfaye et al,[31] 2021, Canada	217 ASD children	2–4 years and 6–8 years	Children's Sleep Habits Questionnaire (CSHQ)	Behavior Rating Inventory of Executive Function (BRIEF)	shifting Significant correlations between two CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF shifting at the age of 6.7 inhibition Significant correlations between two CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF inhibition at the age of 6.7	shifting No significant correlations between two CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF shifting at the age of 3.5 inhibition No significant correlations between two CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF inhibition at the age of 3.5

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Table 1. Continued.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
6	Murata et al,[32] 2017, Japan	30 ASD children with OSA (OSA group) vs 24 ASD children without OSA (control group)	5–14 years	Adenotonsillectomy (AT) for the treatment of obstructive sleep apnea (OSA) (Sleep quality improvement)	Child Behavior Checklist (CBCL): Attention problems subscale	Correlation analysis indicated that CBCL attention problems were significantly decreased after adenotonsillectomy (AT) in the OSA group,	in contrast with the control non-OSA group in which no significant difference was observed between the two assessment points.
7	Loring et al,[33] 2018, USA	18 ASD adolescents	11–18 years	Actigraphy (wrists) Adolescent Sleep Wake Scale (ASWS) Modified Epworth Sleepiness Scale (M-ESS)	Conner's Continuous Performance Test II (C-CPT II) Behavioral Assessment System for Children, Second Edition (BASC-2) Parent Rating Scale ("Attention Problems" subscale)	Significant improvement in an impulsivity/inattention indicator (commission errors) of C-CPT was found after sleep quality improvement through sleep education.	No significant improvements were found for the other EF indicators of C-CPT (reaction time, response speed and consistency, omission errors, and perseverations) which are considered as measures of processing speed and attention. Sleep improvement was not significantly correlated with the attention problems subscale of BASC-2.
8	Reynolds et al,[34] 2017, USA	85 ASD+ADHD children	6.66–12.91 years	Child behavior checklist (CBCL): Problematic sleep behaviors	Behavioral rating inventory of executive functioning (BRIEF) Conners parent rating scale-revised (CPRS-R): Cognitive problems/ Inattention subscale	Multivariate regression analysis showed that total problematic sleep behavior (CSHQ total score) was significantly associated with multivariate functional domains such as executive functioning (BRIEF total score), after controlling for paternal education, internalizing symptoms, ASD and ADHD severity.	Univariate regression analysis indicated no significant correlation between sleep and executive functioning. Bivariate correlation analysis showed a significant correlation between total problematic sleep behavior (CSHQ total score) and cognitive problems/inattention (CPRS).
9	Veatch et al,[35] 2017 USA	2,714 ASD children	4–18 years	Parent reports of the average amount of time slept per night	Child Behavior Checklist: Attention problems subscale	Shorter sleep duration as reported by children's parents was significantly associated with increased attention problems (CBCL attention subscale) as indicated by Spearman's correlation analysis.	

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Table 1. Continued.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
10	Mazurek et al,[36] 2016, USA	81 ASD children	3.6–19.6 years (M=10.3, SD=3.8)	Children's Sleep Habits Questionnaire (CSHQ)	Vanderbilt Attention Deficit/ Hyperactivity Disorder Parent Rating Scale (VADPRS): Inattention subscale	Bivariate correlation analysis that several CSHQ sleep quality indicators (sleep duration, sleep anxiety, night wakings, parasomnias) showed significant correlation with the inattention subscale of VADPRS. Multivariate regression analysis demonstrated that sex along with bedtime resistance and night wakings significantly predicted inattention.	
11	Rousis et al,[37] 2021, Australia	46 ASD children	2–5 years	Children Sleep Habits Questionnaire (CSHQ): children were classified into the three sleep groups: no sleep problem, mild/ typical sleep problem, or severe/atypical sleep problems	Behavioural Assessment System for Children- (BASC-3): Attention Problems subscale	Significant differences in attention problems (BASC-3) between no sleep problems and mild/typical sleep problems groups, as well as between the no sleep problems and severe sleep problems groups.	No significant difference in attention problems was found between the two sleep problems groups.
12	Heinrich et al,[38] 2020, USA	29 ASD children 57 ASD+ADHD children	7–17 years	Clinical interview – questionnaire Pediatric Sleep Questionnaire (PSQ): sleep-breathing disorder (SBD)	Conners rating scales (3rd ed.): Attention functioning subscale Child Behavior Checklist (CBCL): Attention Problems subscale	In comorbid ASD+ADHD children group regression analysis demonstrated that sleep-breathing disorder (SBD) scale was significantly correlated with ADHD Inattentive problems of Conner's, after controlling for intellectual functioning.	Correlation analyses indicated no associations between sleep parameters and inattention (Conners), among ASD and ASD+ADHD groups.
13	Fadini et al,[39] 2015, Brazil	45 ASD children vs 56 TD children	4–18 years	Sleep Disturbance Scale for Children (SDSC)	Child Behavior Checklist (CBCL): Attention Problems subscale	A significant correlation was found between sleep-breathing disorders subscale (SDSC) and attentional problems subscale (CBCL) in the TD control group.	In contrast, correlation analysis showed no significant correlations between sleep parameters and attention for the ASD group.
14	Lambert et al,[40] 2016, Canada	11 ASD children vs 13 TD children	6–13 7–12	Children's Sleep Habit Questionnaire (CSHQ) Polysomnography (PSG)	Child Behavior Checklist (CBCL): Attention Problems subscale	CBCL sleep problems subscale was significantly associated with CBCL attention problems subscale.	In contrast, PSG REM sleep variables were not significantly correlated with CBCL attention problems subscale.

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Table 1. Continued.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
15	Park et al,[41] 2012, Republic Of Korea	166 ASD children	3–15 years M=7,49	Parent-reported sleep questionnaire: ASD children were divided into two groups: ASD with sleep problems vs ASD without sleep problems	Child Behavior Checklist (CBCL): Attention Problems subscale	Between groups comparison showed ASD children with sleep problems had significantly higher inattention scores (CBCL) in comparison with ASD children without sleep problems.	
16	Malow et al,[42] 2014, USA	80 ASD children: 41 were randomized to the individual intervention arm vs 39 were randomized to the group intervention arm	2–12 years 5.6 (2.6) individual arm vs 5.9 (2.8) group arm	Actigraphy (wrists) Children's Sleep Habits Questionnaire (CSHQ) Family Inventory of Sleep Habits (FISH): bedtime routine, sleep environment, and parental interactions	Child Behavior Checklist (CBCL): Attention Problems subscale	Change in sleep quality after sleep education was significantly correlated to CBCL attention subscale.	
17	Gunes et al,[43] 2019, Turkey	112 ASD children vs 112 TD children	2–18 years	Children's Sleep Habits Questionnaire (CSHQ): children were divided into two groups: milder sleep problems (CSHQ<56) vs moderate-to-severe sleep problems (CSHQ>56)	DSM-IV Disruptive Behavior Disorders Rating Scale parent form (T-DSM-IV-S): inattentiveness	ASD children with moderate-to-severe sleep problems showed significantly higher subscore of inattentiveness, as compared to ASD children with milder sleep problems.	
18	Memari et al,[44] USA, 2013	123 ASD children	7–14 years	Activity log: total sleep time	Wisconsin card sorting test (WCST): shifting	Correlation analysis demonstrated a significant negative correlation between sleep time and perseveration errors, namely as the amount of sleep time per night was increased the number of perseveration errors was decreased. Multiple regression analysis showed that sleep time was one of strongest predictors of perseveration errors along with other factors such as language ability, education, social play, and non-verbal IQ.	Contrary, sleep time was not significantly related to categories achieved on both correlation and regression analyses.

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Table 1. Continued.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
19	Backer et al,[45] 2018, Saudi Arabia	18 ASD children	7–10 years	Children's Sleep Habits Questionnaire (CSHQ): children were divided into poor sleepers vs good sleepers Actigraphy (wrists)	Cambridge Neuropsychological Test Automated Battery (CANTAB): Motor screening task (MOT) Simple reaction time task (SRT) Intradimensional/ extradimensional shift (IED)	Correlation analysis for the whole sample indicated significant associations between sleep parameters (CSHQ, actigraphy) and processing speed indicators: bedtime resistance and sleep anxiety (CSHQ) were significantly correlated with response time of SRT task, sleep latency and wake after sleep onset (CSHQ) were correlated with motor speed response (SRT task). Actigraphy data (wrists) indicated that wake after sleep onset was significantly correlated with response time of SRT task.	Processing speed performance (response time and maximum response time in Motor planning task, MOT) was not significantly lower in the poor sleepers as compared to the good sleepers. Shifting (intradimensional/ extradimensional shift, IED), was not significantly different between poor and good sleepers.
20	Limoges et al,[46] 2013, Canada	17 adults with ASD vs 14 TD as control group	16–22 years	Polysomnography (PSG)	Four choices reaction time test (FCRTT): sustained attention Flanker task: selective attention Corsi block-tapping: working memory Tower of London (TOL): problem solving, planning, execution, processing speed	For ASD participants poor sleep indicators (i.e., increased sleep latency, increased light-stage 1 sleep) were significantly correlated with selective attention, such that poor sleep was associated with impaired performance.	Correlation analysis showed that poor sleep indicators (i.e., increased sleep latency, increased light-stage 1 sleep, and increased wake time after sleep onset) were not significantly associated with sustained attention and working memory, in any of the two groups (ASD vs typical).
21	Holingue et al,[47] 2021, USA	177 ASD children vs 235 ADHD children vs 323 TD children	8–12 years	Children's Sleep Habits Questionnaire (CSHQ)	Behavior Rating Inventory of Executive Function (BRIEF) WISC-IV or-V: processing speed index (PSI)	Regression analyses demonstrated that CSHQ total sleep score was significantly associated with BRIEF Inhibition score among all three groups of children (ADHD, ASD, TD), after adjusting for demographic variables, use of stimulant medications, and general cognitive ability… Similarly, regression analyses showed that CSHQ total sleep score significantly predicted BRIEF Shifting score among all three groups (ADHD, ASD, TD) …, Working memory was significantly associated with CSHQ total sleep score even after adjusting for anxiety.	…However, after further adjustment for anxiety, the associations remained significant only for the ADHD group. …but after adjusting for anxiety, the association was no longer significant for any of them. No significant correlation was found between processing speed and CSHQ total sleep score.

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Table 1. Continued.

	Article ID	N	Age	Sleep measures	Neurocognitive measures	Correlation	No correlation
22	Kurzius-Spencer et al,[48] 2018, USA	9378 ASD children	8 year-olds	Standardized protocol: SLEEP: Abnormalities in sleeping; problems or difficulties sleeping	Standardized protocol: ADH: Short attention span; inattentive; hyperactivity; impulsivity (includes being fidgety and general attention problems)	Sleep problems were significantly correlated with the inattention scale, regardless of participants' intellectual disability status.	

Sleep tests: Sleep parameters: Sleep indicators
The Sleep Disturbance Scale for Children (SDSC): initiating and maintaining sleep, respiratory disorders, sleep arousal, sleep-wake transition disorders, excessive sleepiness, restless legs syndrome/periodic limb movement syndrome/growth pains, sleep hyperhidrosis.[27,30]
Actimetry (wrists): Rest-activity measurement/sleep–wake parameters: wake after sleep onset, sleep efficiency, number of sleep episodes, average L5 activity level, sleep duration, L5 start time, sleep onset time, average M10 activity level, M10 start time, and for circadian rhythm: relative amplitude, interdaily stability, intradaily variability.[28] / Actigraphy (wrists): total night-time sleep duration (TST), sleep efficiency (SE), sleep latency (SL), wake after sleep onset (WASO), fragmentation index (FI, all sleep movements).[45] / Actigraphy (wrists)[33] / Actigraphy (wrists): sleep-onset latency, total sleep time, sleep efficiency, and wake after sleep onset.[42]
Children's Sleep Habits Questionnaire (CSHQ): bedtime resistance, sleep-onset delay, sleep duration, sleep anxiety, night wakening, parasomnias, sleep disordered breathing, daytime sleepiness.[37,47,31,45,36,40,42,43,29] Activity log: total sleep time.[44,35]
Adenotonsillectomy (AT) for the treatment of obstructive sleep apnea (OSA): sleep quality improvement indicator.[32]
Adolescent Sleep Wake Scale (ASWS): going to bed, falling asleep, maintaining sleep, reinitiating sleep, returning to wakefulness.[33]
Modified Epworth Sleepiness Scale (M-ESS) (Designed to measure how likely the participant is to fall asleep in seven situations).[33]
Child Behavior Checklist (CBCL): problematic sleep behaviors: nightmares, excessive overtiredness, sleeping more than most kids, sleeping less than most kids, trouble sleeping.[42]
Polysomnography (PSG): sleep onset latency, sleep stage latencies, total sleep time, sleep efficiency, stage 2 sleep spindles, stage 2 K-complexes, density of sleep spindles, density of K-complexes.[40] / Polysomnography (PSG): sleep onset latency, sleep stage latencies, total sleep time, periodic leg movements in sleep, periodic leg movements during wake time after sleep onset.[46]
Sleep Disturbance Scale for Children (SDSC): disorders of initiating and maintaining sleep (DIMS), sleep-breathing disorders (SBD), disorders of arousal (DA), sleep–wake transition disorders (SWTD), disorders of excessive somnolence (DES), sleep hyperhidrosis (SHY).[39]
Parent-reported sleep questionnaire: bedtime resistance, insomnia, parasomnia, sleep disordered, daytime sleepiness.[41]
Family Inventory of Sleep Habits (FISH): bedtime routine, sleep environment, parental interactions.[42]
Standardized protocol: ADH: Short attention span; inattentive; hyperactivity; impulsivity (includes being fidgety and general attention problems).[48]
Clinical interview – questionnaire: history of tonsillectomy and/or adenoidectomy, sleep Insomnia: difficulty falling asleep, frequent wakening; obesity: body mass index (BMI).[38]
Pediatric Sleep Questionnaire (PSQ): sleep-breathing disorder (SBD): snoring, sleepiness, sleep-breathing.[38], EF tests: EF tasks/aspects: EF indicators
Behavioral Rating Inventory of Executive Function – Second Edition (BRIEF-2): inhibition, self-monitoring, switching, emotional control, initiative, working memory, planning, organization, task monitoring.[27]
Behavior Rating Inventory of Executive Function (BRIEF): shifting attention, shifting/mental flexibility, inhibition, self-control, impulsivity, initiation, working memory, planning.[28,47,31,34]
Sensory Profile 2: Attentional responses associated with sensory processing indicator.[30]
Child Behavior Checklist: Attention problems subscale.[29,32,35,40,39,41,42,30]
Weschler's Intelligence Scale for Children -IV/ -V (WISC-IV/V): processing speed index (PSI).[47]
Wisconsin card sorting test (WCST): shifting/cognitive flexibility: perseveration errors, categories achieved.[44]
Cambridge Neuropsychological Test Automated Battery (CANTAB): Motor screening task (MOT): speed, accuracy, and number of errors; Simple reaction time task (SRT): simple reaction time, general alertness, and motor speed; intradimensional/ extradimensional shift (IED): shifting and flexibility of attention.[45]
Conner's Continuous Performance Test II (C-CPT II): inattention, impulsivity, and vigilance: reaction time, response speed and consistency, omission errors, commission errors, and perseverations.[33] Behavioral Assessment System for Children, Second Edition (BASC-2): Attention Problems subscale.[33]
Conners parent rating scale-revised (CPRS-R): Cognitive problems/ Inattention subscale.[34]
Vanderbilt Attention Deficit/Hyperactivity Disorder Parent Rating Scale (VADPRS): Inattention subscale.[36]
Standardized protocol: SLEEP: Abnormalities in sleeping; problems or difficulties sleeping.[48]
DSM-IV Disruptive Behavior Disorders Rating Scale (T-DSM-IV-S): Inattentiveness subscale.[43]
Conners rating scales (3rd ed.): Attention functioning subscale.[38]
Behavioural Assessment System for Children – Third Edition (BASC-3): Attention Problems subscale.[37]
Four choices reaction time test (FCRTT): sustained attention.[46]
Flanker task: selective attention.[6], Corsi block-tapping: working memory.[46]
Tower of London (TOL): problem solving, planning, execution, processing speed.[46]

the sleep-breathing disorder (SBD) scale was significantly correlated with Conner's (CPRS-R) ADHD inattentive problems in the comorbid ASD+ADHD group. On the other hand, Limoges,[46] by using objective measures, showed that PSG poor sleep indicators were not significantly associated with sustained attention (four choices reaction time test), whereas PSG sleep indicators were significantly correlated with selective attention (flanker task). These two studies show that when different tools/aspects of the same type of measurement are used/tested, results about a possible relationship between sleep and attention become less cohesive.

Relationship between sleep and EF as a unitary construct

Three studies (3/22, 14%) tested the relationship between sleep and EF by considering EF as a unitary construct, using BRIEF total raw score in their statistical analyses.[27,28,34] One of them reported negative results.[27] In particular, Gustemps[27] performing univariate linear regression analysis reported that none of the sleep variables of the Sleep Disturbance Scale for Children (SDSC) reached significance in predicting the BRIEF composite score. Two of them found mixed results.[28,34] More specifically, Smidt[28] reported that decreased EF performance (BRIEF total score) was significantly associated with decreased levels of two sleep parameters (earlier start of physical activity, strength of the circadian rhythm) as measured by actigraphy (wrists), in univariate linear regression analysis. Nonetheless, when adjusted for multiple factors in multivariate analysis these associations did not remain significant, likely due to the small sample size (N=31). In Reynolds[34] multivariate regression analysis showed that problematic sleep behavior (CSHQ total score) was significantly predicted by BRIEF total score, after controlling for paternal education, internalizing symptoms, ASD, and ADHD severity. However, univariate regression analysis indicated no significant correlation between sleep and executive functioning. These two studies indicate that control variables may influence the relationship between sleep and EF.

Relationship between sleep and different aspects of EF

Shifting

Shifting was examined by five studies (5/22, 23%).[31,33,44,45,47] Two of them used subjective tools and reported mixed results depending on control variables. More specifically, Holingue et al[47] found that CSHQ sleep quality significantly predicted BRIEF shifting scores, but this relationship became null after controlling for anxiety. Tesfaye[31] found no significant relationships between CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF shifting at the age of 3.5 but they found significant such correlations at the age of 6.7.

The remaining three studies used objective measures. One of them reported mixed results depending on which shifting indicator was tested and two of them reported insignificant results. In particular, Memari[44] found no evidence for a relationship between sleep and categories achieved, but they found evidence for a link between sleep and preservation, of the Wisconsin Card Sorting Test (WCST).[27] Contrary to this result, Loring[33] found that sleep quality improvement after sleep education was not significantly correlated to perseveration errors of the Conner's Continuous Performance Test II (C-CPT II). Adding to this, Backer[45] reported that shifting (interdimensional/ extradimensional shift, IED) was not significantly different between poor and good sleepers divided into groups by CSHQ total score.

Inhibition

Inhibition was investigated by two studies (2/22, 9%).[31,47] Both utilized subjective tools (2/2, 100%) and reported mixed results. Holingue[47] demonstrated that CSHQ total sleep score was significantly associated with BRIEF Inhibition score, after adjusting for demographic variables, use of stimulant medications, and general cognitive ability. However, after further adjustment for anxiety, the associations became insignificant. Tesfaye[31] found no significant associations between two CSHQ sleep indicators (sleep duration, delayed sleep onset) and BRIEF inhibition at the age of 3.5 years, yet they found such significant correlations at the age of 6.7 years. These two studies show that control variables such as anxiety and age may influence the relationship between sleep and EF/inhibition.

Working memory

Working memory was tested by two studies (2/22, 9%).[46,47] They used totally different measures and reported contradicting findings from each other. Holingue47 found that BRIEF working memory was significantly associated with CSHQ sleep total score, even after controlling for anxiety. In contrast, Limoges[46] found that no PSG poor sleep indicator was significantly correlated with working memory measured by a non-verbal experimental task (Corsi blocks).

Relationship between sleep and processing speed

Processing speed was evaluated by three studies (3/22, 14%).[33,45,47] Two of them did not find a significant relationship (2/3, 67%). Holingue[47] reported that

processing speed measured by an experimental WISC task was not significantly correlated with CSHQ total sleep score. Loring[33] reported that, after sleep quality improvement through sleep education, no significant improvements were found for processing speed indicators of the C-CPT (reaction time, response speed). One of them reported mixed results (1/3, 33%). Backer[45] found that processing speed performance (response time and maximum response time in Motor planning task, MOT) was not significantly lower in the poor sleepers as compared to the good sleepers. Nonetheless, correlation analysis for the whole sample indicated significant associations between sleep parameters (CSHQ, actigraphy) and processing speed indicators. In particular, bedtime resistance and sleep anxiety (CSHQ) were significantly correlated with response time (SRT task), while sleep latency and wake after sleep onset (CSHQ) were correlated with motor speed response (SRT task). Adding to this, actigraphy data (wrists) indicated that wake after sleep onset was significantly correlated with response time (SRT task).

Discussion

The objective of the present study was to investigate the relationship between sleep and cognitive functions (attention, EF, processing speed) in children with ASD. As far as cognitive measurement is concerned, most studies used subjective rather than objective tools. Specifically, regarding attention, most studies assessed it as a unitary construct by using subjective measures (questionnaires). Contrary to attention, the majority of EF studies tested specific aspects of EF (shifting, inhibition, working memory) rather than EF as a unitary construct (EF total score). However, subjective tools were more frequently used similar to attention assessment. The few studies that tested processing speed used experimental reaction-time tasks.

The most frequently examined cognitive function is attention. Results depicted a strong relationship between sleep and attention. However, all studies which reported a firm significant correlation used exclusively subjective tools.[29,30,32,34–37,41–43,48] The few studies which used objective measures or combined both types of measurement reported mixed results.[33,38,40,46]

The few studies which tested EF as a unitary construct reported mixed results.[27,28,34] One of them found no significant correlation.[27] Two of them found some evidence for a strong relationship but these results were greatly dependent on control factors.[28,34]

The most frequently studied EF dimension is shifting/cognitive flexibility. Results are incohesive about the influence of sleep quality on perseveration.[33,44] On the other hand, categories achieved seem to not be influenced by sleep quality in both studies which tested this shifting indicator.[44,45] Moreover, results from each of the two studies which used subjective measures are mixed depending on interfering variables such as anxiety[47] and age.[31]

Another EF aspect that was examined is inhibition. Only two studies were found.[31,47] Each of them utilized subjective tools and reported mixed results. The source of contradicting results for both studies was intervening control factors such as anxiety[47] and age,[31] similar to the case of shifting.

Working memory was also tested as a distinct EF dimension by two studies.[46,47] Results lack cohesiveness as the two studies used completely different measures (subjective vs objective, verbal vs non-verbal) and reported contradicting results with each other.

In regard to processing speed, all three relevant studies utilized experimental tasks.[33,45,47] Results show a tendency to the insignificant relationship between sleep and processing speed, as two of them reported no significant correlation[33,47] and one of them reported mixed results.[45] It is noteworthy that positive results derive from testing between actigraphy data and experimental data[45] whereas negative results emerged from testing between questionnaire data and experimental data.[33,47]

Conclusion

In conclusion, cognitive functions are negatively influenced by poor sleep quality in ASD, at least for some specific aspects of them. Hence, an early and accurate diagnosis of sleep disorders could be proved vital for cognitive regulation in children with ASD, as it consequently leads to early and targeted intervention.[32,44,46,47] Based on the findings of the present study, the authors suggest future studies emphasize more on which specific aspects of attention and EF may be influenced by sleep quality, as different aspects may influence different dimensions of everyday behavior. This could be achieved by using objective measures from which specific attention and EF aspects and indicators are extracted, contrary to the current tendency to use subjective tools. It is also suggested that future research focuses on examining developmental differences because only one such study was found.[31] More than that, this review showed that more intervention studies are needed in order to have a clearer view of how to help in practical terms ASD people enhance their sleep quality, as only three relevant studies were found.[32,33,42]

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Ανασκόπηση

Σχέση μεταξύ ύπνου και μετρήσεων προσοχής, επιτελικών λειτουργιών, και ταχύτητας επεξεργασίας σε παιδιά με διαταραχή αυτιστικού φάσματος: Συστηματική ανασκόπηση

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ΠΕΡΙΛΗΨΗ

Οι διαταραχές ύπνου αντιπροσωπεύουν μια κοινή συννοσηρότητα μεταξύ παιδιών και εφήβων με διαταραχή αυτιστικού φάσματος με επιπολασμό που κυμαίνεται από 50 έως 80%. Ο χαμηλής ποιότητας ύπνος έχει αρνητικές επιπτώσεις στις νοητικές λειτουργίες, όπως η αυτορρύθμιση, η προσοχή, οι επιτελικές λειτουργίες, η μνήμη και η ταχύτητα επεξεργασίας. Στόχος της παρούσας βιβλιογραφικής ανασκόπησης ήταν να εξετάσει τη σχέση μεταξύ ύπνου και μετρήσεων προσοχής, επιτελικών λειτουργιών και ταχύτητας επεξεργασίας σε παιδιά με αυτισμό. Στην ανασκόπηση συμπεριλήφθηκαν ερευνητικά άρθρα που δημοσιεύτηκαν από το 2012 έως και τον Μάιο του 2022, στις ηλεκτρονικές βάσεις δεδομένων PubMed και Scopus, χρησιμοποιώντας τις λέξεις-κλειδιά: «sleep» ΚΑΙ «attention» Ή «executive functions» Ή «processing speed» ΚΑΙ «autism» ΚΑΙ «children». Αυτές οι λέξεις-κλειδιά συνοδεύτηκαν από συνώνυμους, στενά σχετιζόμενους ή υποκείμενους όρους χρησιμοποιώντας τον σύνδεσμο Ή. Από την αναζήτηση προέκυψαν 1226 αποτελέσματα αλλά ο συνολικός αριθμός των αρχικών εργασιών μειώθηκε σε 90 μετά τον έλεγχο για διπλότυπες δημοσιεύσεις και τον έλεγχο τίτλου/περιλήψεων. 68 από τα 90 άρθρα αποκλείστηκαν μετά την ανάγνωση των πλήρων κειμένων τους, ως μη σχετικά με το αντικείμενο της παρούσας μελέτης. Ως αποτέλεσμα, 22 μελέτες συμπεριλήφθηκαν στην παρούσα ανασκόπηση, η οποία συντάχθηκε με βάση το πρωτόκολλο PRISMA. Κριτήρια αποκλεισμού αποτέλεσαν εργασίες που δημοσιεύτηκαν σε οποιαδήποτε άλλη γλώσσα πλην της αγγλικής καθώς και μη ερευνητικά άρθρα και μελέτες σε τυπικό ή και ενήλικο πληθυσμό. Αναφορικά με τη μέτρηση της ποιότητας ύπνου, οι περισσότερες μελέτες χρησιμοποίησαν υποκειμενικές μετρήσεις, όπως ερωτηματολόγια με αναφορές και παρατηρήσεις γονέων σχετικά με τις συνήθειες και τις συμπεριφορές των συμμετεχόντων στον ύπνο. Αναφορικά με τη μέτρηση των νοητικών λειτουργιών, οι περισσότερες έρευνες χρησιμοποίησαν υποκειμενικές παρά αντικειμενικές μετρήσεις. Σχετικά με την προσοχή, οι περισσότερες έρευνες την εξέτασαν ως ενιαία εννοιολογική κατασκευή χρησιμοποιώντας ερωτηματολόγια. Αντίθετα, σχετικά με τις επιτελικές λειτουργίες, η πλειονότητα των μελετών εξέτασε συγκεκριμένες πτυχές (εναλλαγή, αναστολή, εργαζόμενη μνήμη) και όχι την επιτελική λειτουργία ως ενιαία εννοιολογική κατασκευή. Τα αποτελέσματα έδειξαν ισχυρή συσχέτιση μεταξύ ύπνου και των μετρήσεων της προσοχής, ενώ τα αποτελέσματα για τις επιτελικές λειτουργίες και την ταχύτητα επεξεργασίας είναι λιγότερο ξεκάθαρα. Η έγκαιρη και ακριβής διάγνωση των διαταραχών ύπνου θα μπορούσε να αποδειχθεί ζωτικής σημασίας στη ρύθμιση των νοητικών λειτουργιών στα παιδιά με αυτισμό, καθώς συνεπάγεται έγκαιρη και στοχευμένη παρέμβαση. Συμπερασματικά, απαιτείται περαιτέρω έρευνα σχετικά με τις παρεμβάσεις βελτίωσης της ποιότητας του ύπνου σε άτομα με αυτισμό.

ΛΕΞΕΙΣ ΕΥΡΕΤΗΡΙΟΥ: Ύπνος, προσοχή, επιτελικές λειτουργίες, ταχύτητα επεξεργασίας, αυτισμός, παιδιά.

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