Psychiatry Research 278 (2019) 188–193

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Shorter REM latency in children with attention-deficit/hyperactivity disorder

Amparo Díaz-Román*, Gualberto Buela-Casal

Sleep and Health Promotion Laboratory, Mind, Brain and Behavior Research Center, CIMCYC, University of Granada, Spain

ARTICLE INFO

Keywords:
Attention-deficit/hyperactivity disorder
ADHD
Sleep
Daytime sleepiness
REM latency

ABSTRACT

The discrepancies in prior research about the actual sleep problems underlying attention-deficit/hyperactivity disorder (ADHD) demand more studies of children with this disorder. This study aimed to compare the subjective and objective sleep characteristics of 20 children with ADHD (DSM-IV criteria) and 20 typically developing children (aged 7–11 years). We assessed the children using sleep questionnaires and polysomnography recordings and analysed differences between the two groups using two-tailed Mann–Whitney *U* exact tests and Rosenthal's *r* as effect size measure. We also assessed associations between sleep measures and psychopathology using Spearman's correlation coefficients. No significant difference was found between the groups in almost any objective sleep variable, except for shorter REM latency in the ADHD group. Children with ADHD also showed significantly higher levels of daytime sleepiness and greater general sleep problems than control children, as reported by their parents, after discarding the primary sleep problems commonly associated with ADHD. Significant correlations were found between psychopathology and sleep measures. Our findings might support the link between narcolepsy-like sleep phenotype and ADHD. However, longitudinal research combining objective and subjective assessments should further explore the involvement of other variables, such as ADHD subtypes, medication, and comorbid symptoms in this relationship.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder in childhood, affecting around 63 million children worldwide (Polanczyk et al., 2015), and which leads to negative consequences in a significant number of fields (American Psychiatric Association, 2013). ADHD is also associated with diverse comorbid conditions, including autism spectrum disorders, bipolar disorder, conduct disorders, anxiety and depressive disorders, eating disorders, and sleep disturbances (Biederman et al., 2008; Jerrell et al., 2014; Melegari et al., 2018; Owens, 2008; Zablotsky et al., 2017; Ziobrowski et al., 2018). The latter may be associated with poorer functional outcomes in children with this disorder (Sung et al., 2008).

As sleep problems were found in around 55% of the children diagnosed with ADHD (Corkum et al., 1998), numerous studies have been conducted to gain a better understanding of these problems. However, two decades later, there is still little agreement about the actual sleep problems underlying ADHD, remaining unclear whether these are related to sleep efficiency or sleep architecture (e.g., Vigliano et al., 2016; Virring et al., 2017), or to other subjectively-reported sleep variables like daytime sleepiness (e.g., Bioulac et al., 2015; Hysing et al., 2016; Langberg et al., 2017; Schneider et al., 2016).

Two factors could have led to this lack of convincing conclusions about the nature of sleep disturbances in children with ADHD. First, participants did not have a clinical diagnosis of ADHD in some studies, as pointed out in a recent meta-analysis (Díaz-Román et al., 2016), and their placement in the ADHD condition group was purely based on subjective ratings. Second, several studies revealed a greater amount of periodic limb movements (PLMS) or breathing-related sleeping problems in children with ADHD (see reviews of Cortese et al., 2006, 2009; Sadeh et al., 2006), but these features could also have been linked to primary sleep disorders and, hence, not directly caused by the ADHD itself.

Definitely, further studies are needed so as to reach a conclusion on the sleep problems inherent in ADHD for them to be correctly managed. Therefore, this study aimed to compare the sleep characteristics of children with a clinical diagnosis of ADHD and a control group, using both subjective and objective sleep measures. On the basis of earlier studies, we expected to find more sleep problems in children with ADHD in comparison with their peers.

* Corresponding author.
E-mail address: adiazroman@ugr.es (A. Díaz-Román).

https://doi.org/10.1016/j.psychres.2019.06.012
Received 14 January 2019; Received in revised form 10 June 2019; Accepted 11 June 2019
Available online 11 June 2019
0165-1781/

2. Methods

2.1. Participants

Twenty children with ADHD and 20 control children aged between 7 and 11 years (mean age ± SD = 8.83 ± 1.43; 67.50% boys), recruited from schools, associations, and public institutions in Andalusia (Spain), were enrolled in this study. Children were matched for age, $t = -0.77$, $p = .45$, and sex, $\chi^2(1) = 1.03$, $p = .50$.

A prior clinical diagnosis of ADHD, in accordance with standardized criteria, was required for children within the ADHD condition to take part in the study. This diagnosis was verified through their medical history report, an interview with their parents based on the DSM-IV, the Child Behavior Checklist (CBCL; Achenbach and Rescorla, 2001), and the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) completed by their parents. Scores higher than the 85th percentile in the ADHD scale of the CBCL and higher or equal than the 75th percentile in hyperactivity subscale of the SDQ were mandatory for children with ADHD to be included. Based on their medical history reports, two children had the inattentive subtype, two had the combined subtype, and 16 did not have any ADHD subtype specified. Five children also presented comorbid disorders to ADHD (three children were diagnosed with comorbid oppositional defiant disorder and two were diagnosed with comorbid conduct disorder). Furthermore, 17 children were taking medication for ADHD (14 methylphenidate, two atomoxetine, and one methylphenidate in combination with atomoxetine).

The children without ADHD had no history of psychiatric or psychological disorder and had no ADHD symptoms reported by their parents. These inclusion criteria were checked following the same procedure as with the children with ADHD and by using the same questionnaires. Their scores had to be lower than the 40th percentile in the ADHD scale of the CBCL and lower than the 50th percentile in the hyperactivity subscale of the SDQ.

The ADHD scale of the CBCL was also used along with the other five DSM-oriented scales of this questionnaire (i.e., Affective Problems, Anxiety Problems, Somatic Problems, Oppositional Defiant Problems, and Conduct Problems; Achenbach and Rescorla, 2001) as a measure of symptom severity and comorbid psychopathology in children.

2.2. Sleep measures

2.2.1. Pediatric Daytime Sleepiness Scale (PDSS)

The PDSS is a reliable and valid questionnaire to assess sleepiness in children (Perez-Chada et al., 2007). It is composed of eight items with a 5-point Likert scale ranging from 0 (*never*) to 4 (*always*). This scale is reversed for the last item of the instrument. The total score ranges from 0 to 32 points, and a higher score indicates a higher level of daytime sleepiness.

2.2.2. Pediatric Sleep Questionnaire (PSQ)

Part A of the PSQ (Tomás et al., 2007), which collects information about the behaviour displayed by the child during the night and while sleeping, was employed. This is a reliable tool to evaluate sleep disorders in children (Tomás et al., 2007), and consists of 43 items related to the behaviour displayed by the child during the night and while sleeping. Six of the items present an open-response format, and the other 37 items are answered using a *yes/no/don't know* response format. The total score is computed by dividing the number of items answered positively by the total number of items answered (either positively or negatively). This total score can vary from 0 to 1, and a higher total score reflects a higher number of general sleep problems.

2.2.3. Sleep diary

This instrument included eight questions on several children's sleep habits (e.g., time to go to sleep, time spent before falling asleep, time to wake and get up in the morning, and the number of times the child woke up during the night). This ad hoc questionnaire was developed to obtain information about some subjective sleep parameters, such as sleep efficiency, total sleeping time, and time awake. The parents recorded data for an entire week.

2.2.4. Polysomnography (PSG) recordings

Home PSG recordings (with a SomnoScreen PSG-Tele system from SomnoMedics, Germany) were performed to evaluate sleep. Electrodes for electroencephalogram (EEG), electro-oculogram (EOG), and electromyogram (EMG) recordings were placed in accordance with the International 10–20 System (Fz-A1, Cz-A1, Pz-A1, Oz-A1, EOG1-EOG2, EMG1, EMG2). Respiratory variables (oral and nasal airflow, pulse oximetry, and thoracic effort), anterior tibialis EMG, and body position during the night were also registered. Electrophysiological and PSG signals were analysed using the DOMINO software, and sleep stages were divided into 30-second epochs in accordance with the Rechtschaffen and Kales criteria (1968). These same scoring criteria were also applied to manually classify either sleep stages or other sleep parameters. The following objective sleep parameters were assessed: time in bed; sleep period time; total sleep time; sleep efficiency; sleep latency; wake time; sleep stages 1, 2, 3, and 4; slow wave sleep; REM sleep; REM latency; arousal index; and index of PLMS. A complete description of these parameters is shown in Table 1. Respiratory and electrophysiological PSG signals, along with sleep data provided by the

Table 1
Objective sleep parameters recorded by polysomnography.

Sleep parameter	Definition
Time in bed (TIB; min)	Time between lights off and lights on.
Sleep period time (SPT; min)	Time from sleep onset to final awakening.
Total sleep time (TST; min)	Actual sleep time in a sleep period (SPT less movement and awake time).
Sleep latency (min)	Time between lights off and the beginning of S1.
Sleep efficiency (SE; %)	(TST/TIB) × 100
Wake time (min)	Total time awake between sleep onset and final awakening.
Stage 1 sleep (S1; %)	(Time spent in S1/TST) × 100
Stage 2 sleep (S2; %)	(Time spent in S2/TST) × 100
Stage 3 sleep (S3; %)	(Time spent in S3/TST) × 100
Stage 4 sleep (S4; %)	(Time spent in S4/TST) × 100
Slow wave sleep (%)	(Time spent in S3 and S4/TST) × 100
REM (%)	(Time spent in REM/TST) × 100
REM latency (min)	Time between S2 and the beginning of the first REM epoch.
Arousal index	Number of rapid changes (per hour of sleep) in the electroencephalography (EEG) frequency of 3 s or greater in duration, and preceded by a minimum of 10 continuous seconds of sleep. These EEG frequency shifts could also lead to a change from sleep to wakefulness, or from a deeper sleep stage to a lighter stage.
Periodic limb movements (PLMS index)	Number of PLMS per hour of sleep. Individual leg movements had to last between 0.5 and 5 s, and a minimum of four consecutive leg movements (spaced 5–90 s apart) was required to include them as part of a PLMS series.

parents through the PSQ, were used to rule out sleep apnoea/hypopnea syndrome in accordance with the diagnostic criteria proposed in the consensus endorsed by several National Institutes of Health (Alonso-Álvarez et al., 2011). A PLMS index higher than five was also considered an indicator of sleep disorder in children (American Academy of Sleep Medicine [AASM], 2014).

2.3. Procedure

Stimulants and non-stimulant ADHD medications were removed 48 h before sleep evaluation by PSG in those children with ADHD who were using them, to preclude medication effects on sleep parameters. To avoid any potential impact on these children's school performance as a result of this medication withdrawal, sleep recordings were performed on Sunday. Researchers also came to the family's home and began with the electrode placement at least two hours before the children's bedtimes to ensure that they became accustomed to the PSG equipment before sleeping. Prior to PSG recordings, parents were requested to complete the sleep diary—for one week—as well as the PDSS and the PSQ.

The study was approved by the Human Research Ethics Committee of the University of Granada (Spain), and written informed consent was obtained from parents. The researchers provided parents with one report reflecting their children's sleep results after their participation in the study was concluded.

2.4. Statistical analysis

Differences between the groups in psychopathology and sleep measures were analysed by two-tailed Mann–Whitney *U* exact tests because the data did not meet the assumptions for parametric statistical tests. Rosenthal's *r* was computed as the effect size measure. Two sensitivity analyses were conducted to elucidate the effect of medication and diagnosed comorbidities on the results: 1) by removing children with ADHD who were using atomoxetine ($n = 3$), as this may have a longer effect than methylphenidate (i.e., > 48 h), and 2) by removing children with comorbid oppositional defiant disorder ($n = 3$) or conduct disorder ($n = 2$). Spearman's correlation coefficients (r_s) were also calculated to examine associations between psychopathology and sleep measures. SPSS® Version 23.0 (IBM Corporation, Armonk, NY, USA) for Windows® was used to perform every data analysis, and statistical significance was set at $p < .05$.

3. Results

As expected, children with ADHD scored significantly higher (*Mdn* = 30.50) than controls (*Mdn* = 10.50) in the ADHD scale of the CBCL ($U = 0.00$, $z = -5.47$, $p < .001$, $r = -0.87$). Additionally, the scores of children with ADHD were also higher in Affective Problems (*Mdn* = 29.75 vs. 11.25), Anxiety Problems (*Mdn* = 30.43 vs. 10.58), Oppositional Defiant Problems (*Mdn* = 30.38 vs. 10.63), and Conduct Problems (*Mdn* = 30.08 vs. 10.93) (*U* ranging from 1.50 to 15.00, *z* ranging from −5.46 to −5.09, all *p*-values < .001, *r* ranging from −0.81 to −0.86). Both groups did not differ in terms of their scores in the scale of Somatic Problems (*Mdn* = 23.88 vs. 17.13; $U = 132.50$, $z = -1.92$, $p = .054$, $r = -0.30$).

Differences between the groups were not found in objective sleep measures, except for REM latency, which was shorter in children with ADHD ($U = 100.00$, $z = -2.71$, $p = .006$, $r = -0.43$). Concerning subjective sleep measures, children with ADHD showed higher levels of daytime sleepiness ($U = 106.00$, $z = -2.55$, $p = .01$, $r = -0.40$) and more sleep problems ($U = 60.50$, $z = -3.78$, $p < .001$, $r = -0.60$) than controls, but no differences were found between both in the sleep diary (Table 2). The sleep diary of one control child could not be collected, and the exact PLMS of two control children could not be computed. None of the participants showed signs of sleep apnoea/hypopnea syndrome or PLMS disorder. The sensitivity analyses conducted by removing children using atomoxetine or children with diagnosed comorbidities did not alter the results (i.e., differences between the groups in REM latency, daytime sleepiness, and general sleep problems remained significant in each case).

Correlational analyses showed significant associations between several sleep measures and children's symptom scores on the CBCL. Specifically, REM latency was negatively correlated with children's scores on the scales of ADHD ($r_s = -0.44$, $p = .005$), Affective Problems ($r_s = -0.45$, $p = .004$), Anxiety Problems ($r_s = -0.37$, $p = .019$), and Conduct Problems ($r_s = -0.46$, $p = .003$). Subjective sleep efficiency was also negatively correlated with the scores on the scales of ADHD ($r_s = -0.42$, $p = .011$) and Anxiety Problems ($r_s = -0.43$, $p = .007$), as well as subjective total sleep time was correlated with the scores on the Somatic Problems scale ($r_s = -0.43$, $p = .007$). Daytime sleepiness and general sleep problems were positively correlated with scores on every CBCL scale (r_s ranging from 0.32 to 0.50 for daytime sleepiness, and r_s ranging from 0.38 to 0.66 for general sleep problems; all *p*-values between <0.001 and 0.042). Other positive correlations were found between the subjective number of awakenings and the scores on the Affective Problems scale ($r_s = 0.35$, $p = .031$), as well as between the PLMS index and the scores on the Conduct Problems scale ($r_s = 0.33$, $p = .045$).

4. Discussion

This study aimed to compare the sleep characteristics of children with a clinical diagnosis of ADHD and those of control children. In this context, our results revealed no statistically significant difference between the two groups in almost any of the assessed objective and subjective sleep variables. Children with ADHD only showed shorter REM latency in PSG, higher levels of daytime sleepiness, and general sleep problems, as reported by their parents, when compared to controls. The same differences between both groups remained after excluding children with ADHD using atomoxetine or those diagnosed with comorbid oppositional defiant disorder or conduct disorder from the analyses.

These results do not support our prior hypothesis, as we had expected to find a large number of differences between the two groups, and they are not sufficiently consistent with the results of earlier studies.

In general, sleep disturbances are highly prevalent in children with ADHD. According to previous results based on subjective sleep data, children with ADHD show higher daytime sleepiness, sleep onset delay, sleep anxiety, night awakenings, and a lower sleep duration (e.g., Gruber et al., 2012; Knight and Dimitriou, 2019; Owens et al., 2000; Papadopoulos et al., 2018; Schneider et al., 2016). Differences between children with and without ADHD were also reported in objective sleep variables in several studies (see meta-analyses of Cortese et al., 2006, 2009; Díaz-Román et al., 2016; Sadeh et al., 2006). However, no difference was found between them in other studies in accordance with either PSG recordings (Příhodová et al., 2012; Wiebe et al., 2013) or actigraphic evaluations (Bergwerff et al., 2016; Mullin et al., 2011; Wiebe et al., 2013).

The presence of primary sleep disorders among participants with ADHD in some subjective studies could be a plausible explanation for our contradictory findings in relation to some common sleep variables (i.e., night awakenings and sleep duration). This is especially valid in light of the fact that subjective sleep data were not always supported by additional objective sleep assessments (e.g., Chiraphadhanakul et al., 2016; Owens et al., 2000; Schneider et al., 2016), which would allow verification of this question. In effect, when our findings are compared with those obtained through an objective sleep assessment, they match to a greater extent. Specifically, the unique objective difference that we found between groups in REM latency seems to support the negative findings of the aforementioned studies. However, the discrepancies still

Table 2
Participants' sleep measures.

Sleep measure	ADHD[a]	Control[a]	*U*	*z* score	*p*	Effect size *r*
PSG recordings						
Time in bed (min)	546.30 (88.22)	551.93 (57.30)	189.00	−0.30	.779	−0.05
Sleep period time (min)	519.55 (83.06)	533.44 (54.08)	188.00	−0.33	.753	−0.05
Total sleep time (min)	482.09 (81.32)	485.37 (45.50)	196.50	−0.10	.931	−0.01
Sleep latency (min)	19.54 (16.42)	14.82 (10.22)	165.00	−0.93	.358	−0.15
Sleep efficiency (%)	88.47 (6.90)	88.36 (7.94)	190.00	−0.27	.794	−0.04
Wake time (min)	9.95 (9.11)	10.05 (5.06)	164.50	−0.96	.343	−0.15
Stage 1 sleep (%)	6.09 (8.79)	4.01 (2.45)	196.50	−0.10	.931	−0.01
Stage 2 sleep (%)	35.65 (7.51)	37.19 (10.95)	170.00	−0.81	.425	−0.13
Stage 3 sleep (%)	13.76 (3.53)	13.13 (6.24)	165.00	−0.95	.351	−0.15
Stage 4 sleep (%)	28.38 (7.63)	29.29 (9.04)	198.50	−0.04	.974	−0.01
Slow wave sleep (%)	42.14 (7.25)	42.46 (11.36)	197.00	−0.08	.941	−0.01
REM sleep (%)	17.99 (5.33)	16.37 (4.93)	168.00	−0.87	.394	−0.14
REM latency (min)	144.19 (53.53)	195.70 (52.75)	100.00	−2.71	.006**	**−0.43**
Arousal index	0.15 (0.23)	0.09 (0.16)	164.00	−1.10	.270	−0.17
PLMS index	0.67 (1.13)	0.61 (1.37)	146.50	−1.09	.282	−0.18
Daytime sleepiness	10.10 (5.98)	5.25 (2.95)	106.00	−2.55	.010*	**−0.40**
General sleep problems	0.30 (0.17)	0.11 (0.13)	60.50	−3.78	<.001***	**−0.60**
Sleep diary						
Time in bed (min)	600.94 (31.85)	600.01 (26.47)	159.00	−0.37	.724	−0.06
Total sleep time (min)	559.66 (32.11)	573.79 (22.86)	146.00	−1.24	.222	−0.20
Sleep efficiency (%)	93.52 (3.44)	95.67 (2.04)	110.00	−1.85	.066	−0.30
No. of awakenings	0.41 (0.58)	0.17 (0.24)	137.50	−1.33	.187	−0.22

Abbreviations: ADHD = attention-deficit/hyperactivity disorder, PSG = polysomnography, PLMS = periodic limb movements.
*$p < .05$, **$p < .01$, ***$p < .001$.
[a] Mean (SD).

observed across objective studies suggest the involvement of variables other than ADHD itself, which may impact results. In this respect, beyond the sleep measure employed to collect data and possible primary sleep disorders among participants, ADHD subtypes and medication could also be potential confounding variables (e.g., Chiraphadhanakul et al., 2016; Kirov and Brand, 2014), but the evidence is not adequately consistent in this regard.

Comorbid conditions may also play a moderate role in children's sleep patterns leading to contradictory findings across studies. In this regard, the significant associations we found between sleep measures and children's symptom scores on the CBCL scales are supported by the results of previous studies on sleep and ADHD in children. In the study of Vélez-Galarraga et al. (2016), higher scores in the ADHD Rating Scale were associated with more sleep disturbances. This is in line with the positive correlations we found between scores on the ADHD scale of the CBCL and sleep problems. In addition, Mayes et al. (2009) found more sleep problems among children with ADHD with versus without comorbid anxiety and depression, and Mulraney et al. (2016) reported a relationship between emotional problems and sleep disturbances. The correlations between sleep problems and the scores on the scales of Affective Problems and Anxiety Problems in our study are thus in agreement with those results. In sum, our results lend support to early findings, as well as to the association of severity of ADHD symptoms and internalizing behaviours with sleep difficulties.

As for externalizing behaviours, Mayes et al. (2009) and Mulraney et al. (2016) found no association between oppositional defiant disorder or conduct problems, respectively, and higher sleep disturbances. However, Bergwerff et al. (2016) observed the moderating effects of externalizing behaviours (measured using the CBCL) on sleep problems, which are consistent with the positive correlations between sleep problems and the children's scores on the scales of Conduct Problems and Oppositional Defiant Problems, on which we report. Therefore, though neither the inclusion nor exclusion of children with comorbid conditions affected our results, the potential involvement of psychopathology on the sleep characteristics of children with ADHD still deserves further attention in research. In this connection, it would also be important to recall the condition labelled as sluggish cognitive tempo (SCT).

The SCT is a condition comprising symptoms including daydreaming, absentmindedness, trouble staying alert, underactivity, lost in thoughts, and lethargy (Becker et al., 2016b; Saxbe and Barkley, 2014). This condition is strongly associated with ADHD (especially with the inattentive subtype) and also seems linked to sleep problems and daytime sleepiness (Becker et al., 2016a). Indeed, the SCT was found to considerably overlap with daytime sleepiness in college students with ADHD, being a predictor for this sleep variable above and beyond symptoms of ADHD or other internalizing disorders (Langberg et al., 2014). Thereby, it would have been worthy to examine the extent to which the presence of SCT symptoms among the participants of our study would have affected results, especially the differences noted between the groups in daytime sleepiness.

On the other hand, higher levels of daytime sleepiness and shorter REM latency are both potential signs of narcolepsy (AASM, 2014). Indeed, this sleep disorder is not usually linked to abnormalities in other PSG sleep parameters in children, with the exception of sleep onset latency and REM sleep (Rao et al., 2012). Therefore, although all the children displayed an REM latency that fell within the normal length range (>15 min; AASM, 2014), the difference found between the two groups in this PSG parameter is remarkable, especially as this was also accompanied by significantly greater daytime sleepiness in the ADHD group, as reported by the parents.

A narcolepsy-like sleep phenotype is hypothesized to be in relation to ADHD (Miano et al., 2012, 2016, 2018), but research is still lacking in this regard. Specifically, although ADHD symptoms have been reported both in children and adults with narcolepsy (Lecendreux et al., 2015; Oosterloo et al., 2006) and a relationship between the two conditions is well established (Morse and Sanjeev, 2018), no symptoms of narcolepsy have consistently been reported in children with ADHD. For instance, despite some multiple latency test (MSLT) findings in this direction (Golan et al., 2004; Lecendreux et al., 2000), objective studies have failed to report significant differences in REM latency between children with and without ADHD in PSG recordings supporting such a hypothesis (see Cortese et al., 2009; Díaz-Román et al., 2016, for meta-analytic evidence). Therefore, the shorter REM latency and the higher levels of daytime sleepiness found in the ADHD group—after ruling out other sleep problems typically associated with ADHD (i.e., sleep

apnoea/hypopnea syndrome and PLMS disorder)—might indicate early signs of narcolepsy in these children.

Interestingly, even when the exclusion criteria for our participants included the presence of primary sleep disorders, no child needed to be excluded for this. This might be also explained by the existing differences between sleep phenotypes. Of note, along with the narcolepsy-like sleep phenotype, the following four sleep phenotypes have also been suggested to be in relation to ADHD: 1) delayed sleep phase syndrome; 2) sleep-disordered breathing; 3) restless legs syndrome and/or PLMS disorder; and 4) sleep epilepsy and/or EEG interictal epileptic discharges. Each sleep phenotype is associated with arousal system dysfunctions during sleep, which are reflected in an increased or decreased level of arousal. Whereas the sleep phenotypes linked to breathing-related sleep disorders and PLMS are characterized by increased arousability, the sleep phenotype resembling narcolepsy is characterized by a hypoarousal state (see Miano et al., 2012, for a review).

Nevertheless, a rebound effect of stimulant medication could certainly be another explanation for the shorter REM latency observed in children with ADHD in our study, beyond any sleep phenotypes-related hypothesis. In particular, stimulants may cause REM sleep suppression that results in an REM rebound—higher REM sleep time along with shorter REM latency—following stimulant withdrawal (Nishino and Mignot, 2017; Roehrs and Roth, 2017). However, this withdrawal symptom was not presented in our study, as our results did not reveal statistically significant differences between children with ADHD and controls in REM sleep. Moreover, stimulants are usually removed before sleep assessments in research, and no shorter REM latency has been found in children with ADHD compared to controls in previous polysomnographic studies. Consequently, even though the narcolepsy-like sleep phenotype requires compliance with other conditions in addition to a significantly shorter REM latency level in these children, our findings suggest the need for future research on this topic. Longitudinal sleep assessments in children with ADHD provide data on their REM latency before and after stimulant intake may offer new insights in this regard.

Our findings should be interpreted with caution, as this study failed to address the impact of possible confounding variables already highlighted in prior research—namely, ADHD subtypes, medication, and SCT symptoms. However, there are also some strengths to be noted: 1) the requirement of clinical diagnosis for children with ADHD rather than their participation being based only on cut-off scores on subjective questionnaires; 2) the collection of symptomatology data through parents' reports, which permitted us to ensure the ADHD diagnoses of children with this condition and prevent the inclusion of children with subthreshold ADHD in the control group; and 3) the sleep assessment through both subjective and objective methods, which allowed us to prevent the inclusion of children with primary sleep disorders that could have hidden the real sleep characteristics linked to ADHD.

In summary, our results suggest that children with ADHD suffer from more subjectively reported sleep problems and daytime sleepiness levels and show shorter REM latency in PSG than typically developing children. This is, to the best of our knowledge, the first study that provides polysomnographic evidence of shorter REM latency in children with ADHD when compared to controls, which might support the narcolepsy-like sleep phenotype in ADHD among this population. Future studies should further explore this question by considering the involvement of other variables in the sleep problems identified in such children in prior research. In particular, apart from different sleep phenotypes, primary sleep disorders among participants, medication, predominant ADHD symptoms or subtypes, and comorbid conditions might be also responsible for the discrepancies observed between prior studies. A longitudinal approach and the combination of subjective and objective sleep assessment methods could help clarify some of these questions in forthcoming studies.

Funding

This work was supported by the Spanish Ministry of Science and Innovation [grant number EDU2010-21215].

Author contributions

The supporters had no role in the design, analysis, interpretation, or publication of this study.

Declaration of Competing Interest

The authors have no conflicts of interest to declare.

References

Achenbach, T.M., Rescorla, L.A., 2001. The Manual for the ASEBA School-Age Forms & Profiles. University of Vermont Research Center for Children Youth and Families, Burlington, VT.

Alonso-Álvarez, M.L., Canet, T., Cubell-Alarco, M., et al., 2011. Consensus document on sleep apnea-hypopnea syndrome in children. Arch. Bronconeumol. 47 (suppl 5), 2–18.

American Academy of Sleep Medicine, 2014. International Classification of Sleep Disorders. In: Darien, IL. (Ed.), International Classification of Sleep Disorders, third ed. .

American Psychiatric Association, 2013. Diagnostic and Statistical Manual of Mental Disorders. In: Washington, DC. (Ed.), Diagnostic and Statistical Manual of Mental Disorders, fifth ed. .

Becker, S.P., Garner, A.A., Byars, K.C., 2016a. Sluggish cognitive tempo in children referred to a pediatric Sleep Disorders Center: examining possible overlap with sleep problems and associations with impairment. J. Psychiatry Res. 77, 116–124.

Becker, S.P., Leopold, D.R., Burns, G.L., Jarrett, M.A., Langberg, J.M., Marshall, S.A., McBurnett, K., Waschbusch, D.A., Willcutt, E.G., 2016b. The internal, external, and diagnostic validity of sluggish cognitive tempo: a meta-analysis and critical review. J. Am. Acad. Child Adolesc. Psychiatry 55, 163–178.

Bergwerff, C.E., Luman, M., Oosterlaan, J., 2016. No objectively measured sleep disturbances in children with attention-deficit/hyperactivity disorder. J. Sleep Res. 25, 534–540.

Biederman, J., Petty, C.R., Dolan, C., et al., 2008. The long-term longitudinal course of oppositional defiant disorder and conduct disorder in ADHD boys: findings from a controlled 10-year prospective longitudinal follow-up study. Psychol. Med. 38, 1027–1036.

Bioulac, S., Micoulaud-Franchi, J.A., Philip, P., 2015. Excessive daytime sleepiness in patients with ADHD-Diagnostic and management strategies. Curr. Psychiatry Rep. 17, 608.

Chiraphadhanakul, K., Jaimchariyatam, N., Pruksananonda, C., Chonchaiya, W., 2016. Increased sleep disturbances in Thai children with attention-deficit hyperactivity disorder compared with typically developing children. Behav. Sleep Med. 14, 677–686.

Corkum, P., Tannock, R., Moldofsky, H., 1998. Sleep disturbances in children with attention-deficit/hyperactivity disorder. J. Am. Acad. Child Adolesc. Psychiatry 37, 637–646.

Cortese, S., Faraone, S.V., Konofal, E., Lecendreux, M., 2009. Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. J. Am. Acad. Child Adolesc. Psychiatry 48, 894–908.

Cortese, S., Konofal, E., Yateman, N., Mouren, M.C., Lecendreux, M., 2006. Sleep and alertness in children with attention-deficit/hyperactivity disorder: a systematic review of the literature. Sleep 29, 504–511.

Díaz-Román, A., Hita-Yáñez, E., Buela-Casal, G., 2016. Sleep characteristics in children with attention deficit hyperactivity disorder: systematic review and meta-analyses. J. Clin. Sleep Med. 12, 747–756.

Golan, N., Shahar, E., Ravid, S., Pillar, G., 2004. Sleep disorders and daytime sleepiness in children with attention-deficit/ hyperactive disorder. Sleep 27, 261–266.

Goodman, R., 1997. The Strengths and Difficulties Questionnaire: a research note. J. Child Psychol. Psychiatry 38, 581–586.

Gruber, R., Fontil, L., Bergmame, L., et al., 2012. Contributions of circadian tendencies and behavioral problems to sleep onset problems of children with ADHD. BMC Psychiatry 12, 212.

Hysing, M., Lundervold, A.J., Posserud, M.B., Silvertsen, B., 2016. Association between sleep problems and symptoms of attention deficit hyperactivity disorder in adolescence: results from a large population-based study. Behav. Sleep Med. 14, 550–564.

Jerrell, J.M., McIntyre, R.S., Mark, Y.M., 2014. Correlates of incident bipolar disorder in children and adolescents diagnosed with attention-deficit/hyperactivity disorder. J. Clin. Psychiatry 75, e1278–e1283.

Kirov, R., Brand, S., 2014. Sleep problems and their effect in ADHD. Expert Rev. Neurother. 14, 287–299.

Knight, F.L.C., Dimitriou, D., 2019. Poor sleep has negative implications for children with and without ADHD but in different ways. Behav. Sleep Med. 17, 423–436.

Langberg, J.M., Becker, S.P., Dvorsky, M.R., Luebbe, A.M., 2014. Are sluggish cognitive tempo and daytime sleepiness distinct constructs? Psychol. Assess. 26, 586–597.

Langberg, J.M., Molitor, S.J., Oddo, L.E., Eadeh, H.M., Dvorsky, M.R., Becker, S.P., 2017.

Prevalence patterns and predictors of sleep problems and daytime sleepiness in young adolescents with ADHD. J. Atten. Disord. https://doi.org/10.1177/1087054717690810.
Lecendreux, M., Konofal, E., Bouvard, M., Falissard, B., Mouren-Siméoni, M.C., 2000. Sleep and alertness in children with ADHD. J. Child Psychol. Psychiatry 41, 803–812.
Lecendreux, M., Lavault, S., Lopez, R., et al., 2015. Attention-deficit/hyperactivity disorder (ADHD) symptoms in pediatric narcolepsy: a cross-sectional study. Sleep 38, 1285–1295.
Mayes, S.D., Calhoun, S.L., Bixler, E.O., Vgontzas, A.N., Mahr, F., Hillwig-Garcia, J., Elamir, B., Edhere-Ekezie, L., Parvin, M., 2009. ADHD subtypes and comorbid anxiety, depression, and oppositional-defiant disorder: differences in sleep problems. J. Pediatr. Psychol. 34, 328–337.
Melegari, M.G., Bruni, O., Sacco, R., Barni, D., Sette, S., Donfrancesco, R., 2018. Comorbidity of attention deficit hyperactivity disorder and generalized anxiety disorder in children and adolescents. Psychiatry Res. 270, 780–785.
Miano, S., Amato, N., Foderato, G., Pezzoli, V., Ramelli, G.P., Tofolet, L., Manconi, M., 2018. Sleep phenotypes in attention deficit hyperactivity disorder. [published online ahead of print September 20, 2018]. Sleep Med. https://doi.org/10.1016/j.sleep.2018.08.026.
Miano, S., Esposito, M., Foderaro, G., Ramelli, G.P., Pezzoli, V., Manconi, M., 2016. Sleep-related disorders in children with attention-deficit hyperactivity disorder: preliminary results of a full sleep assessment study. CNS Neurosci. Ther. 22, 906–914.
Miano, S., Parisi, P., Villa, M.P., 2012. The sleep phenotypes of attention deficit hyperactivity disorder: the role of arousal during sleep and implications for treatment. Med. Hypotheses 79, 147–153.
Morse, A.M., Sanjeev, K., 2018. Narcolepsy and psychiatric disorders: comorbidities or shared pathophysiology? Med. Sci. 6, 16.
Mullin, B.C., Harvey, A.G., Hinshaw, S.P., 2011. A preliminary study of sleep in adolescents with bipolar disorder ADHD and non-patient controls. Bipolar Disord. 13, 425–432.
Mulraney, M., Giallo, R., Lycett, K., Mensah, F., Sciberras, E., 2016. The bidirectional relationship between sleep problems and internalizing and externalizing problems in children with ADHD: a prospective cohort study. Sleep Med. 17, 45–51.
Nishino, S., Mignot, E., 2017. Wake-promoting medications: basic mechanisms and pharmacology. In: Kryger, M.H., Roth, T., Dement, W.C. (Eds.), Principles and Practices of Sleep Medicine, sixth ed. Elsevier, Philadelphia, United States, pp. 446–461.
Oosterloo, M., Lammers, G.J., Overeem, S., de Noord, I., Kooij, J.J.S., 2006. Possible confusion between primary hypersomnia and adult attention-deficit/hyperactivity disorder. Psychiatry Res. 143, 293–297.
Owens, J.A., 2008. Sleep disorders and attention-deficit/hyperactivity disorder. Curr. Psychiatry Rep. 10, 439–444.
Owens, J.A., Maxim, R., Nobile, C., McGuinn, M., Msall, M., 2000. Parental and self-report of sleep in children with attention-deficit/hyperactivity disorder. Arch. Pediatr. Adolesc. Med. 154, 549–555.
Papadopoulos, N., Stavropoulos, V., McGinley, J., et al., 2018. Moderating effect of motor proficiency on the relationship between ADHD symptoms and sleep problems in children with attention deficit hyperactivity disorder-combined type. [published online ahead of print March 12, 2018]. Behav. Sleep Med. https://doi.org/10.1080/15402002.2018.1443455.
Perez-Chada, D., Perez-Lloret, S., Videla, A.J., et al., 2007. Sleep disordered breathing and daytime sleepiness are associated with poor academic performance in teenagers. A study using the Pediatric Daytime Sleepiness Scale (PDSS). Sleep 30, 1698–1703.
Polanczyk, G.V., Sagum, G.A., Sugaya, L.S., Caye, A., Rohde, L.A., 2015. Annual research review: a meta-analysis of the worldwide prevalence of mental disorders in children and adolescents. J. Child Psychol. Psychiatry 56, 345–365.
Příhodová, I., Paclt, I., Kemlink, D., Nevšímalová, S., 2012. Sleep microstructure is not altered in children with attention-deficit/hyperactivity disorder (ADHD). Physiol. Res. 61, 125–133.
Rao, S.C., Mansukhani, M.P., Lloyd, R.M., Slocumb, N.L., Kotagal, S., 2012. Nocturnal polysomnographic characteristics of pediatric narcolepsy. Sleep Biol. Rhythms 10, 69–71.
Rechtschaffen, A., Kales, A. (Eds.), 1968. A Manual of Standardized Terminology Techniques and Scoring System and Sleep Stages of Human Subjects. University of California Brain Information Service, Los Angeles.
Roehrs, T., Roth, T., 2017. Medication and substance abuse. In: Kryger, M.H., Roth, T., Dement, W.C. (Eds.), Principles and Practices of Sleep Medicine, sixth ed. Elsevier, Philadelphia, United States, pp. 1380–1389.
Sadeh, A., Pergamin, L., Bar-Haim, Y., 2006. Sleep in children with attention-deficit hyperactivity disorder: a meta-analysis of polysomnographic studies. Sleep Med. Rev. 10, 381–398.
Saxbe, C., Barkley, R.A., 2014. The second attention disorder? Sluggish cognitive tempo vs. attention-deficit/hyperactivity disorder: update for clinicians. J. Psychiatr. Pract. 20, 38–49.
Schneider, H.E., Lam, J.C., Mahone, E.M., 2016. Sleep disturbance and neuropsychological function in young children with ADHD. Child Neuropsychol. 22, 493–506.
Sung, V., Hiscock, H., Sciberras, E., Efron, D., 2008. Sleep problems in children with attention-deficit/hyperactivity disorder. Arch. Pediatr. Adolesc. Med. 162, 336–342.
Tomás, M., Miralles, T., Beseler, B., 2007. Spanish version of the Pediatric Sleep Questionnaire (PSQ). A useful instrument in investigation of sleep disturbances in childhood. Reliability analysis. An. Pediatr. 66, 121–128.
Vélez-Galarraga, R., Guillén-Grima, F., Crespo-Eguílaz, N., Sánchez-Carpintero, R., 2016. Prevalence of sleep disorders and their relationship with core symptoms of inattention and hyperactivity in children with attention-deficit/hyperactivity disorder. Eur. J. Paediatr. Neurol. 20, 925–937.
Vigliano, P., Galloni, G.B., Bagnasco, I., et al., 2016. Sleep in children with attention-deficit/hyperactivity disorder (ADHD) before and after 6-month treatment with methylphenidate: a pilot study. Eur. J. Pediatr. 175, 695–704.
Virring, A., Lambek, R., Jennum, P.J., Møller, L.R., Thomsen, P.H., 2017. Sleep problems and daily functioning in children with ADHD: an investigation of the role of impairment ADHD presentations and psychiatric comorbidity. J. Atten. Disord. 21, 731–740.
Wiebe, S., Carrier, J., Frenette, S., Gruber, R., 2013. Sleep and sleepiness in children with attention deficit / hyperactivity disorder and controls. J. Sleep Res. 22, 41–49.
Zablotsky, B., Bramlett, M.D., Blumberg, S.J., 2017. The co-occurrence of autism spectrum disorder in children with ADHD. J. Atten. Disord. https://doi.org/10.1177/1087054717713638.
Ziobrowski, H., Brewerton, T.D., Duncan, A.E., 2018. Associations between ADHD and eating disorders in relation to comorbid psychiatric disorders in a nationally representative sample. Psychiatry Res. 260, 53–59.