DOI: 10.1590/0004-282X20130174

ARTICLE

Correlation between sleep disorder screening and executive dysfunction in children with attention deficit-hyperactivity disorder

Correlação entre rastreamento dos distúrbios do sono e funções executivas em crianças com transtorno do déficit de atenção/hiperatividade

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ABSTRACT

Objective: To compare frequency of sleep disorders (SD) and executive dysfunction (ED) in children with attention deficit-hyperactivity disorder (ADHD) and a control group. **Method:** We studied 156 children with ADHD with a mean age of 8.5 years, and a control group with 111 children with a mean age of 8.3 years. We utilized the Pediatric Sleep Questionnaire (PSQ) to screen SD and the working memory measurement from the Wechsler intelligence scale for children (WISC-IV) to screen ED. **Results:** We did not observe an increased frequency of SD in children with ADHD compared with the controls. However, we did identify ED in children with ADHD; additionally a significant correlation was observed between the type of ADHD and SD and among ED, WISC-IV measurements, and type of SD in children with ADHD. **Conclusion:** An increase of SD frequency in children with ADHD was not observed, but we did identify ED in children with ADHD. Additionally, a correlation among ADHD types, SD, ED, and WISC-IV measurements was observed in children with ADHD.

Keywords: attention deficit-hyperactivity disorder, sleep disorders, executive dysfunction, pediatric sleep questionnaire, Wechsler intelligence scale for children.

RESUMEN

Objetivo: Comparar la frecuencia de trastornos del sueño (TS) y disfunción ejecutiva (DE) en niños con trastorno por déficit de atención-hiperactividad (TDA-H) y un grupo control. **Método:** Estudiamos 156 niños con TDA-H con una media de 8,5 años. El grupo control incluyó 111 niños con una media de 8,3 años. Utilizamos la versión traducida del Cuestionario pediátrico del sueño (CPS) para tamizar TS. Para estudiar la DE, usamos la medición de la memoria de trabajo de la escala de inteligencia de Wechsler para niños-IV (WISC-IV). **Resultados:** No encontramos una mayor frecuencia de TS en niños con TDA-H. Sin embargo, encontramos DE y correlaciones entre los diferentes tipos de TDA-H, y entre los TS, DE y de mediciones del WISC-IV. **Conclusión:** No hallamos un incremento en la frecuencia de TS en niños con TDA-H. Encontramos evidencia de DE y correlaciones entre el tipo de TDA-H, TS, DE y medidas del WISC-IV.

Palabras clave: trastorno por déficit de atención-hiperactividad, trastornos del sueño, disfunción ejecutiva, cuestionario pediátrico del sueño, escala de inteligencia infantil de Wechsler.

Attention deficit-hyperactivity disorder (ADHD) is an alteration that begins early in infancy and whose main symptoms include inattention, hyperactivity, and impulsivity[1,2]. Children with ADHD present adaptation difficulties in several areas of their life, such as at school, at home, or in different social environments, due mainly to impulsivity, hyperactivity, and inattention that may affect their quality of life (QoL)[3]. Moreover, children with ADHD frequently present different co-morbidities such as oppositional defiant disorder (ODD), learning disabilities (LD), conduct disorder (CD), or others.

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Conflict of interest: There is no conflict of interest to declare.

Received 30 January 2013; Received in final form 14 June 2013; Accepted 21 June 2013.

Moreover, children with ADHD may demonstrate alterations in domains other than those of attention and impulse control or hyperactivity, such as in their sleep behavior.

Adequate sleep is necessary to accomplish awake and cognitive behaviors. Sleep disorders in children may result in excessive diurnal somnolence, accidents in school and at home, and lack of attention in classrooms[4]. Although a higher frequency of sleep disorders (SD) in children with ADHD has been previously reported[5], information on the relationship between SD and alteration of higher cerebral functions such as executive dysfunction (ED) is lacking[6]. Thus, we studied a group of children with ADHD from the Prospective Study of Children with ADHD from Mexico City (PSC-ADHD-Mex), to determine the contribution of different types of SD in ED. Our working hypothesis was that SD may at least partly contribute to cognitive dysfunction observed in children with ADHD.

METHOD

Subjects

We evaluated children, between 7-12 years of age, who were students at a government-run-public elementary school and were referred by the school principal or teachers for suspected ADHD. The children were examined at the Laboratory of Cognitive Neurophysiology of the National Institute of Rehabilitation (NIR) in Mexico City using neurological, psychiatric, neuropsychological, psychological, and electrophysiological tests. Some of the results have been reported previously elsewhere. Following acceptance into the study, the students were included in the PSC-ADHD-Mex protocol. ADHD diagnosis was carried out in agreement with the recommendations of the American Psychiatry Society guidelines[1], as published previously by our work team[7], in a three-step evaluation as follows: the first step was at-school suspicion and screening; the second step was conducted using the Diagnostic and Statistical Manual of Mental Disorders, 4th edition, Revised (DSM-IV-R) questionnaire; the third step comprised a semi-structured multidisciplinary interview, taking into account the persistence of the symptoms of the ADHD disorder for a period of >6 months in at least two environments, such as in school and at home. Children with ADHD were classified into the three recognized DSM-IV-R sub-types as follows: ADHD combined (-C), mainly with inattention symptoms (-I), and mainly with hyperactivity-impulsivity (-H). All children with ADHD were medication-free and were questioned prior to examination concerning the consumption of any drugs. Exclusion criteria comprised the following: mental retardation, epilepsy, cerebral palsy, autism, blindness, deafness, or another pediatric neurological behavioral condition. Moreover, exclusion criteria also included children who were previously tested within the last 6 months with the same neuropsychological or psychological tests that we employed in this research, and those who rejected participation in the study. We constructed an age-, school-grade-, and socio-economic background-matched control group for comparison with healthy asymptomatic children. Controls were tested using the same neurological, psychiatric, neuropsychological, psychological, and electrophysiological examinations as children with ADHD, but showed normal results. Parents and children of both groups were informed in detail about the study and the importance of their participation. The Research and Ethics Committee of NIR in Mexico City approved this investigation, and the parents or guardians of the participating children signed the informed consent.

Pediatric sleep questionnaire

The translated version of the Pediatric Sleep Questionnaire (PSQ), which has been validated in Spanish-speaking children, was utilized[8], and the resulting data has been published elsewhere[9]. Questionnaires were administered via structured interview by the primary researcher. The questionnaire possesses high sensitivity and specificity for detecting SD in children and was utilized for sleep assessment. The questionnaire, which is divided into two sections, probes for abnormalities during nocturnal sleep behavior or when the children are asleep (section A), while the second section seeks alterations in diurnal behavior, including excessive somnolence or other difficulties (section B). The questionnaire comprised 76 items and included the non-specific dichotomous item: "Do you think ____(child's name) has problems sleeping." Questions could be responded to as "yes," "no," or "I don't know," and were assessed by a senior clinician-researcher in sleep disorders. Results from SD screening were classified according to the Sleep Disorders International Classification of the American Academy of Sleep Medicine criteria[10] and were correlated with the examinations.

Executive dysfunction assessment

To screen ED, we utilized the Wechsler intelligence scale for children (WISC-IV) test[11]. The test consists of four subscales that include the following: 1. verbal comprehension with the following domains: information, vocabulary, similarities, word reasoning, and comprehension; 2. perceptual reasoning with the following domains: matrix reasoning, picture concepts, block design, and picture completion; 3. working memory with the following domains: arithmetic, digit span, and letter-number sequence, and 4. processing speed with the following domains: symbol search, coding, and cancelation. We used the working memory sub-test as an index of ED, although strictly speaking, none covers all executive functions. The test was performed by a clinical psychologist, in the absence of other subjects whenever possible. The test was performed based on the manual's instructions in each subtest by the main author, and results were obtained after accounting for the age of the subject, to determine the final score. T-IQ scores were classified as follows: ≥130, very superior; 120-129, superior; 110-119, high average; 90-109, normal; 80-89, low average; 70-79, border-line, and ≤69, mental retardation.

Statistics

We measured the mean and standard deviation (SDv) of continuous variables and percentages in binomial variables. Differences in binomial variables were compared using the X^2 test. We used one-way analysis of variance (ANOVA) to compare the means of three or more groups, with the Tukey *post-hoc* test to locate differences between groups. Subsequently, we calculated the correlation values among psychometric data values using the Spearman method. The *a-priori* alpha value accepted was $p \leq 0.05$. We utilized the SPPS ver. 14.0 software.

RESULTS

General data

We studied 156 children with ADHD with a mean age of 8.5±1.2 years; 67.4% were males and 32.6% were females. Seventy three children (46.7%) had ADHD -C, 44 (28.2%) were of the ADHD-type and 39 (25%) were ADHD-I. The control group included 111 healthy children with a mean age of 8.3±1.4; 73% were males and 27% were females.

Sleep disorders frequency

The most frequent SD present in children with ADHD were obstructive sleep apnea-hypopnea syndrome (OSAHS) (n=109; 69%), inadequate sleep hygiene (ISH) (n=103; 66%), restless legs syndrome (RLS) (n=89; 57%), and periodic limb movement disorder (PLMD) (n=88; 56%). The most frequent SD in controls were ISH (n=85; 76%), PLMD (n=72; 64%), OSAHS (n=71; 63%), and RLS (n=69, 62%). We observed no significant differences in frequencies of SD, when these were compared between groups ($p>0.05$, X^2 test). The Cronbach *alpha* score of the Pediatric Sleep Questionnaire was α=0.83.

Executive dysfunction and ADHD

We disclosed significant differences in all WISC-IV subtest scores, including working memory, among the groups of children with ADHD and the controls (Table 1). We observed significant differences in ED when we compared children with ADHD and healthy controls in the following variables: similarities (F=6.5; df=3, 263; p=0.05), and *post-hoc* analysis showed the differences between children with ADHD-C and the children in the control group. We observed significant differences in comprehension between children with ADHD and the control children (F=5.4; df=3, 263; p=0.05), and *post-hoc* analysis identified differences between children with ADHD-I and control children. We recognized significant differences in vocabulary between children with ADHD and the control children (F=3.41; df=3; 263; p=0.5), and *post-hoc* analysis revealed differences between the group of children with the ADHD-H type and those in the control group. In the block design, we observed significant differences between children with ADHD and children in the control group (F=7.4; df=3, 263; p=0.05), and *post-hoc* analysis located differences between the group of children with ADHD-I and children in the control group. In digit span, we found significant differences among children with ADHD and those in the control group (F=4.52; df=3, 263; p=0.05), while *post-hoc* analysis showed differences between children with ADHD-C and the control children. In coding, we observed significant differences between the group of children with ADHD and the control group (F=9.0; df=3, 263; p=0.05); *post-hoc* analysis located differences between children with ADHD-C type and the control children. In symbol search, a significant differences between the group of children with ADHD and the children in the control group was identified (F=8.0; df=3, 263; p=0.05), and *post-hoc* analysis revealed differences between children with ADHD-C and those of the control group.

Correlation between ADHD type and SD

A significant correlation was observed between PLMD frequency and ADHD-C type frequency and between ISH frequency and ADHD-C and ADHD-H type frequency (Table 2).

Correlations between ADHD type, ED, and WISC-IV measurements

We found several significant correlations between SD frequency and ED in children with ADHD. A differential distribution was observed in each type of ADHD group. In children with ADHD-C, we found significant correlations between children with PLMD and coding values, between OSAHS and block design scores, and between ISH and digit values (Table 3). In children with ADHD-H, significant correlations in OSAHS

Table 1. Wechsler intelligence scale for children-version IV (WISC-IV) test in the control group and in the groups of children with attention deficit-hyperactivity disorder (ADHD).

Subtest	ADHD-C		ADHD-I		ADHD-H		Control		F	p-value
	x	SDv	x	SDv	x	SDv	x	SDv	x	SDv
Verbal comprehension	8.3	3.8	8.5	4.2	7.6	3.4	9.9	2.2	6.5	0.05
Perceptual reasoning	9.1	2.7	8.4	3.1	8.0	3.0	9.9	2.0	7.4	0.05
Working memory	8.3	3.2	8.7	3.5	7.7	3.2	9.9	2.2	3.8	0.05
Processing speed	7.5	3.5	6.9	3.3	7.7	4.0	9.5	2.7	9.0	0.05

WISC-IV: Wechsler intelligence scale for children-version IV; ADHD-C: attention deficit hyperactivity disorder-combined type; ADHD-I: attention deficit hyperactivity disorder-Inattentive type; ADHD-H: attention deficit hyperactivity disorder-hyperactive type; x: average; SDv: standard deviation.

with digits score, and between ISH with block designs values were detected (Table 4). Finally, in children with ADHD-I, we discovered significant correlations between ISH and each of coding, block designs, and digits scores (Table 5).

DISCUSSION

Main findings

In this study, we did not find an increase in SD frequency in children with ADHD when they were compared with the control group of healthy children. However, as expected from previous data, we found alterations in ED in children with ADHD[12]. Moreover, we found significant correlations between ADHD types and SD, and several additional correlations between ED, WISC-IV measurements, and SD type in children with ADHD according to the group type.

Table 2. Significant correlation between sleep disorders (SD) frequency and attention deficit-hyperactivity disorder (ADHD) type.

Sleep disorder	ADHD type		
	ADHD-C	ADHD-I	ADHD-H
PLMS	0.78*		
RLS	0.65*		0.65*

PLMS: periodic limb movements during sleep; RLS: restless legs syndrome; ADHD-C: attention deficit hyperactivity disorder-combined type; ADHD-I: attention deficit hyperactivity disorder-inattentive type. ADHD-H: attention deficit hyperactivity disorder-hyperactive type. *p=0.05

Table 3. Correlation between SD and executive functions in children with ADHD-C.

Sleep disorder	Executive functions		
	Coding	Block designs	Digits
PLMS	0.75*		
OSAHS		0.64*	
ISH			0.57*

PLMS: periodic limb movements during sleep; OSAHS: obstructive sleep apnea-hypopnea syndrome; ISH: inadequate sleep hygiene; ADHD-C: attention deficit hyperactivity disorder-combined type. *p=0.05

Table 4. Correlations between sleep disorder and executive functions in children with attention deficit-hyperactivity disorder-hyperactive type (ADHD-H).

Sleep disorder	Executive functions		
	Coding	Block designs	Digits
PLMS			
OSAHS			0.54*
ISH		0.77*	

PLMS: periodic limb movements during sleep; OSAHS: obstructive sleep apnea-hypopnea syndrome; ISH: inadequate sleep hygiene; ADHD-H: attention deficit hyperactivity disorder-hyperactive type. *p=0.05

Table 5. Correlation between sleep disorder and executive functions in children with ADHD-I.

Sleep disorder	Executive functions		
	Coding	Block designs	Digits
PLMS			
OSAHS			
ISH	0.81*	0.69*	0.71*

PLMS: periodic limb movements during sleep; OSAHS: obstructive sleep apnea-hypopnea syndrome; ISH: inadequate sleep hygiene; ADHD-I: attention deficit hyperactivity disorder-inattentive type. *p=0.05

Comparison with other studies

Some studies indicate that 30% of children and 60%-80% of adults with ADHD have symptoms of SD, such as daytime sleepiness, insomnia, delayed sleep phase syndrome, fractured sleep, RLS, and sleep disordered breathing (SDB). The frequency of sleep disorders found in our sample is high, and this may reflect some bias, which compels us to expend caution in our observations. The range and diversity of findings by different researchers have posed challenges in establishing whether sleep disturbances are intrinsic to ADHD or whether disturbances occur due to co-morbid sleep disorders. As a result, an understanding of the nature of the relationship between sleep disturbances/disorders and ADHD remains unclear[13]. Our data do not support observation of a higher prevalence of SD in children with ADHD.

The relationships between sleep and ADHD are complex, and are routinely overlooked by practitioners. Motor alteration and somnolence, the most consistent complaints and objectively measured sleep problems in children with ADHD, may develop as a consequence of multidirectional and factorial pathways. Therefore, subjective perception or RLS should be evaluated with specific attention to RLS or PLMD, and awakenings should be asked with regard to parasomnias, dysomnias, and SDB. Sleep hygiene alterations retard sleep onset and may result in several alterations[14].

However observations by some other researchers have followed a different course. One study assessed the sleep characteristics of children with ADHD through polysomnographic (PSG) recordings. All of the subjects were studied *via* the Children's Sleep Habits Questionnaire, which was completed by the study children's parents. Standard overnight PSG was performed to record sleep in 27 children with ADHD and in 26 healthy controls, aged 7 to 12 years. Based on the findings from the questionnaire, the ADHD group had significantly higher scores in sleep onset delay, sleep duration, night waking, parasomnias, daytime sleepiness, and total sleep disturbance factors than children in the control group. However, there were no differences between children with ADHD and healthy children on any PSG variable, including sleep structure, arousals, and respiratory disturbances[15]. Our data do not concur with these results. On the one hand, researchers found a higher frequency of some SD in children with ADHD, whereas they found no differences in PSG architecture among children with ADHD and controls.

Sleep disorders and higher cerebral function alterations in children with ADHD

The deleterious effect of SD in higher cerebral functions has hardly been studied. A wide range of clinical and observational data support a general picture that inadequate sleep results in tiredness, difficulties with focused attention, low threshold for expressing a negative effect (irritability and easy frustration), and difficulty in modulating impulses and emotions. In some cases, these symptoms may resemble ADHD[5]. A number of theoretical models of ADHD have emerged in recent years that may be employed as systematic guides for clinical research. The cognitive-energetic model (CEM) proposes that overall efficiency of information processing is determined by an interplay of three levels: computational mechanisms of attention, state factors, and management/EF. The CEM encompasses both top-down and bottom-up processes and draws attention to the fact that ADHD causes defects at all three levels. These include the following: cognitive mechanisms, such as response output; energetic mechanisms, such as activation and effort, and management/ED. Increasing evidence suggests that inhibition deficits associated with ADHD may, at least in part, be explained in terms of an energetic dysfunction. The activation and effort energetic pools appear most relevant to ADHD, being directly related with response organization; however, further testing of CEM is critically dependent on the development of a direct measurement of these energetic pools. The CEM is a comprehensive model of ADHD, but is not without limitations. In particular, further research is required to more specifically define the relationship between process dysfunction and state dysregulation in ADHD[16].

Cognitive and electrophysiological disturbances were identified in children experiencing SD and in children with ADHD, or both, by Sawyer et al.[17] Four groups (age, 7-18 years) were compared: children with combined ADHD and SD, children with ADHD or SD alone, and children with neither disorder. Electrophysiological and cognitive function measurements included: absolute EEG power with eyes open and eyes closed, event-related potential (ERP) components indexing attention and working memory processes (P3 wave), in addition to a number of standard neuropsychological tests. Children with symptoms of both ADHD and SD had a different profile from those of children with either ADHD or SD alone. These findings suggest that it is unlikely that disturbances in brain and cognitive functioning associated with SD also give rise to ADHD symptoms of diseases and consequent diagnosis. Furthermore, our analysis suggested that children with symptoms of both ADHD and SD may possess a different underlying etiology than children with ADHD-only or SD-only, perhaps necessitating unique treatment interventions.

To investigate which memory processes are affected by OSAHS, verbal episodic memory was tested after forced encoding; in order to control the level of attention during item presentation, procedural memory was tested employing a simplified version of a standard test with an interfering task; finally, working memory was examined with validated paradigms based on a theoretical model. Ninety-five patients with OSAHS and 95 control subjects matched for age and academics were studied. Compared with the matched controls, patients with OSAHS exhibited the following: a retrieval deficit of episodic memory but intact maintenance, recognition, and forgetfulness, decreased overall performance in procedural memory, although pattern learning did occur, and impairment of specific working memory capabilities despite normal short-term memory. No consistent correlation was observed between OSAHS severity and memory deficit[18].

One review comprehensively studied the association between childhood sleep-disordered breathing and neurobehavioral functioning. The conclusions reached by 61 studies on the relationship between childhood SDB and neurobehavioral functioning were critically evaluated and integrated. There is strong evidence that childhood SDB is associated with deficits in the regulation of behavior and emotions, scholastic performance, sustained attention, selective attention, and alertness. There is also evidence that SDB has minimal association with a child's typical mood, expressive language skills, visual perception, and working memory. Findings have been insufficient to draw conclusions concerning intelligence, memory, and some aspects of executive functioning. Mechanisms by which SDB may result in neurobehavioral morbidity are being explored, but clinical symptoms such as chronic snoring remain the best predictors of morbidity. Short-term SDB treatment outcome studies were encouraging, but long-term outcomes remain unknown. Failure to treat SDB appears to leave children at risk for long-term neurobehavioral deficits[19].

In adults, slowness and decreased attention capacity in higher executive attention have been taken into account in the study of sleep apnea. Thirty-six patients diagnosed with PSG participated in the study, together with 32 healthy controls. Neuropsychological tests included Trail Making part A and B, Symbol Digit Modalities (SDMT), Digit Span forward and backward, Stroop Color-Word, Five-Point design fluency, and an attentional flexibility task. Patients' surveillance data indicated time-on-task decrements after 10 min. Moreover, the children's performance was significantly reduced in the SDMT, the Digit Span forward task, number of errors on the basic 2-choice reaction time subtest of the attentional flexibility task, and the mean reaction time in the actual attentional flexibility subtest. Researchers argued that poor performance in the latter was probably primarily related with the task's phonologic loop component of working memory rather than with an attentional switching deficit *per se*. No other performance differences were observed between patients and healthy controls[20].

Lim et al.[21], determined the predictors of neuropsychological functioning, including ED in patients with OSAHS, and whether treatment with 2-week continuous positive airway pressure (CPAP) or supplemental oxygen would improve cognitive functioning have been investigated. Participants underwent PSG and completed a battery of neuropsychological tests before and after treatment. Prior to treatment, patients with OSAHS showed diffuse impairments, particularly in terms of speed of information processing, attention and working memory, ED, learning and memory, as well as in alertness and sustained attention. A global deficit score at baseline was positively correlated with percentage of stage 1 sleep only but not with obesity, daytime sleepiness, depression, fatigue, OSAHS severity, and the remaining PSG variables. When examining individual neuropsychological test scores, two thirds of these improved with time regardless of treatment, although Digit Vigilance-Time showed significant improvement specific to CPAP treatment.

From the critical review of the previously mentioned citations, we have several data of the ED in children and adults with ADHD and DS, particularly measured in patients with OSAHS.

Study limitations

Our study has some limitations. It is necessary to study a larger population in order to obtain stronger conclusions. A long-term prospective follow-up would strengthen our results. Moreover, PSG confirmation of SD would be necessary for future research, and we must account for other co-variables in the statistical design. Thus, additional research is required to update and reinforce our results.

In conclusion, according to our data, there is no increase in the frequency of SD in children with ADHD when compared with the healthy control children. Several alterations of EF measurements in children with ADHD were found, in addition to significant correlations between ADHD types and SD, and between ED and SD type in children with ADHD according to group type.

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