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Shorter rapid eye movement sleep duration in children with attention-deficit /hyperactivity disorder: The impact on quality of life

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Abstract

Objectives: The relationship of sleep with attention deficit hyperactivity disorder (ADHD) remains complex and unclear. The current study aimed to compare the subjective and objective sleep parameters among children with and without ADHD. Moreover, to address the effect of sleep parameters on the quality of life (QoL).

Methods: We assessed 42 participants who were children with ADHD (aged 6-12years), with predominant combined presentation (23), compared to 42 healthy children, who underwent a sleep study assessment subjectively (the Children's Sleep Habits Questionnaire), and objectively (one-night Polysomnographic recording). Also, parents completed the pediatric quality of life inventory (PedsQL-P).

Results: Children with ADHD had more subjective sleep problems. ADHD patients also had a significant decrease in total sleep time and sleep efficiency, spending more time in wake and N1 sleep stages. Moreover, they had significantly lower rapid eye movement (REM)sleep duration and less duration of deep sleep stages. Multivariate regression analysis showed that REM sleep duration was the most contributing and predictive factor to QoL and school function impairment.

Conclusion: Children with ADHD have a significantly lower sleep quantity and poor sleep quality. In addition, short REM sleep duration independently contributes to further deterioration in different areas of QoL.

Keywords: ADHD, Children, Sleep, Polysomnogram, Quality of life.

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is a frequent neurodevelopmental disorder that is widespread throughout the world, affecting 7% of children worldwide [1], for instance; 7.47% of African school-age children and teenagers [2], and 1.3 to 16 % in Arab countries [3].

The correlation between sleep and ADHD is a difficult and unclear mechanism. It received much attention as clinicians observed that the children with ADHD experienced frequent sleep problems and had more complaints [4].

Regarding subjective sleep reports, parents reported that their children with ADHD suffer from a wide range of sleep problems, as well as sleep disorders. Sleep disorders including delayed sleep onset, bedtime resistance, insomnia, sleep anxiety, and frequent nocturnal awakenings [5-7].

On the contrary, the results of objective evaluation of sleep in ADHD children were controversial. Previous studies have failed to find a significant difference regarding the objective sleep parameters among children with ADHD compared to healthy children [8-10].

Nonetheless, other studies have reported a significant difference in a single objective sleep parameter. A study found that rapid eye movement (REM) latency and REM duration in children with ADHD significantly increased [11]. Also, Virring et al. (2016) reported that children with ADHD developed a lower sleep

efficiency and a lower deep sleep stages duration than typically developing children [12].

Quality of life has defined as; how a person perceives his (or her) life status as indicated by their physical, emotional, social, and academic functions [13].

Many researchers demonstrated that children with ADHD experienced deterioration in various parameters of QoL such as; physical, emotional, social, and academic, especially when exposed to comorbid sleep problems [14-16].

However, there is a gap in the literature that independently investigated the effect of sleep problems on the QoL among children with ADHD and particularly the impact of objective sleep parameters. A recent study examined the effect of subjective sleep problems and ADHD on the QoL of school-age children and found that ADHD symptoms and sleep problems independently predicted further deterioration in the quality-of-life functions [17]. Another subjective sleep study demonstrated that children with ADHD and comorbid sleep problems have lower scores in QoL and poor academic performance [18].

Therefore, the current study is concerned with comparing the subjective and objective sleep parameters in children with ADHD, in contrast to healthy children, focusing on objective measures after controlling confounding factors (comorbidity and medication status). It addresses both the effect and relation of different

subjective sleep problems and objective sleep parameters in different domains of QoL.

It hypothesized that; there is a remarkable difference in the sleep parameters, subjectively, or objectively among children with or without ADHD. Furthermore, sleep problems or objective sleep parameters independently predicted or contributed to further impairment in the various QoL domains.

2. Methods

The current study is a case-control study, a registered clinical trial (NCT03737552) conducted at "Okasha Institute of Psychiatry" Ain-Shams Institute of Psychiatry, Department of Neurology, and Psychiatry, Ain-shams University Hospitals, Ain-Shams University. The study was conducted in the period between May 2019 to September 2020. The Medical Ethical Review Board of Assiut University approved the study. Moreover, informed consent from parents, as well as child assent, were obtained from all participants.

2.1. Participants

Participants included two groups:

2.1.1. Attention deficit hyperactivity disorder group:

The ADHD group consisted of 42 children aged (6-12) years; mean age ± SD (7.92 ± 1.66), 29 boys (69.0%), were prospectively recruited from the child psychiatry outpatient clinic, faculty of medicine, Ain-Shams University. They were diagnosed with ADHD based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5-) criteria by a child psychiatrist.

We enrolled both sexes in the study, with an Intelligence Quotient (IQ) of 85 or higher, measured via the Wechsler Intelligence Scale for Children (III or IV) [19], Arabic Version [20].

Children with a history of chronic/significant neurological or medical condition, other psychiatric comorbid disorder, or a history of psychotropic or currently used drugs, including non-stimulant medications for ADHD before the study, a history of substance abuse, and a family history of bipolar disorder or psychosis excluded from the study.

2.1.2. Control group

From a group of ADHD patients who are classmates with the ADHD group or relatives of the clinical staff, 42 children who were identical in terms of age, sex, IQ level, and body mass index (BMI) were selected (control group). They had no

medical, neurological, or psychiatric disorders, nor a previous history of drug or substance use.

2.1.3. Sample size calculation:

We calculated the sample size via the Open Epi software program Version III. To ensure computation strength, the mean difference in Sleep onset latency (SOL) of the ADHD and control groups (which was considered a significant difference) is the chief important parameter of PSG. In a previous study conducted by Estrada-part (2019) [21], the mean (SOL) of the ADHD and control groups was 22.19 and 15.92 minutes, respectively, and the mean difference between the two groups was 6.27.

To find a significant difference (6.27 minutes) between the ADHD group and the control group. The current study enrolled (38) children at least in each group with an 80 % power and 5% type 1 error.

2.2. Procedures

The procedures included three steps; First, the initial clinical evaluation and diagnosis of ADHD patients; second, sleep assessment (subjective and objective) for all participants; and finally assess the different domains of quality of life.

2.3. Behavioral assessment

2.3.1. The Kiddie Schedule for Affective Disorders and Schizophrenia School-Age Children–Present and Lifetime Version [22].

The Kiddie Schedule for Affective Disorders and Schizophrenia School-Age Children–Present and Lifetime Version (K-SADS-PL) is a structured diagnostic interview with children and their parents used to diagnose ADHD symptoms and to exclude other comorbid psychiatric disorders.

2.3.2. Conner's parent rating scale-revised-long version [23]:

We used the Conner's parent rating scale-revised-long version (CPRS- L) to measure ADHD symptoms and to assess the different subtypes based on the DSM-IV diagnostic criteria. It includes various subscales such as; inattention, impulsivity, hyperactivity. Moreover, multiple problems as cognitive, behavioral, social, and learning. The scale consists of four points Likert-type scale (0=never, 1=rarely, 2=often, and 3=always) that we asked parents to answer. Mohamed El Sheik et al. [24] prepared the Arabic version of this scale. The test has the Cronbach Alpha coefficient of 0.82 with subscales test-retest reliability coefficient of 0.94.

2.4. Sleep study assessment

2.4.1. The Children's Sleep Habits Questionnaire [25]

The Children's Sleep Habits Questionnaire (CSHQ) is a widely used sleeping tool in school-aged children and rated by one or both parents to describe their child's sleep habits during the past week. This questionnaire consists of (48 items), in total, and eight subscale scores (33 items), that encompass different domains of sleep and include a variety of sleep disorders. When the tool scores high on the various subscales, this may indicate a sleep problem, with an overall score of 41 or more indicating a sleep disturbance for further evaluation.

The CSHQ has nine subscales: sleep anxiety, bedtime resistance, delayed sleep onset, night awakening, parasomnias, sleep-disordered breathing, sleep duration, daytime sleepiness, and total sleep disturbance score. It is formed of 3 points Likert-type scale; usually (if a problem occurs five or more times/week), sometimes (2-4 times/week), and rarely (one time/week or never). The Arabic version of this scale, including its validity and reliability, was conducted by Asaad and Khala [26]. This test has the Cronbach Alpha coefficient of 0.78 with subscales test-retest reliability coefficient of 0.81.

2.4.2. Polysomnogram

We applied Polysomnography overnight for all participants in the Sleep Laboratory, Somni Pro 19 device (Deymed Diagnostic S.R.O., Hronov, Czech Republic) used. We told participants to arrive one to two hours early before their usual bedtime for each PSG study, asked them to bring their child's blanket, and to follow the child's sleep routines as before the study.

To reduce the effect of the first night in the sleep laboratory unit, the researchers tried to make the child's sleep habits similar to the sleeping atmosphere at home, such as their favorite toys, blanket, etc. In addition, parents were allowed to stay with their child if he(she) became anxious or resisted falling asleep, and a toilet nearby was available.

Polysomnographic recordings were obtained with Sandman software (version 9.3), using the standard polysomnographic protocol, which includes 20 electrodes: 6 electrodes of electroencephalogram (EEG); 2 electrodes of electrocardiogram (ECG); 2 electrodes of electrooculogram (EOG); 3 electrodes of chin electromyogram (EMG); 4 electrodes of anterior tibialis EMG; 2 electrodes of mastoid; and one ground electrode. We used Sandman Oximeter with a Nellcor probe to measure pulse rate and oxygen saturation and a thermistor used to measure airflow in all participants that could tolerate it. We used two piezoelectric bands to

measure the breathing effort, movement (chest and abdomen), and a manual score used to score PSG recordings by the same sleep technician (based on The American Academy of Sleep Medicine version 2.0).

2.5. Quality of life assessment

2.5.1. Pediatric Quality of Life Inventory 4.0 generic version [27]

We used the Pediatric Quality of Life Inventory 4.0 generic version (Peds QL) to assess different domains of quality of life for children and teenagers (between the ages of 2 and 18 years). Three main categories derived from it are; physical (8 items; same Physical performance measure); psychosocial (15 items; the mean sum of items included in the social, emotional, and school function scales), and a total summary score. Higher overall scores of Peds QL-P (parent version) are associated with a better quality of life.

Khaled El-Beh et al. performed the validity of the Arabic version and Peds QL reliability study [28]. The test has a Cronbach Alpha coefficient of 0.89 and a subscale test-retest reliability coefficient of 0.98. PedsQL-P (parent form) is a straightforward, rapid assessment tool, takes approximately five minutes, and includes five Likert-type scale points.

In the current study, a psychiatrist asked the child's parent to complete the scale after explanation.

2.6. Statistical analysis

All data were analyzed using SPSS (Statistical Package for Social Sciences) software package version 16 (SPSS Inc., Chicago, Illinois, USA). First, the Shapiro-Wilk test and visual inspection of histograms used to assess the normality of the data. Most of the subjective and objective sleep variables indicated a lack of normality ($p < 0.05$), and thus non-parametric tests were conducted. For quantitative variables, we used the Mann-Whitney-U test to contrast subjective sleep domains with objective sleep parameters between the control group and the ADHD group. We used the Spearman rank test to detect the correlation between the different quality of life domains, whether subjective sleep problems or objective sleep parameters. We conducted multivariate regression analyses to reveal the influence of subjective sleep problems or PSG parameters on the quality-of-life ln the ADHD group. Statistical significance is determined at a p-value <0.05.

3. Results

3.1. The results of sociodemographic and clinical data for the control and ADHD groups are shown in (Table 1).

It was evident that males with ADHD were more prevalent than females at rates of 29 (69.0%) and 13 (31.0%), respectively. In addition, the combined ADHD presentation was more prevalent 23 (54.8%), inattentive 10 (23.8%), followed by

hyperactive/impulsive 9 (21.4%). Both groups showed no statistically significant difference regarding age, sex, IQ level, and BMI (p-value>0.05).

3.2. The subjective and objective sleep assessments for both groups showed in Tables (2-3).

The parental subjective sleep reports revealed that children with ADHD had significantly higher scores in all subscales as well as total CSHQ scores than the control group (p-value <0.05) (Table 2).

Furthermore, PSG parameters showed that ADHD patients had significantly reduced total sleep time, decreased sleep efficiency (%), delayed sleep onset latency, and rapid eye movement (REM) latency. In addition, they spent more time in the N1 sleep stage and less time in the REM and N3 sleep stages (p-value<0.05) (Table 3). Furthermore, ADHD patients showed more waking time and frequent arousal during PGS recording (p-value<0.05). Both groups showed no statistically significant difference in apnea/hypopnea index, limb movements, and periodic limb movement index (p>0.05) (Table 3).

3.3. Comparison between both groups regarding the quality-of-life domains.

The findings of the current study revealed that ADHD patients showed a statistically significant impairment in the overall QoL domains, including (physical, emotional, social, and school functions), the overall psychosocial score, as well as the total score than the control group (P-value<0.05) (Table 4).

3.4. The correlation between subjective sleep problems / objective sleep parameters and pediatric quality of life inventory scores in ADHD patients.

We performed the Spearman rank correlation test to estimate the association between subjective sleep problems (CSHQ) and different domains of QOL by the pediatric quality of life inventory in ADHD patients.

Table 5. shows that delayed sleep onset latency was negatively associated with impaired physical function (r= -0.32, p= 0.04), Moreover, sleep onset delay, parasomnia, and daytime sleepiness were significantly associated with emotional dysfunction (r=-0.44, p= 0.00), (r=-0.42, p= 0.01), (r= -0.39, p= 0.01), respectively. Finally, bedtime resistance was significantly associated with impaired school function (r = - 0.31, p= 0.04), However, no statistically significant relationship was found between the different subscales of CSHQ and social dysfunction. Moreover, based on different PSG parameters, REM sleep duration was positively correlated with the school function domain in children with ADHD (Table 6).

3.5. Multivariate regression analyses.

We performed multivariate regression analysis to detect the effect of different subjective sleep problems on various quality of life domains, emotional and social functions after managing the effect of ADHD (Tables 7).

The current study showed that delayed sleep onset latency and parasomnia are the most fundamental factors contributing to emotional functional impairment in ADHD patients (beta = -0.387, P-value = 0.007), (beta = -0.347, P-value = 0.014), respectively, and these two factors represent (34 %) of the emotional functional impairment. In addition, parasomnia was the most essential factor contributing to the impairment of social function in ADHD patients (beta = -0.340, P-value = 0.027), and it is estimated of (11%) of social functional impairment.

With regard to PSG scores, duration of REM sleep is the most contributing and predictive factor to school function (beta = 0.863, P-value =0.000), followed by sleep onset latency (beta =-0.253, P-value = 0.006), followed by total sleep time (TST) (beta = -0.493, P-value = 0.002), While the lowest factor is sleep efficiency (beta = 0.311, P-value = 0.046) in ADHD patients, and the overall parameters contribute (84 %) to school function (Table 8).

4. Discussion

Nonetheless, many studies extensively investigated ADHD in Egypt and Arab countries [29-31], with limited studies concerned with assessing the impact of different objective sleep parameters on QoL domains in children with ADHD [32].

Therefore, the current study aimed to compare the characteristics of sleep parameters in children with and without ADHD, whether subjectively or objectively.

We examined the effect and the relationship of different sleep parameters on the quality of life.

The results of the present study support our prior hypothesis, found high abnormalities in the objective sleep parameters in children with ADHD (lower sleep efficiency, delayed sleep onset latency, and lower duration of REM as well as deep sleep stages) compared to healthy children, additionally, a significant impact of lower REM sleep duration on the domains of quality of life.

Regarding parents who reported a subjective sleep assessment, the current study indicated that the ADHD group had more sleep problems in all subscales. In addition to the overall results of the children's sleep habits questionnaire (CSHQ) compared to typically developed children, findings are in line with many previous studies [12, 33-35].

Furthermore, among subscales of CSHQ, the ADHD patients had significantly higher scores of bedtime resistance, parasomnia, and daytime sleepiness. In this regard, these results are consistent with [7, 11, 36].

In this sense, findings, especially bedtime resistance, attributed to many factors, including; behavioral problems (that occur before bedtime where oppositional behavior is commonly associated with ADHD), inappropriate sleep environments, and poor sleep routine before bedtime.

In addition, the current study found a significant difference in sleep macrostructures, detected by polysomnogram between the ADHD sample and the control group. However, previous literature failed to replicate this finding [37-40]**,** or in other words, they reported little difference in a single objective sleep parameter [41-44].

Our results demonstrated that; ADHD patients had significantly lower total sleep time and lower sleep efficiency, in contrast to that of healthy children. Findings are compatible with the studies [12, 45]**,** who reported that the ADHD children had a short total sleep time (TST) and lower sleep efficiency (%) compared to typically developed children. Results align with the subjective CSHQ sleep reports conveyed by parents, which include problems with sleep duration.

We also found that the ADHD sample encountered more delayed sleep onset latency (SOL) and REM latency than the control group. Findings align with data obtained from previous studies [34, 45], using one-night polysomnographic assessment showing that school-aged children with ADHD had longer SOL time and REM latency**.**

Several explanations for these results are neurohumoral disturbance mechanism (as melatonin disturbance secretion reported in patients with ADHD), environmental factors (for instance, exposure to light), and meal before bedtime. In addition, children with ADHD have a defective delivery of pleasure signals, unable

to reach a passive sleep state (due to their hyperactive state) besides sometimes their disorganized behavior at bedtime resulting in problems in sleep initiation [46].

Regarding the architecture of sleep stages, the current study found that ADHD children spent a long time of sleep (in stage N1) compared to controls. That supported evidence from a previous meta-analysis that included (11) polysomnographic studies that examined sleep problems in children with ADHD. Accordingly, ADHD patients spend more time in stage one sleep compared to healthy children [47].

On the contrary, a previous study conducted by Virring [12], comparing sleep structure between ADHD and non-ADHD children using polysomnography, showed that N1 sleep duration decreased in the ADHD group, in contrast to the control group. There are possible explanations as; the presence of comorbidity in the ADHD sample affected sleep structure besides the variation in sample size between the ADHD group (n =76) and the control group (n =25).

The difference between the results of our study and previous studies is that the ADHD subtypes included, in addition to the selection of equal sample size. Consequently, findings demonstrated the ADHD group had less deep sleep compared to the control group.

Rapid eye movement (REM) sleep abnormalities in ADHD patients remain a controversial point in the literature. Previous studies revealed no difference in REM sleep duration [9, 48]. In contrast, other studies reported a significant difference in REM duration between ADHD children and their peers [35, 49].

The results of our study proved that ADHD patients have a significantly lower period of REM sleep than controls. Consistent with previous studies reporting that; ADHD children had a shorter duration of rapid eye movement sleep stage than their peers [45, 50].

Rapid eye movement abnormalities are associated with multiple mechanisms included; a reward learning defect due to dopamine hypofunction, which is a primary deficit in children with ADHD that contributes to reduced REM sleep duration [51]. Other authors attributed this to; the existence of primary sleep disorders such as periodic limb movements disorder that leads to instability of REM and thus reduces REM duration [50].

However, a previous study reported an increased REM sleep duration, to infer these findings to an increased number of sleep cycles in the ADHD group, leading to a faster REM sleep transition and increased REM sleep duration [12].

The ADHD sample in the current study did not have periodic limb movement or breathing disorders during sleep, which interrupted the duration of REM sleep, and thus affected this result.

Furthermore, the ADHD group had a remarkable decrease in the duration of the N3 sleep stage, which confirmed that ADHD children have less deep sleep than healthy children. Consistent with the previous systematic review that investigated the abnormalities of the deep sleep stage among ADHD patients [52].

We found a significantly higher number of arousal and arousal index concerning the waking time and the frequent arousal during sleep. In addition to a longer waking time in the ADHD group, in contrast to the control group, which aligns with a study by Stephens [43], who found high microarousal and frequent waking in free medicated ADHD patients.

Moreover, in the current study, the ADHD sample was unmedicated or drug naïve, so the higher number of arousals was not a result of drug effects.

The current study did not find any significant difference in the apnea/hypopnea index, limb movements, or periodic limb movement index in the ADHD sample [7, 48, 53]. Due to; exclusion of patients with sleep-related breathing disorders and

sleep-related movement disorders after the polysomnographic assessment due to their effect on sleep architecture.

As expected, the ADHD group had impairment in all domains of quality of life, whether physical or psychosocial, compared to healthy children. Findings support multiple previous studies [54-56].

Poor sleep or sleep problems proved to affect the overall functions of QoL [57, 58]. However, in the current study, there is a need to determine which subjective sleep problems or abnormal PSG sleep parameters; have a higher impact on the different QoL functions.

The current results revealed that; delayed sleep onset latency and parasomnia were significantly strong predictors of impairment of emotional and social functions among the other subscales of CSHQ. That is identical to data obtained by Virring et al. (2017) and Craig et al. (2020), who used the same scale and demonstrated that sleep problems on CSHQ independently predicted more impairment in quality of life [17, 59], this can be attributed to delayed sleep onset latency implicating sleep initiation problems. Results in decreased overall sleep time and thus; poor sleep is associated with emotional and social functions impairment.

Even though previous research reported that daytime sleepiness was significantly associated with academic functional impairment [60, 61], we didn't find a relationship between subjective sleep problems or school functional impairment except for bedtime resistance.

Concerning the correlation between objective sleep parameters and different functions of (QoL), the current findings proved a significant relationship between short overall sleep time, reduced sleep efficiency, and physical functional impairment. Which, suggested that poor sleep and physical dysfunction are common among children with ADHD [14, 17].

Furthermore, the current study supports the evidence role of REM sleep duration and REM latency on academic performance. We found that reduced REM sleep duration was associated with poor academic performance, which aligns with previous studies demonstrating that an adequate REM period is essential for improving academic performance [62, 63].

The primary finding; the duration of REM sleep is the most contributing and predictive factor with the main effect on school activities in children with ADHD. Along with sleep efficiency, total sleep time, as well as sleep onset latency.

The findings of our study supported the diagnosis of ADHD based on structural information, interviews, validated scales, and the objective evaluation of sleep. Furthermore, the patients were drug naïve or without comorbidity that had an impact

on their sleep pattern. Finally, we selected a proper sample size to achieve sufficient strength to detect a clinically remarkable difference between the two groups.

The study had limitations; it examined the different ADHD presentations that affected various sleep parameters. Moreover, the overnight PSG recording was conducted in a sleep lab, not home, which contributed to the first night's effect on sleep pattern. In addition, the sample of the current study was predominantly males that considered in future studies.

5. Conclusion

In conclusion, the current findings show that there is sleep parameters differentiation among children with ADHD compared to healthy children, either subjectively or objectively. The PSG results indicate that children with ADHD have lower sleep duration, poor sleep quality, and REM sleep duration, which is the most contributor and predictor in quality-of-life domains and possibly a biomarker in ADHD. Also, the results provide the importance of subjective or objective sleep evaluation among children with ADHD and the proper treatment strategies of sleep problems with ADHD symptoms that help provide better QoL among those children.

Future studies should focus on combined long-term subjective sleep habits, such as sleep diary and longitudinal objective sleep measures, to confirm the diversity of sleep patterns from night to another night. Finally, longitudinal studies are required to characterize the sleep habits of each different subtype of ADHD.

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Table 1.

Sociodemographic and clinical data for both attention deficit hyperactivity disorder(ADHD) and control groups.

	Patients (*n*= 42)		**Controls (*n*= 42)**		***P-value***
	No.	**%**	**No.**	**%**	
Sex: n(%)					
Male	29	69.0%	29	69.0%	1.000
Female	13	31.0%	13	31.0%	
Age: (years)					
Mean ± SD	7.92 ± 1.66		7.45 ± 1.55		0.923
Range	(6-12)		(6-12)		
BMI:(Kg/m2)					
Mean ± SD	23.48 ± 2.55		23.71±2.4		0.907
IQ:					
Mean ± SD	95.40 ± 7.70		95.45 ± 7.70		0.989
Range	90.0-123.0		90.0-123.0		
ADHD presentations, n(%)					
Combined	23 (54.8%)		-		
Inattentive	10 (23.8%)		-		
Hyperactive/impulsive	9 (21.4%)		-		
Comorbidity, n(%)					
Oppositional defiant disorder	5 (11.9%)		-		
Conduct disorder	2 (4.8%)		-		

All data are given as n (%), mean ± Standard deviation or range

ADHD: Attention deficit hyperactivity disorder; BMI: body mass index; N: number; IQ: intelligence quotient.

Table 2.

Comparison of mean scores of Children's Sleep Habits Questionnaire subscales and total score between ADHD and control groups.

CSHQ	Patients (*n*= 42)	Controls (*n*= 42)	*P-value*
Bedtime resistance:			
Mean ± SD	7.98 ± 2.46	3.07 ± 0.97	0.000***
Sleep onset delay:			
Mean ± SD	1.71 ± 0.46	1.14 ± 0.57	0.000***
Sleep duration:			
Mean ± SD	4.14 ± 1.69	1.88 ± 0.71	0.000***
Sleep anxiety:			
Mean ± SD	2.40 ± 1.23	1.69 ± 0.75	0.002**
Sleep-disordered breathing:			
Mean ± SD	0.36 ± 0.58	0.05 ± 0.22	0.000***
Night waking:			
Mean ± SD	3.71 ± 1.45	2.07 ± 0.68	0.000***
Parasomnia:			
Mean ± SD	8.17 ± 2.21	4.14 ± 1.18	0.000***
Daytime sleepiness:			
Mean ± SD	12.52 ± 1.95	4.52 ± 1.67	0.000***
CSHQ total score:			
Mean ± SD	41.00 ± 7.25	18.57 ± 4.70	0.000***

All data are given as mean ± Standard deviation.

*Note: ** p-value<0.01, *** p-value <0.001*

ADHD: Attention deficit hyperactivity disorder; CSHQ : Children sleep habits questionnaire; n; number.

Mann-whitney test.

Table 3

Comparison of different objective sleep parameters between ADHD and control groups.

Polysomnographic parameters	Patients (*n*= 42)	Controls (*n*= 42)	*P-value*
TRT (min):			
Mean ± SD	455.52 ± 7.76	459.15 ± 7.86	0.829
TST (min):			
Mean ± SD	398.23 ± 21.56	430.85 ± 13.1	0.000***
Sleep efficiency %:			
Mean ± SD	87.42 ± 4.66	93.84 ± 2.56	0.000***
WASO (min):			
Mean ± SD	28.31 ± 15.9	11.11 ± 7.64	0.000***
WASO %:			
Mean ± SD	8.62 ± 6.6	2.75 ± 1.96	0.000***
Sleep onset latency (min):			
Mean ± SD	28.85 ± 9.67	17.15 ± 4.71	0.000***
REM latency (min):			
Mean ± SD	160.77 ± 49.41	124.59 ± 26.90	0.000***
Wakefulness %:			
Mean ± SD	13.6 ± 4.9	6.42 ± 2.55	0.000***
REM %:			
Mean ± SD	15.06 ± 1.78	21.62 ± 1.67	0.000***
N1 %:			
Mean ± SD	13.85± 2.92	4.56 ± 2.17	0.000***
N2 %:			
Mean ± SD	52.71 ± 2.33	51.60 ± 2.38	0.034*
N3 %:			
Mean ± SD	18.36 ± 1.94	22.21 ± 1.86	0.000***

A/H index(n/h):			
Mean ± SD	0.14 ± 0.46	0.03 ± 0.14	0.357
Arousal index(n/h):			
Mean ± SD	5.04 ± 4.88	2.20 ± 0.57	0.04*
PLM index(n/h):			
Mean ± SD	1.19 ± 0.71	0.9 ± 0.56	0.090

All data are given as mean ± Standard deviation.

*Note: *p-value <0.05, *** p-value <0.001*

TRT: total recording time; TST: total sleep time; WASO: Wake after sleep onset; REM: Rapid eye movement; N1: stage 1 sleep ; N2 : stage 2 sleep; N3: stage 3 and 4 sleep; n : number ; A/H : Apnea /hypopnea; PLM: Periodic limb movement; n/h: number/hour.

Mann-whitney test.

Table 4.

A comparison of different domains of the pediatric quality of life between ADHD and control groups.

PedsQL	Patients (*n*= 42) Mean ± SD	Controls (*n*= 42) Mean ± SD	*P-value*
Physical	86.75 ± 10.73	98.43 ± 2.31	0.000***
Emotional	50.47 ± 13.82	97.02 ± 4.28	0.000***
Social	39.16 ± 14.09	95.83 ± 4.26	0.000***
School	27.38 ± 12.45	97.5 ± 3.53	0.000***
Psychosocial	39.01±10.18	96.78 ±2.39	0.000***
Total summary score	125.76 ±17.54	195.22 ±3.81	0.000***

All data are given as mean ± Standard deviation. n; number

*Note: *** P-value <0.001*

PedsQL: Pediatric quality of life inventory; Psychosocial include (emotional, social and school function)

Mann-whitney test.

Table 5.

Correlation between CSHQ subscales and different PedsQL domains among ADHD patients.

PedsQL Domains		Bedtime resistance	Delayed Sleep onset	Sleep duration	Sleep anxiety	Sleep breathing	Night waking	Parasmonia	Daytime sleepiness
Physical	**r**	0.03	-0.32	-0.02	0.00	-0.28	0.06	-0.04	-0.08
	p	0.86	0.04*	0.92	0.99	0.07	0.72	0.83	0.62
Emotional	**r**	-0.23	-0.44	-0.05	-0.15	-0.08	-0.22	-0.42	-0.39
	p	0.14	0.00***	0.75	0.33	0.62	0.17	0.01*	0.01*
Social	**r**	-0.08	-0.16	-0.06	-0.13	-0.11	-0.14	-0.28	0.01
	p	0.63	0.32	0.72	0.40	0.49	0.37	0.07	0.95
School	**r**	-0.31	-0.00	-0.14	-0.25	-0.03	-0.16	-0.23	-0.14
	p	0.04*	0.98	0.38	0.11	0.84	0.30	0.13	0.38

*Note: *p-value<0.05, **p-value<0.01, ***p-value<0.001*

CSHQ : Children sleep habits questionnaire; r : Spearman rank correlation; PedsQL: Pediatric quality of life inventory.

Table 6.

Correlation between polysomnographic parameters and Pediatric domains of quality of life among ADHD patients.

PedsQL		TST (min)	Sleep efficiency %	WASO (min)	WASO %	Sleep onset latency (min)	REM latency (min)	REM duration (%)
Physical	***r***	-0.336	-0.328	0.366	0.358	0.160	0.336	-0.076
	P	0.029*	0.034*	0.017*	0.020*	0.310	0.029*	0.632
Emotional	***r***	0.010	0.027	-0.052	-0.048	0.100	-0.009	0.132
	P	0.948	0.867	0.742	0.763	0.527	0.956	0.405
Social	***r***	-0.183	-0.150	0.186	0.198	0.139	0.283	0.338
	P	0.246	0.342	0.239	0.208	0.379	0.070	0.029*
School	***r***	-0.140	-0.135	0.200	0.208	0.052	0.359	0.329
	P	0.376	0.394	0.203	0.186	0.746	0.020*	0.033*

*Note: *p-value<0.05.*

TST: Total sleep time; WASO: wake after sleep onset ; REM : Rapid eye movement; r: Spearman rank correlation; PedsQL: Pediatric quality of life inventory.

Table 7.

Multivariate regression analysis detects the impact of different subjective sleep problems on quality-of-life domains (emotional and social functions).

Outcome domain	**Variable**	***Beta***	***P***	***R –square***
Emotional function	Sleep onset	-0.387	**0.007****	
	Parasomnia	-0.347	**0.014***	0.342
	Bedtime resistance	-0.206	0.128	
	Sleep duration	0.047	0.740	
	Night waking	0.118	0.474	
	Daytime sleepiness	-0.104	0.493	
Social function	Parasomnia	-0.340	**0.027***	0.116
	Bedtime resistance	-0.013	0.934	
	Sleep onset	-0.066	0.676	
	Sleep duration	0.061	0.707	
	Sleep anxiety	-0.107	0.480	
	Sleep breathing	-0.159	0.291	
	Night waking	0.063	0.735	
	Daytime sleepiness	0.187	0.257	

*Note : *p-value <0.05 , **p-value <0.01*

Table 8.

Multivariate regression analysis detects the impact of different objective sleep parameters on the quality-of-life domain (school function).

Outcome domain	**Variable**	***Beta***	***P***	***R-square***
School function	REM duration(min)	0.863	**0.000*** **	0.847
	Sleep onset latency (min)	-0.253	**0.006** **	
	TST (min)	-0.493	**0.002** **	
	Sleep efficiency %	0.311	**0.046***	

*Note : *p-value <0.05 , **p-value <0.01 , ***p-value<0.001*

REM ; Rapid eye movement , TST ; Total sleep time .

Highlights:

- Children with ADHD have considerable sleep parameter differences either subjectively or objectively compared to healthy children.
- Children with ADHD objectively have a significantly lower sleep quantity and poor sleep quality.
- Specific subjective sleep problems (delayed sleep onset latency and parasomnia) independently predict and contribute to impairment in emotional and social functions.
- Shorter REM sleep duration independently predicts and contributes to impairment in a school function.

Conflict of Interest:

The authors report no conflicts of interest in this work