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ORIGINAL PAPER

Clinical characterization of children and adolescents with ADHD and sleep disturbances

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Abstract

Sleep disturbances (SD) are commonly reported concerns among parents and caregivers of children and adolescents with Attention-Deficit/Hyperactivity Disorder (ADHD). While it is widely acknowledged that SD can worsen various aspects of children and adolescents' well-being (e.g., academic performance and emotional/behavioral state), a comprehensive clinical characterization of ADHD and SD is currently lacking. To address this gap, 136 children and adolescents diagnosed with ADHD (aged 6 to 14 years) were retrospectively selected by reviewing electronic health records of hundreds of patients with neuropsychiatric disorders referred to the children's hospital. Participants were divided into two groups based on the presence of SD, assessed via a parent-report questionnaire (94 ADHD without SD and 42 ADHD with SD). Standardized measures of adaptive behavior, academic performance, ADHD-related and emotional/behavioral symptoms were collected. Results documented that the group of ADHD with SD obtained worse scores in specific aspects of adaptive behavior (conceptual and practical domains), academic performance (text comprehension, writing), ADHD symptoms (inattention) and emotional/behavioral difficulties (especially, mood/emotional regulation and stress) compared to those with ADHD without SD. In addition, our results established a relationship between sleep problems and diverse clinical aspects of children and adolescents with ADHD, while controlling for age, cognitive level, gender, ADHD symptoms severity, and Body Mass Index. From a clinical perspective, our study suggests that the presence of SD in patients with ADHD may serve as an indicator for strengths and weaknesses in this population, even demonstrating an independent relationship with specific clinical dimensions. Implications to improve clinical diagnostic and therapeutic interventions are discussed.

Keywords Sleep disturbance scale for children · Adaptive behavior · Academic performance · Emotional and behavioral difficulties · Neurodevelopmental disorders

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) represents one of the most common neurodevelopmental conditions, characterized by the presence of developmentally-inappropriate, persistent, pervasive, and impairing symptoms of inattention and/or hyperactivity/impulsivity [1], affecting approximately 5% of children globally [2]. Children and adolescents with ADHD often exhibit poorer adaptive behavior when compared to their peers, facing academic underachievement or exclusion from educational settings [3]. Additionally, they encounter difficulties in social interactions, experiencing peer rejection and social isolation [4]. Moreover, children and adolescents with ADHD usually present comorbidity with other neurodevelopmental disorders, such as specific learning disorders [5], or neuropsychiatric disorders, including anxiety, depression, oppositional defiant problems, conduct disorder, and emotional dysregulation [6]. Amidst the daily-life challenges posed by ADHD, parent-reported sleep complaints among patients with this condition are significantly more prevalent when compared to typically developing children [7].

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Sleep, a fundamental state of the central nervous system, serves as a cornerstone of human existence [8]. It is a process that goes beyond providing relaxation and physical rest; it facilitates the processing of emotions and impressions acquired during waking hours, aids in physical recovery, and rejuvenates our energy reserves [9]. Sleep disturbances (hereafter, SD), characterized by recurrent difficulties initiating or maintaining sleep and experiencing excessive daytime sleepiness [10], are alarmingly prevalent in the pediatric population, affecting at least 25% of children [11], and highlighting that 1 out of every 4 children grapple with inadequate sleep duration and/or quality.

The altered quantity and quality of sleep have far-reaching consequences in children and adolescents. Fragmented or insufficient sleep is associated with detrimental effects on overall daytime functioning and adaptive behavior [12, 13]. It adversely affects academic performance [14–16], with research revealing a positive correlation between sleep duration (measured in hours) and school grades; specifically, evidence showed that students who manage to secure less than 8 h of sleep tend to achieve lower grades [17]. Beside quantity, the quality of sleep is also a critical variable; in particular, studies have underscored the connection between sleep quality and learning motivation, demonstrating that reduced sleep quality is a significant predictor of academic failure among undergraduate students [18]. Furthermore, sleep problems in pediatric population are often considered transversal signs of emotional and behavioral symptoms, such as inattention, hyperactivity, emotional dysregulation, depression, and anxiety, or otherwise diagnosed neuropsychiatric disorders [19–23].

Among neurodevelopmental disorders, sleep-related complaints are a common concern reported by parents and caregivers of children and adolescents with ADHD [24]. Research indicates that the prevalence of SD among children with ADHD is nearly three times higher, ranging from 70 to 85%, than that reported in the general childhood population, around 30% [11, 25].

The relationship between ADHD and SD is undeniably complex and bidirectional [26]. Children with ADHD have difficulties in relaxing their minds, ignoring distractions, or adhering to a consistent bedtime routine, resulting in troubles to settle down enough to fall asleep or stay asleep. Sleep problems, thus, can be interpreted as a consequence of impaired arousal, and alertness and regulation circuits within the brain [27]. Furthermore, SD may be attributed to a delayed circadian rhythm in ADHD, with a later onset of melatonin production—a hormone critical for regulating the sleep-wake cycle [28, 29]. The delayed circadian rhythm may be explained by genetic factors related to the circadian clock system, such as the CLOCK gene [30], which is responsible for sleep homeostasis and is associated with ADHD symptoms [31]. On the other hand, a lack of sleep could exacerbate ADHD symptoms, especially inattention rather than hyperactivity [32–34]. In line with this, evidence in children and adolescents showed that the presence of SD is not only related to ADHD symptoms but explains further ADHD-related aspects such as poor quality of life and adaptive behavior [35, 36], worse academic performance [37, 38], emotional/behavioral difficulties and emotional dysregulation [39–45].

While extensive research focuses on the impact of SD and ADHD on various dimensions during childhood and adolescence, the effects on later stages of development, such as adulthood and beyond, remain less explored. However, the co-presence of SD and ADHD can undoubtedly have long-term effects on later stages of development. Longitudinal analyses from a nationally representative cohort of twins demonstrate that children and adolescents with ADHD and SD are more likely to experience SD even during adulthood [46, 47]. Therefore, further research in adults is needed. Recognizing the influence of SD and its interactions with ADHD in children and adolescents is crucial for implementing timely and effective treatments to prevent negative outcomes in adults. In this context, several aspects merit further investigation.

In children and adolescents, most of the research has mainly concentrated on the relationship between sleep and emotional/behavioral difficulties or psychopathological comorbidities but has less explored adaptive behavior and/or academic performance associated with SD in children with ADHD. In addition, the few studies examining academic performance associated with SD in children with ADHD did not control for specific learning disorders in comorbidity, and considered only school-grades as outcomes, without including objective measures of reading, writing and math. Further, studies mainly included pediatric populations screened for ADHD symptoms via parent-report questionnaires without a clinically confirmed diagnosis of ADHD. This aspect, therefore, makes it difficult to generalize results on population with clinically-diagnosed ADHD. Lastly, the relation between sleep problems and various facets of adaptive behavior, academic performance, emotional/behavioral problems, considering the possible influence of factors, such as age or ADHD symptoms severity, remains unexplored in pediatric population with ADHD.

The purpose of this study is to address key gaps in the literature by comparing children and adolescents with clinically confirmed diagnosis of ADHD, both with and without SD, considering measures of adaptive behavior, reading, writing, and math (considering the presence of comorbid specific learning disorders), as well as ADHD symptoms and emotional/behavioral problems (considering the presence of comorbid neuropsychiatric disorders). Furthermore, the current work aims to clarify the relationship between sleep problems and various clinical dimensions, such as adaptive behavior, academic performance, emotional/behavioral problems, while controlling for confounding variables (e.g., age, cognitive level, gender, ADHD symptoms severity, and Body Mass Index, BMI).

The overarching goal is to delineate the clinical profiles of children with ADHD and SD as well as to understand how sleep problems impact on several clinical outcomes, both independently and in interaction with ADHD symptoms.

Building upon previously reported evidence, our hypothesis posits that the presence of SD or the interplay between the presence of ADHD and SD exacerbate various dimensions under consideration.

Materials and methods

Participants

The study cohort was composed of 136 Italian outpatients with a diagnosis of ADHD aged 6 to 14 years old (Males/Females = 109/27) evaluated at the Child and Adolescent Neuropsychiatry Unit of the Bambino Gesù Children's Hospital (Rome, Italy) – a tertiary care hospital with multiple specialty clinics. The sample size was calculated a priori using G*Power, based on the effect size derived from a study with a similar design [34]. In the referenced study, 100 children with suspected ADHD were divided into two groups based on the presence of SD and were compared on ADHD symptoms using SNAP-IV scores. The effect size of the difference in SNAP-IV total scores between the group without SD (22.70 ± 10.11) and the group with SD (32.46 ± 14.29) was moderate to large ($t_{94.526} = -3.983$, $p < 0.0001$), corresponding to a Cohen's d of 0.78. Given that our study involves children and adolescents with a clinical diagnosis of ADHD and uses the DSM-IV Total of CPRS as a measure, we anticipated a moderate effect size to be conservative. Assuming an estimated f = 0.25, an α value = 0.05 (indicating a 5% probability of false positives), and a $\beta = 0.80$ (indicating at least 80% power), the required sample size for the Analysis of Variance (ANOVA) with two groups (Group with SD and Group without SD) was calculated to be 128.

This is a retrospective, cross-sectional study. Participants with ADHD were retrospectively selected from a comprehensive database by reviewing electronic health records of hundreds of patients with neurodevelopmental and/or neuropsychiatric disorders referred for a clinical evaluation at the Child and Adolescent Neuropsychiatry Unit of the Bambino Gesù Children's Hospital (Rome, Italy) between September 2016 and August 2020. The database included a comprehensive array of information such as age, gender, BMI, current treatments (pharmacological and non-pharmacological), primary diagnosis, comorbidities, cognitive level assessments, sleep measures, adaptive behavior measures, academic performance evaluations, and questionnaires for screening emotional and behavioral problems. All data were collected following the best clinical practices recommended by international guidelines for neuropsychiatric disorders.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (2541_OPBG_2021) and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent was obtained from parents or legal guardians of each participant included in the study. The anonymity of the participants and the confidentiality of the data were guaranteed.

Participants were selected based on their diagnosis of ADHD as a primary disorder (15 with inattentive presentation (ADHD-I), 11%; 3 with hyperactive/impulsive presentation (ADHD-HI), 2.2%; 118 with combined hyperactive/impulsive and inattentive presentation (ADHD-C), 86.8%), according to the criteria of the *Diagnostic and Statistical Manual of Mental Disorders*, *Fifth Edition*, DSM-5 [1], extensively investigated by neuropsychiatrists and developmental psychologists throughout a clinical examination based on the observation of the patient, the developmental history, the ADHD parent-report scale – Conners' Parent Rating Scales Long Version Revised–CPRS-R: L [48], and the semi-structured interview – the Kiddie Schedule for Affective Disorders and Schizophrenia – Present and Lifetime version, K-SADS-PL DSM-5 [49].

Participants were also selected based on a non-verbal Intelligence Quotient (nvIQ) above 85.

None of them had a comorbidity with autism spectrum disorder and a personal history of neurological, medical, genetic diseases.

Among the total sample with ADHD, 31 participants (22.8%) did not meet criteria for any additional comorbidities. However, 71 participants with ADHD (52.2%) were diagnosed with specific learning disorders, and 25 of them (35.2%) had additional comorbidities, including anxiety disorders (25.3%, 18/71), oppositional-defiant disorder (8.5%, 6/71), and mood disorders (1.4%, 1/71). Of the 34 children and adolescents with ADHD who did not have specific learning disorders, additional comorbidities were identified as follows: anxiety disorders (38.2%, 13/34), oppositional-defiant disorder (47.1%, 16/34), mood disorders (5.9%, 2/34), and stress-related disorders (8.8%, 3/34).

Instruments

ADHD assessment

Kiddie Schedule for Affective Disorders and Schizophrenia – Present and Lifetime version. ADHD symptoms were assessed using the Schedule for Affective Disorders and Schizophrenia for School Aged Children Present and Lifetime Version DSM-5 (K-SADS-PL DSM-5). K-SADS-PL DSM-5 is a semi-structured interview that investigates the possible presence of psychopathological disorders according to DSM-5 [49]. This instrument not only relies on the input from the children and adolescents but also incorporates insights from their parents, enhancing the breadth and depth of information gathered. The K-SADS-PL DSM-5 has a 3-point scale, whereby absent symptoms are coded as 0, subclinical symptoms is coded as 1, and clinical symptoms (e.g., symptoms severe and frequent enough to impair individuals' functioning in multiple contexts) is coded as 2.

Conners' Parent Rating Scales Long Version Revised – CPRS-R: L. The CPRS-R: L [48] comprises 14 subscales. In the present study, we considered DSM-IV Inattention, DSM-IV Hyperactivity-Impulsivity and DSM-IV Total subscales. According to the CPRS-R: L normative data, a T-score < 60 was considered as "non-clinical"; a T-score between 60 and 70 as "borderline"; and a T-score > 70 as "clinical. Coefficient alphas ranged from 0.75 to 0.94 for males, and 0.75 to 0.93 for females [48]. The questionnaire was completed by 111 out of 136 parents of participants with ADHD.

Non-verbal cognitive level

Non-verbal intelligence quotient was assessed by using the Leiter International Performance Scale (Leiter-Revised or Leiter-3 [50], , the Raven Progressive Matrices (Coloured Progressive Matrices – CPM; Standard Progressive Matrices – SPM; respectively [51, 52] or the Perceptual Reasoning Index of the Wechsler intelligence scales (Wechsler Intelligence Scale for Children – Fourth Edition, WISC – IV Wechsler Adult Intelligence Scale – IV – WAIS-IV; respectively [53, 54]). All coefficient alphas are greater than 0.60 [50–54].

Body mass index

BMI has been considered in the light of evidence showing its strong relationship to sleep functioning [55]. For each participant, the BMI – calculated by dividing weight (kg) by height (m) squared – was considered and was standardized to z-scores based on age and gender and compared with baby growth parameters from the World Health Organization [56].

Sleep evaluation

SD were assessed throughout the Sleep Disturbances Scale for Children (SDSC) questionnaire [57]. This scale evaluates specific SD and provides an overall measure of SD suitable for use in clinical screening and research in youth populations aged 6 to 15 years. It consists of 26 items, and parents were asked to read each item (i.e., 'the child has difficulty to fall asleep') and indicate how frequently certain behaviors were exhibited by their children in a five-point Likert scale from 1 ('never') to 5 ('always'). Parents were also required to offer estimates of sleep quantity and onset time of their children. This questionnaire investigates 6 main areas representing some of the most common sleep difficulties affecting children and adolescents: Disorders of Initiating and Maintaining Sleep (DIMS), Sleep Breathing Disorders (SBD), Disorders of Arousal (DA), Sleep-Wake Transition Disorders (SWTD), Disorders Of Excessive Somnolence (DOES), and Sleep Hyperhydrosis (SHY). SDSC Total Score could be obtained from the sum of all the previous scales. According to the SDSC normative data, a T-score ≤ 60 was considered as "non-clinical"; a T-score between 61 and 70 as "borderline"; and a T-score ≥ 71 as "clinical". Coefficient alphas range from 0.71 to 0.79 [57].

Adaptive behavior

The adaptive behavior was evaluated by using the Adaptive Behavior Assessment System Second Edition for Ages 5–21 (ABAS-II [58]), which provides a complete assessment of adaptive skills across the life span from 5 to 21 years. The ABAS-II investigates 10 areas of adaptive skills, covering 4 domains: Conceptual Adaptive Domain (subscales: Communication, Functional Academic, Self-direction), Social Adaptive Domain (subscales: Social and Leisure) and Practical Adaptive Domain (subscales: Community Use, Home Living, Health and Safety, Self-care), and a General Adaptive Composite. These domains include the practical and everyday skills needed to function, meet environmental needs, take care of oneself and interact with others effectively and independently. According to the ABAS-II normative data, a composite score ≥ 85 was considered as "non-clinical"; a composite score between 84 and 70 as "borderline"; and a composite score < 70 as "clinical". Coefficient alphas are greater than 0.90 [58].

The questionnaire was completed by 95 out of 136 parents of participants with ADHD.

Academic performance

Text reading task. Children and adolescents were asked to read a text aloud as accurately and rapidly as possible [59, 60]. Accuracy raw scores were calculated as the total number of errors, while speed raw scores were calculated as a ratio between the number of syllables read in total and the seconds spent to read. Accuracy and speed raw scores were converted to z-scores based on schooling normative data. The task was completed by 104 out of 136 participants with ADHD.

Text comprehension task. In the text comprehension task, children and adolescents were asked to read the text in silence at their own pace, then answer a number of multiple-choice questions (12 for the primary and middle school students, 10 for the high school students), choosing one of four possible answers [59, 60]. There was no time limit, and the students could reread the text whenever they wished. The final score was calculated as the total number of correct answers. The final score was converted to z-scores based on schooling normative data. The task was completed by 60 out of 136 participants with ADHD.

Writing task. Children and adolescents were asked to write down a text under dictation or to product a spontaneous text [60, 61]. Accuracy raw scores were calculated as the total number of incorrect written words, and then converted in z-scores based on schooling normative data. The task was completed by 103 out of 136 participants with ADHD.

Math task. In the mental calculation task, children and adolescents were asked to solve 9 additions (i.e., '7 + 5', '15 + 8', '420 + 161') and 9 subtractions (i.e., '5–2', '52–19', '850–250') in a maximum of tot seconds for each item [60, 62]. The raw scores are calculated as the total number of correct answers provided in the given time and converted to z-scores based on schooling normative data. The task was completed by 71 out of 136 participants with ADHD.

All coefficient alphas are greater than 0.60 [59–62].

Emotional and behavioral symptoms

The co-occurring emotional and behavioral problems was detected by using the Child Behaviour Checklist 6–18 (CBCL) parent questionnaire [63]. The hierarchic structure of the CBCL encompasses 20 subscales. In the present study, we considered the T-scores of the *DSM-Oriented Scales* (Affective Problems, Anxiety Problems, Somatic Problems, ADHD Problems, Oppositional Defiant Problems, Conduct Problems) and the *2007 Scales* (Sluggish Cognitive Tempo, Obsessive-Compulsive Problems, Post-traumatic Stress Problems). According to the cut-off thresholds of Achenbach and Rescorla (2001), a T-score < 65 was considered as "non-clinical"; a T-score between 65 and 69 as "borderline"; and a T-score > 69 as "clinically-relevant".

The CBCL Dysregulation Profile (CBCL-DP) was also calculated by adding the T-scores of the Anxious/Depressed, Attention Problems, and Aggressive Behavior subscales and considered in the statistical analyses. A summed T-score of < 180 was considered as "non-clinical" scores; a score between 180 and < 210 as "borderline" scores; and a T-score ≥ 210 as "clinically-relevant" scores.

Coefficient alphas ranged from 0.78 to 0.97 [63].

Procedures

In line with the aim of the current study, the cohort was divided into two groups according to the presence or absence of SD based on the SDSC Total Scores [57]. According to Bruni et al. [57], ninety-four children with SDSC Total Score < 71 were classified as children with ADHD without SD (ADHD). Forty-two children with SDSC Total Score ≥ 71 were classified as children with ADHD with SD (ADHD + SD).

Statistical analysis

The data were first examined for assumptions of normality via Shapiro–Wilk test and homogeneity of variance via Levene's test. As the distribution of the variables was found to be non-Gaussian, non-parametric tests were applied.

Mann–Whitney *U* tests were used to test differences between the two groups (ADHD v*s*. ADHD + SD) on sample characteristics for continuous variables (SDSC Total Score and subscales; age; nvIQ; BMI, CPRS-R: L subscales). Chi-square (χ^2) analyses were utilized to verify differences between the two groups on sample characteristics for the distribution of categorical variables (ADHD presentations: ADHD-I, ADHD-HI, ADHD-C; MPH treatment; specific learning disorders; neuropsychiatric disorders).

A *p-value* ≤ 0.05 was considered statistically significant.

Mann–Whitney *U* tests were also used to test differences between the two groups (ADHD v*s*. ADHD + SD) on adaptive behavior (ABAS-II: Conceptual Adaptive Domain, Social Adaptive Domain, Practical Adaptive Domain), academic performance (text reading accuracy, text reading speed, text comprehension, writing, mental calculation), and emotional and behavioral symptoms (*DSM-Oriented Scales* and the *2007 Scales* of CBCL; CBCL-DP). For the *p-value*, Bonferroni-Holm method correction was applied for multiple comparisons.

χ^2 was run to test differences between groups in the distribution of patients who obtained "at risk" or "clinical" scores (z-scores ≤ -1.5 standard deviations) in the academic performance (only on significant results identified by Mann–Whitney *U* where appropriate). A *p-value* ≤ 0.05 was considered statistically significant.

Lastly, partial Spearman's rank correlations (*rho*) were conducted to evaluate the specific relationship between sleep problems (SDSC Total Scores) and adaptive behavior

(ABAS-II: Conceptual Adaptive Domain, Social Adaptive Domain, Practical Adaptive Domain), academic performance (text reading accuracy, text reading speed, text comprehension, writing, mental calculation), and emotional and behavioral symptoms (*DSM-Oriented Scales* and the *2007 Scales* of CBCL; CBCL-DP), controlling for age, nvIQ, gender, BMI, and ADHD symptoms (CPRS-R: L subscale: DSM-IV Total). For the *p-value*, Bonferroni-Holm method correction was applied for multiple comparisons.

Results

To confirm the presence or absence of SD, the two groups were compared for the SDSC Total Score and subscales. The groups differed in the SDSC Total Score (Mann–Whitney $U=0$, $p<0.0001$,) and in each subscale: DIMS (Mann–Whitney $U=746$, $p<0.0001$), SBD (Mann–Whitney $U=846$, $p<0.0001$), DA (Mann–Whitney $U=1175$, $p<0.0001$), SWTD (Mann–Whitney $U=649.5$, $p<0.0001$), DOES (Mann–Whitney $U=441.5$, $p<0.0001$), and SHY (Mann–Whitney $U=1214.5$, $p<0.0001$). See Table 1.

Table 1 Description of groups in terms of sleep functioning, age, nvIQ, BMI, ADHD manifestations and treatments

Variables	ADHD	ADHD + SD
	(M ± SD)	(M ± SD)
SDCS Subscales		
DIMS	59.5 ± 11.6	78.1 ± 18*
SBD	50.3 ± 6.6	65.9 ± 18.4*
DA	53.4 ± 11.2	66.9 ± 19.5*
SWTD	54.9 ± 11.2	72.7 ± 13.8*
DOES	52 ± 9.3	72.3 ± 14.6*
SHY	50.4 ± 9.6	59.9 ± 14.6*
Total Score	56.2 ± 8	83.4 ± 9.7*
Demographic		
Age[a]	9.6 ± 1.9	10.17 ± 1.96
nvIQ	111.1 ± 12.7	111.4 ± 12
BMI	18.9 ± 3.4	19.4 ± 3.9
ADHD symptoms		
DSM-IV Inattention	74.2 ± 13.8	83.4 ± 10.8*
DSM-IV Hyperactivity-Impulsivity	69.4 ± 13.7	74 ± 10
DSM-IV Total subscales	74.2 ± 14.1	82.1 ± 9.9*
	N (%)	N %
ADHD-manifestations		
ADHD-I	9 (9.6)	6 (14.3)
ADHD-HI	2 (2.1)	1 (2.4)
ADHD-C	83 (88.3)	35 (83.3)
Treatments		
MPH	19 (20)	13 (31)
Cognitive-behavioural therapy	75 (80)	29 (69)

[a]in years; * $p<0.05$

No significant difference emerged between groups in terms of age (Mann–Whitney $U=1660$, $p=0.14$), nvIQ (Mann–Whitney $U=1938.5$, $p=0.87$), and BMI (Mann–Whitney $U=1793$, $p=0.39$, Table 1).

Regarding ADHD symptoms, a significant difference emerged between children in the ADHD–SD group ($n=92$) and children in the ADHD + SD group ($n=39$) in the DSM-IV Inattention (Mann–Whitney $U=1084.0$, $p=0.000352$) and DSM-IV Total (Mann–Whitney $U=1174.0$, $p=0.0018$). In particular, children in the ADHD + SD group exhibited higher T-scores compared to children in the ADHD group (see Table 1). No difference was found for DSM-IV Hyperactivity-Impulsivity subscale between the two groups (Mann–Whitney $U=1416$, $p=0.06$). Additionally, no significant difference was observed between groups in the distribution of ADHD presentations (ADHD-I: $\chi^2_{(1)}=0.66$, $p=0.42$; ADHD-HI: $\chi^2_{(1)}=0.009$, $p=0.93$; ADHD-C: $\chi^2_{(1)}=0.62$, $p=0.43$, Table 1).

Lastly, no significant difference was found between groups in the distribution of patients who followed drug-treatment for ADHD, nor vice versa, in those who underwent behavioral therapy such as parent training and/or cognitive-behavioral ($\chi^2_{(1)}=1.86$, $p=0.2$, Table 1).

Adaptive behavior

In the ABAS-II, results showed a significant difference between children in the ADHD group ($n=69$) and children in the ADHD + SD group ($n=26$) for the Conceptual Adaptive Domain (Mann–Whitney $U=359.50$, $p=0.000007$) and for the Practical Adaptive Domain (Mann–Whitney $U=371.50$, $p=0.000012$, see Table 2). In particular, children in the ADHD + SD group exhibited lower composite scores, more than 2 standard deviations below the average, compared to children in the ADHD group (see Table 2).

However, results did not document a significant difference between children in the ADHD group and those in the ADHD + SD group for the Social Adaptive Domain (Mann–Whitney $U=786$, $p=0.35$, see Table 2).

After Bonferroni-Holm method correction, significant differences for Conceptual Adaptive Domain and Practical Adaptive Domain between the two groups survived.

Academic performance

To control for the presence of learning disorders, the two groups (ADHD + SD *vs*. ADHD) were first compared in the distribution of comorbid specific learning disorders; however, no difference was found between the groups ($\chi^2_{(1)}=0.59$, $p=0.44$).

Considering academic performance, results documented a significant difference between children in the ADHD

Table 2 Differences between the two groups in terms of adaptive behavior, academic performance, ADHD as well as emotional and behavioral symptoms, and the distribution of comorbid specific learning disorders/neuropsychiatric disorders

Variables	ADHD	ADHD + SD
	(M ± SD)	(M ± SD)
Adaptive behavior		
Conceptual	82 ± 12.6	68.8 ± 10*
Social	78.8 ± 13.1	76.1 ± 13.6
Practical	76.7 ± 16.4	59.5 ± 14*
Academic measures		
Text reading accuracy	-1.1 ± 2.4	-1.5 ± 1.9
Text reading speed	-0.8 ± 1.1	-0.9 ± 1.3
Text comprehension task	-0.3 ± 1	-1.1 ± 1.2#
Writing task	-2.5 ± 4.3	-4.2 ± 4.7#
Math task	-0.7 ± 1.6	-0.6 ± 1.2
Emotional and behavioral symptoms		
CBCL – DSM-Oriented Scales		
Affective Problems	63.1 ± 8.5	72.5 ± 6.7*
Anxiety Problems	63.1 ± 7.6	67.3 ± 6.3*
Somatic Problems	57.9 ± 7.1	62.6 ± 9.3*
ADHD Problems	67.2 ± 7.4	71 ± 6.4*
Oppositional Defiant Problems	60.9 ± 8.5	65.6 ± 8.5*
Conduct Problems	60.9 ± 8.7	65 ± 7.9*
CBCL – 2007 Scales		
Sluggish Cognitive Tempo	59.8 ± 7.9	65.6 ± 7.5*
Obsessive-Compulsive Problems	59.9 ± 8.3	65 ± 8.9*
Post-traumatic Stress Problems	64.9 ± 7.5	70.8 ± 6.9*
Dysregulation Profile	123.5 ± 15.9	142.5 ± 16.4
	N (%)	N (%)
Specific learning disorders comorbidity		
Yes	47 (50)	24 (57.7)
No	47 (50)	18 (42.3)
Text comprehension task z-scores		
> -1.5	33 (89)	14 (61)
≤ -1.5	4 (11)	9 (39)#
Writing task z.-scores		
> -1.5	47 (64)	11 (33)
≤ -1.5	26 (36)	23 (67)#
Neuropsychiatric disorders comorbidity		
Yes	37 (39.4)	22 (52.4)
No	57 (60.6)	20 (47.6)

* *p* still significant after Bonferroni-Holm method correction; #$p < 0.05$

group and those in the ADHD + SD group for text comprehension task (ADHD group: $n = 37$, ADHD + SD group: $n = 23$; Mann–Whitney $U = 283$, $p = 0.030$) and for writing task (ADHD group: $n = 73$, ADHD + SD group: $n = 34$; Mann–Whitney $U = 921.50$, $p = 0.033$, see Table 2). In particular, children in the ADHD + SD group exhibited lower z-scores compared to children in the ADHD group.

No difference was found for text reading accuracy (ADHD group: $n = 73$, ADHD + SD group: $n = 31$; Mann–Whitney $U = 925$, $p = 0.14$) and speed (ADHD group: $n = 74$, ADHD + SD group: $n = 31$; Mann–Whitney $U = 1074$, $p = 0.61$) and for mental calculation task (ADHD group: $n = 49$, ADHD + SD group: $n = 23$; Mann–Whitney $U = 520.5$, $p = 0.60$).

After Bonferroni-Holm method correction, significant differences between the two groups struggled to survive (see Table 2).

However, the prevalence of patients who scored z-scores ≤ -1.5 standard deviations in both the text comprehension and writing tasks has been calculated. Significant differences were found between groups in the distribution of patients who scored z-scores ≤ -1.5 SD in the text comprehension task ($\chi^2_{(1)} = 6.70$, $p = 0.009$) and the writing task ($\chi^2_{(1)} = 5.59$, $p = 0.002$).

Emotional and behavioral symptoms

To control for the presence of neuropsychiatric comorbidities, the two groups (ADHD + SD *vs*. ADHD) were also compared in the distribution of comorbid neuropsychiatric disorders; however, no difference was found between the groups ($\chi^2_{(1)} = 2$, $p = 0.16$; Table 2).

In the CBCL, results documented significant differences between children in the ADHD group ($n = 94$) and children in the ADHD + SD group ($n = 42$) for Affective Problems (Mann–Whitney $U = 768.5$, $p < 0.0001$), Anxiety Problems (Mann–Whitney $U = 1322.5$, $p = 0.0002$), Somatic Problems (Mann–Whitney $U = 1346.5$, $p = 0.0031$), ADHD Problems (Mann–Whitney $U = 1366.5$, $p = 0.0042$), Oppositional Defiant Problems (Mann–Whitney $U = 1362.5$, $p = 0.0039$), Conduct Problems (Mann–Whitney $U = 1351$, $p = 0.0033$), Sluggish Cognitive Tempo (Mann–Whitney $U = 1183.50$, $p < 0.0001$), Obsessive-Compulsive Problems (Mann–Whitney $U = 1332.5$, $p = 0.0025$), and Post-traumatic Stress Problems (Mann–Whitney $U = 1038$, $p < 0.0001$). In particular, children in the ADHD + SD group exhibited higher T-scores in all the aforementioned subscales compared to children in the ADHD group (see Table 2).

In general, children in the ADHD + SD group demonstrated higher T-scores, albeit not "clinically-relevant", for the CBCL-DP compared to children in the ADHD group (Mann–Whitney $U = 797$, $p < 0.0001$).

After Bonferroni-Holm method correction, significant differences between the two groups survived.

Relationship between sleep and adaptive behavior, academic performance, emotional/behavioral problems

Controlling for age, nvIQ, gender, BMI, and ADHD symptoms, SDSC Total Score was found to be significantly and negatively correlated with Conceptual Adaptive Domain ($p = 0.005$, $n = 84$) and Practical Adaptive Domain ($p < 0.001$, $n = 84$; Table 3), indicating that higher T-scores on sleep problems were associated with lower composite scores on conceptual and practical adaptive functioning. Similarly, SDSC Total Score was significantly and negatively correlated with the writing task ($p = 0.04$, $n = 95$; Table 3), meaning that higher T-scores on sleep problems were associated with lower writing skills.

Additionally, controlling for age, nvIQ, gender, BMI, and ADHD symptoms, SDSC Total Score was significantly and positively correlated with Affective Problems ($p < 0.001$, $n = 124$), Anxiety Problems ($p = 0.02$, $n = 124$), Somatic Problems ($p = 0.001$, $n = 124$), Sluggish Cognitive Tempo ($p = 0.01$, $n = 124$), Obsessive-Compulsive Problems ($p = 0.03$, $n = 124$), Post-traumatic Stress Problems subscales ($p = 0.003$, $n = 124$; Table 3) and CBCL-DP ($p = 0.004$, $n = 124$). This means that higher T-scores on sleep problems were associated with higher T-scores on affective, anxiety, somatic, sluggish cognitive tempo, obsessive-compulsive, stress-related problems and dysregulation profile.

After applying the Bonferroni-Holm correction, significant relationships were only observed between SDSC Total Score and Practical Adaptive Domain, Affective Problems, Somatic Problems, and Post-traumatic Stress Problems subscales (Table 3). No further significant correlations were found ($p > 0.05$).

Table 3 Correlations (Spearman's rho) between sleep and adaptive behavior, academic perfromance as well as emotional and behavioral symptoms, controlling for age, nvIQ, gender, BMI, and ADHD symptoms

Variables	Sleep	
	SDSC Total Score	
	rho	*p-value*
Adaptive behavior		
Conceptual	-0.30	0.005
Social	-0.05	0.78
Practical	-0.39	< 0.001*
Academic measures		
Text reading accuracy	-0.15	0.15
Text reading speed	-0.06	0.57
Text comprehension task	-0.20	0.16
Writing task	-0.21	0.04
Math task	-0.18	0.16
Emotional and behavioral symptoms		
CBCL – DSM-Oriented Scales		
Affective Problems	0.39	< 0.001*
Anxiety Problems	0.22	0.02
Somatic Problems	0.29	0.001*
ADHD Problems	0.05	0.57
Oppositional Defiant Problems	0.11	0.21
Conduct Problems	0.14	0.11
CBCL – 2007 Scales		
Sluggish Cognitive Tempo	0.22	0.01
Obsessive-Compulsive Problems	0.20	0.03
Post-traumatic Stress Problems	0.27	0.003*
Dysregulation Profile	0.26	0.004

* *p* still significant after the Bonferroni-Holm correction

Discussion

To the best of our knowledge, this study represents the first effort to characterize the profile of children and adolescents with a clinically confirmed diagnosis of ADHD and SD compared to those without SD, evaluating adaptive behavior, reading, writing and math as well as ADHD symptoms, and emotional/behavioral problems.

In line with previous literature, our findings revealed that children and adolescents with ADHD and SD exhibited a significantly more impaired clinical profile compared to patients with ADHD without SD in terms of adaptive behavior, academic performance, ADHD symptoms, and emotional/behavioral problems. Furthermore, our results established a relationship between sleep problems and diverse clinical aspects of children and adolescents with ADHD, while controlling for age, cognitive level, gender, ADHD symptoms severity, and BMI. From a clinical standpoint, these findings suggest that the presence of SD in patients with ADHD may help identify strengths and weaknesses in this population, even demonstrating an independent relationship with specific clinical dimensions.

First, in terms of adaptive behavior, children and adolescents with ADHD and SD obtained mean lower and clinical scores in conceptual competences (i.e., the ability of properly communicate, the ability of achieving school-age-appropriate success) and everyday life practical skills (i.e., activities of daily living and household management) compared to those with ADHD without SD. Although children and adolescents with ADHD without SD also displayed borderline scores on each domain of adaptive functioning, the co-presence of SD seems to more exacerbate the challenges in the development of conceptual and practical adaptive behaviors. Nevertheless, in the social domain, both groups with ADHD did not differ each other and demonstrated equal difficulties. This suggests that a primary diagnosis of ADHD uniquely influences social functioning. The current finding is in line with evidence that children and adolescents with ADHD exhibit poor social competences and difficulties in building solid relationships [4].

In additions, correlations documented a significant association between sleep problems and conceptual domains/daily-life practical skills, even controlling for confounding variables and especially ADHD symptoms severity. Despite a paucity of research on the interplay between ADHD and SD on adaptive behavior, overall our results align with prior evidence, documenting that: (i) children with ADHD, who tend to report elevated levels of SD, used to concomitantly experience greater impairment in daily functioning compared to controls [35]; and (ii) the simultaneous presence of SD and ADHD contribute to explain daily-life adaptive functioning [36]. While our evidence points to the detrimental effects of their co-occurrence, future studies should elucidate the specific causal influence of SD on adaptive behavior and quality of life within the context of ADHD diagnosis. This aspect can be thoroughly longitudinally examined by comparing groups with ADHD with and without SD to a group with only SD.

The deficit found in the conceptual domain of adaptive behavior in children and adolescents with ADHD with SD is reflected in their academic performance. Indeed, even when considering the co-presence of specific learning disorders, participants with ADHD and SD displayed mean lower scores in complex academic skills (such as text comprehension and writing tasks), but not in accuracy and speed of text reading and mental calculations, compared to participants with ADHD without SD. Our investigation is convergent with research describing sleep as a crucial and vital mechanism for children and adolescents' learning processes and school performance (for a review see [40, 64]). Thus, the assessment of complex academic skills becomes fundamental to clarify their school-age-appropriate functioning, especially for ADHD who also experience SD, even beyond the presence of a diagnosed learning disorder. This aspect is highlighted in our findings, which document that the distribution of specific learning disorders remained consistent across the groups; however, the severity of the disorders was more pronounced in participants with ADHD and SD.

Although both groups showed similar distributions of ADHD presentations, patients with both ADHD and SD displayed clinically relevant and higher scores on the DSM-IV Inattention scale. Current findings are consistent with the extensive literature showing the associations between sleep difficulties and inattention in patients with neuropsychiatric disorders, such as ADHD [32, 65, 66], autism [67], anxiety [68], as well as in general population [69, 70].

Difficulties in conceptual functioning and complex academic skills observed so far in patients with both ADHD and SD may be also largely attributed to the greater impairment of inattention symptoms compared to patients with ADHD without SD (for a comprehensive overview, refer to Lunsford-Avery and colleagues [40]). Accordingly, a recent study by Trane and Willcutt [71] highlighted that among approximately 500 children with ADHD, inattention symptoms were a significant independent predictor of performance in tasks assessing complex academic performance. This association persisted even after adjusting for basic academic performance (such as reading accuracy or speed, calculation task), indicating that inattention might compromise high-level skills essential for effective reading comprehension and writing composition (e.g., attention), beyond basic academic performance. Translate to our findings, it could be that the lack of sufficient and quality sleep, which further weakens attentive skills, has an additional and indirect negative effect in interfering with academic difficulties.

Similarly, compromised performance in practical everyday-life skills observed in children with ADHD and SD may also be linked to inattention symptoms. The relation between inattention and the ability to manage and drive behavior properly towards everyday-life commitments is widely recognized and supported [72]. Consequently, insufficient and poor-quality sleep, which further undermines attentive skills, could exert an additional and indirect adverse impact on interfering with practical everyday-life skills.

Lastly, even considering the presence of neuropsychiatric disorders, children and adolescents with ADHD and SD presented significantly mean higher emotional and behavioral symptoms than children and adolescents with ADHD without SD. Participants with both ADHD and SD exhibited mean borderline scores on internalizing and externalizing symptoms. In addition, correlations shown a significant relationship between sleep problems and mood regulation, somatic complaints, and stress-related problems, which does not depend on age, cognitive level, gender, the severity of ADHD symptoms and BMI.

Existing research extensively discusses the interconnectedness between SD and internalizing symptoms (e.g., anxiety [23], sluggish cognitive tempo [73], obsessive-compulsive problems [74] as well as externalizing symptoms [e.g., oppositional defiant [75] and conduct problems [76]) in the pediatric population. While these symptoms do not yet meet the criteria for a psychopathological disorder, they raise concerns as they have the potential to worsen the adaptive functioning of our participants with ADHD.

Of importance, children and adolescents with ADHD and SD obtained clinically-relevant scores on scale assessing mood/emotional regulation symptoms. This is not surprising, considering that sleep difficulties is one of the symptoms required for the diagnosis of mood disorders. In addition, children and adolescents with ADHD and SD also exhibit clinically-relevant scores on scale assessing stress-related symptoms. A possible explanation is that inadequate sleep could contribute to an increased perception of stressors (i.e., activities/situations/requests) that exceed the cognitive/emotional resources of children and adolescents. Children with both ADHD and SD may perceive a decreased sense of capability in handling stressful situations and an increased perception of stressors. This, in turn, could lead to an intensification of physiological stress, with a heightened emotional tension, irritability, mood swings, and difficulty managing their emotions. This association between SD and elevated stress further emphasizes the critical need to thoroughly examine the impact of sleep on the overall emotional well-being of children. The intricate intertwined between SD, mood and stress symptomatology find merit to be clinically considered and monitored along developmental trajectories.

This study has some limitations. First, sleep has been assessed only through subjective measure (i.e., parent-report questionnaire). The used parent-report questionnaire is primarily intended to assess the sleep-related disorders in childhood and adolescence and not to provide an accurate clinical diagnosis, while its validity and consistency are well-proved. Moreover, parent-report questionnaires are always potentially limited by observer bias and by limitations of parents' memory and stress-perception. Future studies should use both subjective and objective measures, such as polysomnography or actigraphy. Moreover, a control group of typically developing children is absent. In addition, this study did not differentiate by age group considering children, pre-adolescents and adolescents separately in order to estimate the role of age and did not take into consideration the chronotype of the included children. Future studies should consider these crucial aspects.

From a clinical perspective, findings of this study hold the potential to significantly inform professionals in the field, enhancing the diagnostic process and tailoring interventional programs for patients with ADHD who also experience SD. The therapeutic approach should encompass comprehensive patient management by integrating diverse programs that address various levels, particularly for ADHD with SD. Firstly, multimodal programs, incorporating cognitive-behavioral interventions such as individual therapy and parenting sessions, can play a pivotal role in instilling healthy sleep habits and fostering a positive and balanced well-being in children and adolescents with ADHD. Additionally, considering the severity of both the core diagnosis and SD, pharmacological treatments may be warranted.

In conclusion, a key finding of this study is that SD in individuals with ADHD significantly contribute to the comorbidity of various psychopathological conditions. By addressing sleep issues, healthcare providers can improve overall mental health outcomes, enhance treatment efficacy, reduce the burden of co-occurring psychiatric disorders, and enhance the quality of life and adaptive behaviors in children with ADHD. This emphasizes the importance of routine and accurate screening for primary or comorbid SD in children and adolescents diagnosed with ADHD in primary care settings. Additionally, it is crucial to develop and implement evidence-based guidelines for managing sleep disorders in this population.

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Data availability The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

Declarations

Competing interests The authors declare that the research will be conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Compliance with ethics guidelines See Method's section.

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