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Changes in sleep duration and disturbances during Covid-19 lockdown and internalizing-externalizing behaviors in children with attention deficit hyperactivity disorders

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ABSTRACT

Objective: To examine how changes in sleep patterns and sleep problems occurring between the pre-pandemic and the Covid-19 lockdown period influenced mood-behavioral functioning of children with Attention Deficit Hyperactivity Disorder (ADHD).

Methods: Parents of 992 children with ADHD (85.4% boys, mean age: 11.52 years, *SD* = 3.17), recruited from the Italian ADHD family association, completed a modified version of the Sleep Disturbance Scale for Children and filled out 11 emotional behavioral items selected from the Child Behavior Checklist (CBCL) 6–18 questionnaire. Subgroups identified based on sleep duration changes ("maintained", "increased", "reduced") and of sleep problems during lockdown ("onset", "remission", "maintained", "no sleep problem") were analyzed to evaluate the association with internalizing and externalizing scores.

Results: Sleep duration showed no or low influence on internalizing and externalizing behaviors after control for age, sex, and socioeconomic status. Patients with ADHD with "no sleep problem" showed significant lower scores in internalizing and externalizing behaviors than those who "maintained" or had "onset" of different sleep problems. The effect sizes were higher for internalizing than externalizing behaviors. Lower internalizing scores were found in those who remitted difficulty in falling asleep, daytime sleepiness, nightmares, vs. the "maintained" or "onset" groups and those who remitted hypnic jerks vs. the "onset" group.

Children with ADHD who "maintained" sleep terrors reported higher internalizing and mainly externalizing scores than the other groups.

Conclusion: Sleep problems negatively influence daytime functioning of patients with ADHD. but mood and behavioral domains show different susceptibility to the changes of sleep problems, and different vulnerability to specific sleep problems.

1. Introduction

Sleep plays a central role in regulating emotions and behavior in the general population; this function is crucial in children and adolescents with Attention Deficit Hyperactivity Disorder (ADHD) since the brain areas involved (dorsolateral prefrontal, anterior cingulate, and parietal cortices) are strongly vulnerable to inadequate or disturbed sleep. Up to 70% of children with ADHD have sleep problems [1] and important associations between sleep quality and emotional and behavioral functioning in ADHD patients have been reported [2–5]. In particular, reduced sleep duration and sleep problems play a critical role on internalizing and externalizing behaviors of children and adolescents with ADHD [2,6].

Abbreviations: ADHD, Attention Deficit Hyperactivity Disorder; h, hours.

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Despite the increasing interest, the topic of sleep and psychopatology has been quite overlooked in the literature [7], even though it was initially mentioned among the clinical guidances on the management of ADHD during the pandemic [8]. Moreover, little is known on the nature of the relationship; in particular: 1) how some aspects of sleep, such as duration or onset or persistence, or remission of sleep problems influence mood and behavioral functioning of children and adolescents with ADHD, with the exception of few longitudinal studies [4,6,9] and, 2) if ADHD patients with internalizing and externalizing behaviors show a different vulnerability to specific sleep problems. These aspects are not neutral for understanding the role that sleep could play on the developmental trajectories of children with ADHD.

Several studies have highlighted that the Covid-19 lockdown experience created the condition for the occurrence of critical disruption of previous sleep habits and routine and of important changes in mood-behavioral functioning in the young and adult population of the entire world [10–18], and in children with neurodevelopmental disorders, in particular [19–22].

Specifically, previous reports highlighted that, in patients with ADHD, the lockdown experience caused significant delay of bedtime, critical changes of sleep duration and an increase in sleep problems, with respect to the pre-pandemic condition [20]. Similarly, some studies reported that lockdown significantly exacerbated emotional and disrupted symptoms in children with ADHD; although also improvements in some aspects of emotional and behavioral functioning were reported, involving a lowering of the distress created by rhythms imposed by school activities [19] and interactional stressors [22].

In this cross-sectional study, we tried to identify subgroups of ADHD children based on spontaneous changes in sleep problems and sleep patterns occurred between the pre-pandemic and the lockdown period. Specifically, we attempted to identify children with ADHD who started or remitted or maintained sleep problems during the lockdown, as well as those who did not show specific sleep problems, either before and during. Similarly, we aimed to define subgroups of ADHD patients who increased, maintained or reduced their sleep duration during lockdown.

Based on the above subgroups, the aim of the current study was to assess, in children with ADHD: 1) how sleep pattern or problems changes (duration, onset or persistence, or remission or absence) influence internalizing and externalizing behaviors, and 2) which specific sleep problems, linked to these changes, might mostly influence mood and/or behavioral functioning.

We hypothesize that: 1) internalizing and externalizing behaviors in children with absence or remission of sleep symptoms during lockdown might be lower than in children who continue or start a sleep problem; 2) children who continue to have sleep problems might show higher scores in internalizing and externalizing behaviors than those who remit.

To our knowledge no study has considered the lockdown timeframe to examine the nature of the relationship between sleep and mood-behavioral functioning, despite that it represents an universally recognized experience that has created the condition of significant changes of these two domains.

2. Materials and methods

2.1. Participants and procedure

Data reported in this study were extracted from a large online cross-sectional survey with both current and retrospective reports of functioning. The methods of data collection and storage have been extensively reported elsewhere [20,22,23]. Synthetically, parents of children and adolescents with ADHD were asked to define behaviors of their children relative to several behavioral domains regarding two temporal frames (3 months before of pandemic and during lockdown). The online survey was advertised through the Italian ADHD Family Association website for a limited time (from June 4 to 21, 2020). Before accessing the survey, caregivers gave their consent to participate in the study. The families were in total and partial lockdown for 88 days at the time of the survey.

For this study we selected: 1) responses relative to questions of sleep duration and sleep problems before and during lockdown, and 2) responses relative to questions on mood-behavioral patterns during the lockdown.

A total 992 ADHD children and adolescents (85.4% boys, mean age = 11.52 years, SD = 3.17; range = 5–18 years) satisfied the criteria of selection and none of them was excluded from the study.

All ADHD patients had been diagnosed and were followed-up by a child and adolescent psychiatrist of the Child and Adolescent Mental Health Service before the lockdown. The clinical diagnosis of ADHD was based on the ADHD Italian guidelines that reflect international guidelines of the American Academy of Child and Adolescent Psychiatry.

There was no monetary or credit compensation for participating in the study. The study was approved by the Ethics Committee of the Department of Developmental and Social Psychology, Sapienza University of Rome, and was conducted in accordance with the Declaration of Helsinki (October 2008).

2.2. Internalizing and externalizing child behaviors assessment

Eleven emotional behavioral problems considered to be more appropriate to the lockdown condition were selected from the Child Behavior Checklist (CBCL) 6–18 questionnaire [24,25]: 5 internalizing behaviors (sadness, irritability, little enjoy/interests in activities, boredom, and anxiety) and 6 externalizing behaviors (restlessness, temper tantrum, verbal aggression, physical aggression, oppositional behavior, and argument behavior). The score of the presence of each emotional behavioral item during lockdown, defined by parents in terms of frequency/week (1–2 time/week = 1; 3–4 time/week = 2; 5–7 time/week = 3) was added up within the two internalizing and externalizing categories for defining the total scores relative to every child. The CBCL items were completed by parents mainly mothers (88.6%). Chronbach alpha was .748 for internalizing and 0.780 for externalizing items.

2.3. Sleep duration assessment

Parents were asked to select the range of sleep duration, before and during lockdown, categorized as follows: <6 h; 6–7 h, 8–9 h; 10–11 h; 12 h or more.

In order to evaluate the effective changes of sleep duration during the lockdown, with respect to the pre-pandemic condition, we recoded the changes into three categories: children who maintained, increased, or decreased sleep duration.

2.4. Sleep disturbance assessment

For the purpose of this study, we used 12 items of the Sleep Disturbance scale for Children (SDSC) [26,27]. Parents were asked to define each sleep symptom coded into dummy variables: absence of the disorder = 0; presence = 1, either before or during lockdown.

Paired codes before and during lockdown of each sleep problem was recoded into four possible groups: children and adolescents with ADHD who showed sleep problems before and during lockdown (coded 1-1) labeled with “maintained”; children who neither

showed sleep problems before and during (coded 0-0) labeled with "no sleep problem"; children who did not have sleep problems before but started to show them during lockdown (coded 0–1) labeled with "onset"; children who had sleep problems before but reported a remission during lockdown (coded 1–0) labeled with "remission".

2.5. Statistical analysis

Descriptive statistics were applied to define frequencies and percentage of ADHD patients within three groups of sleep duration and four groups of sleep problems. Internalizing and externalizing scores expressed as continuous variables were defined with means and standard deviations. Inter-group comparisons were performed by ANOVA, carried out by means of a General Linear Model using internalizing and externalizing behavior scores as dependent variables and sleep problems subgroup, sex, age, and socioecoconomic status as independent predictors. The tables report the statistical results of the effect of sleep problems, described by the F statistics and the η^2 effect size, followed by post-hoc intergroup comparisons by means of the Tukey HSD (not computed when F was not statistically significant). The effect size η^2 can range between 0 and 1 and values of $\approx$0.01, $\approx$0.06, and >0.14 are usually considered as small, medium, and large effect sizes, respectively. Significance threshold was set at $p < 0.05$. Statistical Analysis was performed using SPSS v.23 (IBM, Armonk, NY, United States).

3. Results

The sample was composed by 528 children [441 M (83.5%); 87 F (16.5%); age range 5–11.11 years; mean age 9.06 y, S.D. 1.63] and 464 adolescents [406 M (87.5%); 58 F (12.5%); age range 12–17.11 years. No significant gender difference between two age groups was found ($\chi^2_{=}$3.130; $p = 0.077$). Five hundred and ninety-nine (60.4%) patients with ADHD had one or more comorbid disorders; 39.6% of them did not present with comorbidity.

Family economic status of the whole sample was high in 3%, middle in 75.2% and low in 21.8%.. As for the education level the majority of participants have a graduate (29%) or high school degree (52.6%); middle school was represented in 17.9% and elementary school in 0.5%. Moreover, the family composition was reported as follows: parents with one offspring member: 31.3%; parents with two offspring members: 51.9%; parents with three offspring members: 13.3%; parents with four or more offspring members: 3.5%.

Parents reported that 441 ADHD patients were taking medication before pandemic, but some of them reported the difficulties in finding these drugs during lockdown. Five hundred fifthy-one did not take medication before and during the lockdown.

The frequency and percentage of the changes of sleep duration and sleep problems are reported in Table 1: 21.5% reduced and 25.4% increased the duration of sleep while 53.1% of the total sample maintained their sleep duration. Difficulties of falling asleep, anxiety at bedtime and night awakenings (i.e. insomnia), as well as nightmares and sleep related movement disorders, were more prevalent in those who maintained or had the onset of sleep problems.

Table 2 shows the statistical comparison of internalizing and externalizing scores obtained in the different sleep duration groups controlled for age, sex, and socioeconomic status. No differences were found for the three groups of sleep duration.

3.1. Internalizing scores

Table 3 shows that the group of subjects who did not present sleep problems showed significant lower internalizing scores compared to the "maintained" and "onset" groups for almost all the sleep problems, with the exception of sleep walking, sleep terrors, bruxism and snoring vs. the "onset" group and of rhythmic movements and snoring vs. the "maintained" group). Furthermore, the "no sleep problem" group did not show differences vs. the "remission" group with the exception of higher scores in anxiety at bedtime in the latter.

The "onset" and "maintained" groups compared to the "remission" group showed higher internalizing scores in difficulty in falling asleep, daytime sleepiness and nightmares. Moreover, children with "onset" in hypnic jerks during lockdown showed higher internalizing scores vs. those of remission of the same problem whereas children who "maintained" sleep terrors during lockdown reported higher internalizing scores vs. those with remission of the same problem. The effect of these sleep problems groups on internalizing behaviors was medium-to-large but sleepwalking, and sleep terrors displayed a small effect size. No differences were found between the "onset" group and the "maintained" group.

3.2. Externalizing scores

As it can be seen in Table 4, the "no sleep problem" group showed significantly lower externalizing scores than the "onset" and "maintained" groups in most of sleep disorders (with the exception of sleep walking, sleep terrors, snoring, restless sleep vs. the "onset" group and bruxism and rhythmic movements vs. both "maintained" and "onset" groups). No significant difference in externalizing scores was found between the "remission" group vs. "no sleep problem" and "onset" groups. Finally, the group of subjects who "maintained" sleep terrors showed higher externalizing scores than those with "remission" or "onset". The effect of these groups on externalizing behaviors had a small size but approached the medium value for anxiety at bedtime.

4. Discussion

The aim of this study was to examine differences in internalizing and externalizing behaviors in a large sample of children with ADHD and with different trends of sleep duration and sleep problems, based on their variations during lockdown, with respect to the pre-pandemic condition..

4.1. Sleep duration

After control for age sex and socioeconomic status, we found a very small effect size of the three sleep duration groups on internalizing and externalizing behaviors; this small effect is probably linked to the similar variations of the internalizing and externalizing scores in the three groups of sleep duration. This consideration is also supported by the higher instability of sleep patterns among children with ADHD also under normal condition [28,29].

Our findings are consistent with other studies [21,30] suggesting that patients with ADHD did not benefit from the COVID-19 lockdown, unlike their healthy peers that experienced an increase of sleep duration in school days. However, it should be taken into account that the participants who increased or decreased their sleep duration in this study were only a minority of the sample.

Moreover, the results of our study suggest to clinicians and researchers that there is a need to carefully intercept this ADHD subgroup (22.3% in Bruni's sample [21]; 21.5% in this sample) at high risk for more severe and chronic impairment in sleep patterns in lifetime.

Table 1
Frequencies and percentage of children in the sleep duration and sleep disturbance subgroup. Data are shown as N (%).

	N° (%)	N° (%)	N° (%)	N° (%)
Sleep duration	**No change**	**Increased**	**Decreased**	
	504 (53.1)	241 (25.4)	204 (21.5)	
Sleep disorders	**No Sleep Problem**	**Onset**	**Remission**	**Maintained**
Difficulties falling Asleep	462 (46.6)	248 (25)	67 (6.8)	215 (21.7)
Anxiety at bedtime	722 (72.8)	111 (11.2)	32 (3.2)	127 (12.8)
Awakening[a]	816 (82.3)	89 (9.0)	18 (1.8)	68 (6.9)
Daytime sleepiness	700 (71.6)	126 (12.9)	50 (5.1)	101 (10.3)
Sleep walking	902 (90.9)	23 (2.3)	21 (2.1)	46 (4.6)
Sleep terrors[a]	938 (94.7)	15 (1.5)	15 (1.5)	23 (2.3)
Snoring	910 (91.7)	8 (0.8)	18 (1.8)	56 (5.6)
Nightmares	770 (77.6)	93 (9.4)	33 (3.3)	96 (9.7)
Hypnic jerks	799 (80.5)	54 (5.4)	32 (3.2)	107 (10.8)
Restless sleep[a]	541 (55.0)	60 (6.1)	66 (6.7)	317 (32.2)
Bruxism[a]	824 (84.4)	6 (0.6)	46 (4.7)	100 (10.2)
Rhythmic movements	922 (92.9)	24 (2.4)	10 (1.0)	36 (3.6)

[a] Total different from 992 because of missing data.

Table 2
Differences in internalizing and externalizing behaviors across sleep duration subgroups. Data shown as mean (SD).

	1. Maintained	2. Increased	3. Decreased	ANOVA F	Effect size	Post-hoc, Tukey HSD		
					η^2	1 vs. 2	2 vs. 3	1 vs. 3
Internalizing behaviors, mean (SD)	4.48 (3.6)	5.02 (3.7)	6.22 (3.8)	1.1	0.001	–	–	–
Externalizing behaviors. mean (SD)	6.16 (4.5)	6.05 (4.2)	7.53 (4.5)	0.1	0.000	–	–	–

Table 3
Differences in internalizing behaviors across sleep problems subgroups. Data shown as mean (SD).

	1.	2.	3.	4.	ANOVA	Effect size	Post hoc, Tukey HSD					
	No Sleep Problem	Onset	Remission	Maintained	F	η^2	1 vs. 2	1 vs. 3	1 vs. 4	2 vs. 3	2 vs. 4	3 vs. 4
Difficulties falling asleep	3.96 (3.4)	5.82 (3.6)	4.48 (3.4)	6.14 (4)	24.8	0.070	<0.0001	0.706	<0.0001	0.031	0.775	0.005
Anxiety at bedtime	4.16 (3.3)	7.11 (4.0)	5.91 (3.8)	7.19 (3.9)	41.1	0.112	<0.0001	0.029	<0.0001	0.312	0.998	0.244
Awakening	4.54 (3.5	6.99 (3.6)	5.22 (4.2)	6.85 (4.2)	17.8	0.052	<0.0001	0.864	<0.0001	0.227	0.995	0.318
Daytime sleepiness	4.26 (3.5)	7.02 (3.7)	4.94 (3.4)	6.70 (3.8)	35.2	0.097	<0.0001	0.630	<0.0001	0.002	0.903	0.019
Sleep walking	4.78 (3.6)	6.83 (3.8)	6.29 (4.5)	6.41 (4.1)	5.0	0.015	0.042	0.249	0.018	0.962	0.971	0.999
Sleep terrors	4.86 (3.7)	6.13 (3.6)	3.93 (2.7)	8.13 (3.1)	6.2	0.018	0.540	0.763	0.000	0.352	0.353	0.003
Snoring	4.82 (3.7)	7.5 (3.1)	5.89 (4.1)	6.09 (3.7)	3.9	0.012	0.171	0.620	0.062	0.730	0.739	0.997
Nightmares	4.46 (3.5)	6.69 (3.6)	4.70 (3.8)	7.14 (3.8)	21.2	0.061	<0.0001	0.984	<0.0001	0.031	0.826	0.004
Hypnic jerks	4.45 (3.5)	7.98 (3.9)	5.47 (3.7)	6.81(3.7)	26.0	0.074	<0.0001	0.398	<0.0001	0.008	0.199	0.237
Restless sleep	4.16 (3.5)	6.33 (3.8)	4.88 (3.6)	5.96 (3.7)	16.9	0.049	<0.0001	0.481	<0.0001	0.106	0.884	0.117
Bruxism	4.69 (3.6)	8.50 (4.4)	4.93 (3.7)	6.36 (3.9)	6.6	0.020	0.059	0.987	0.0002	0.111	0.503	0.126
Rhythmic movements	4.80 (3.7)	7.54 (3.5)	6.30 (4.5)	6.25 (3.5)	5.8	0.017	0.002	0.575	0.094	0.804	0.537	1.000

Table 4
Differences in externalizing behaviors across sleep problems subgroups. Data shown as mean (SD).

	1.	2.	3.	4.	ANOVA	Effect size	Post hoc, Tukey HSD					
	No Sleep Problem	Onset	Remission	Maintained	F	η2	1 vs. 2	1 vs. 3	1 vs. 4	2 vs. 3	2 vs. 4	3 vs. 4
Difficulties falling asleep	5.75 (4.4)	7.02 (4.5)	6.09 (4.2)	7.09 (4.5)	6.8	0.020	0.002	0.943	0.002	0.415	0.998	0.365
Anxiety at bedtime	5.75 (4.2)	8.07 (4.6)	7.28 (4.4)	8.26 (4.8)	16.0	0.047	<0.0001	0.210	<0.0001	0.800	0.987	0.664
Awakening	6 (4.3)	7.62 (4.4)	6.89 (4.8)	9.22 (4.8)	12.9	0.038	0.005	0.831	<0.0001	0.916	0.102	0.181
Daytime sleepiness	5.91 (4.4)	8.07 (4.0)	6.44 (4.3)	7.42 (4.7)	13.4	0.039	<0.0001	0.863	0.008	0.112	0.672	0.565
Sleep walking	6.22(4.4)	7.52 (4.6)	6.57 (4.4)	8.83 (4.7)	4.7	0.014	0.508	0.985	0.001	0.892	0.653	0.211
Sleep terrors	6.28 (4.4)	6.47 (3.8)	6.27 (4.4)	10.87 (5)	7.3	0.022	0.998	1.000	<0.0001	0.999	0.013	0.009
Snoring	6.25 (4.4)	9.25 (4.2)	8.39 (4.4)	7.36 (4.5)	3.7	0.011	0.226	0.180	0.275	0.968	0.668	0.824
Nightmares	6.01 (4.4)	7.46 (4.5)	6.36 (4.3)	8.27 (4.7)	7.8	0.023	0.015	0.973	<0.0001	0.604	0.585	0.137
Hypnic jerks	5.95 (4.3)	8.83 (4.4)	7.13 (4.3)	8.10 (4.6)	12.4	0.037	<0.0001	0.451	<0.0001	0.295	0.747	0.681
Restless sleep	5.51 (4.3)	7.02 (4.6)	6.53 (4.1)	7.58 (4.5)	12.1	0.036	0.084	0.372	<0.0001	0.924	0.798	0.286
Bruxism	6.21(4.46)	10.7 (2.7)	6.48 (4.3)	6.91 (4.2)	1.9	0.006	-	-	-	-	-	-
Rhythmic movements	6.24 (4.4)	8.58 (5.0)	9 (6.4)	7.86 (3.8)	4.2	0.013	0.051	0.202	0.136	0.994	0.925	0.888

4.2. Sleep problems

Consistent with previous studies [5], our findings confirm that sleep problems might exert an influence on internalizing and externalizing behaviors; inter-group comparisons highlight how the presence of sleep problems ("maintained" and "onset" groups)

plays a role on mood-behavioral functioning.

It is noteworthy that the "onset" and "maintained" groups did not show significant differences between them in internalizing and externalizing scores, suggesting that the presence of sleep problems might underlie an increase of both emotional-behavioral problems despite the different duration of sleep problems. The findings support the consideration that the influence of most sleep problems on internalizing and externalizing behaviors seems to occur in a short time and, once established, the severity of mood-behavioral impairment remains stable over time. Although these negative changes in sleep problems were present for a minority of the participants, it is remarkable that the influence of "onset" and "maintained" groups on internalizing scores showed medium and large effect sizes; conversely we observed a small effect size for the same groups on externalizing behaviors.

Again, children with internalizing behaviors resulted susceptible to remission of some sleep problems; conversely, this did not happen with children with externalizing behaviors. Studies on patients with ADHD during lockdown reported significantly increased disruptive behaviors in around 50% of them, and altered child/parents interaction characterized by marked increase in irritability, shouts and verbal abuse, and punishments [19,22,31,32]. Altogether the results suggest that sleep problems could contribute to exacerbate or promote the externalizing behaviors considering that, other studies highlighted a positive association with the externalizing behaviors but not with the internalizing ones [32]. Conversely, the hypothesis of a bidirectional relationship between some sleep problems and internalizing symptoms reported in recent studies seems also to be supported [5].

Finally, our findings indicate that some sleep problems may play a role on internalizing-externalizing behaviors more than others. Previous studies [28,33,34] reported that difficulty falling asleep, nighttime awakenings and daytime sleepiness, are the most common sleep disturbances mainly among children with ADHD and internalizing disorders [35]. Although we have not taken into account comorbidities, our conclusions confirm that ADHD patients with internalizing and externalizing behaviors seem to be vulnerable to the presence of these sleep problems. Moreover, our study underlines that children with internalizing behaviors are significantly responsive also to the "remission" of the same sleep disorders, suggesting that the trends (presence and remission) of these sleep problems play a role on emotional modulation of these children, even at short term. Conversely, variation of parasomnias such as sleep walking, and sleep terrors seem to have a low effect on internalizing and externalizing behaviors even when the presence of these sleep problems is "maintained" over time.

Some studies reported the presence of sleep terrors and sleep walking among patients with ADHD [36] while others referred a prevalence of these parasomnias in children with ADHD similar to that in the general population of the same age [37]. Although sleep disruption in patients with ADHD does not seem to be dependent on comorbidity, suggesting that sleep abnormalities are intrinsic to the ADHD condition [38,39], Ming & Walters [40] observed that it is not clear if sleep terrors and sleep walking reported among children with ADHD could be associated to ADHD itself. Our study does not provide a response to this consideration but suggests longitudinal studies with a wider time interval in order to examine if the persistence of these sleep problems could represent a risk factor over time for the worsening of internalizing-externalizing behaviors in these children [3].

4.3. Strength and limitations

The major strength of this study consists in having identified some changes in sleep problems from a "baseline" to the lockdown condition that could contribute to better define the nature of their relationship with internalizing-externalizing behaviors in children with ADHD. These findings should be taken into account by clinicians in order to modify the natural trajectories of children with ADHD-sleep comorbidity, and for planning targeted interventions involving both domains.

Some limitations must be acknowledged. This cross-sectional survey was conducted a few days after the end of the lockdown, although with still ongoing restrictions, but we cannot exclude a memory bias by the parents. However, other Italian studies on sleep problems of ADHD patients [21], utilizing a different survey and sample, but a similar procedure, reported similar results. Moreover, the questions taken into account defined the pre-pandemic and the lockdown time frames but no specific timing of onset or remission of specific sleep disorders. For a more accurate reliability of the results, further studies should consider this aspect. In addition, since findings taken in account the sleep variations linked to unprecedented experience they couldn't reflect the sleep and mood-behavioral functioning under normal condition, the research model should be replicated though longitudinal studies.

Another important limitation is that the same rater (parents) rated sleep and internalizing/externalizing behaviors therefore, the correlation found might be conditioned by parents bias. We also did not examine the relationship with the medication status, since some parents did not answer to the specific question about the access to medication during the lockdown. Finally, we did not control for other factors that could play a direct or indirect role on severity of internalizing-externalizing behaviors (for example, comorbid conditions, parenting and pa-rental emotion patterns).

This study offers suggestions for future investigations exploring the relationship between sleep and internalizing-externalizing behaviors across other neurodevelopmental disorders characterized by significant sleep issues (e.g. autism spectrum disorders) [41]. These studies would increase our knowledge and help the identification of similarities and differences between these two developmental disorders that show common sleep problems and important rates of comorbidity.

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Institutional review board statement

The study was conducted in accordance with the Declara-tion of Helsinki, and approved by the Ethics Committee of the Department of Developmental and Social Psychology, Sapienza University of Rome.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

CRediT authorship contribution statement

Maria Grazia Melegari: M. conceptualization and study design; data collection and interpretation, Formal analysis, preparation and revision of the manuscript; approved the final manuscript as submitted. **Raffaele Ferri:** conceptualization and study design data collection and interpretation, Formal analysis, revision of the manuscript; approved the final manuscript as submitted. **Martina Giallonardo:** preparation and revision of the manuscript; approved the final manuscript as submitted. **Renato Donfrancesco:** study design; data collection and interpretation; preparation and revision of the manuscript; approved the final manuscript as submitted. **Oliviero Bruni:** conceptualization and study design, data

collection, interpretation; revision of the manuscript; approved the final manuscript as submitted.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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