BPB Reports

Regular Article

Effects of Attention-Deficit/Hyperactivity Disorder Medication on Sleep as Assessed by Actigraphy

Shusuke Uekusa,[a,*] Masumi Watanabe,[a] Yuki Hanai,[a] Seiji Hongo,[b,c] Takashi Yoshio,[d,e] and Kazuhiro Matsuo[a]

[a]*Department of Clinical Pharmacy, Faculty of Pharmaceutical Sciences, Toho University, 2-2-1 Miyama, Funabashi, Chiba 274-8510, Japan;* [b]*Nanko Clinic of Psychiatry, 33 Sekibehikimehashi, Shirakawa, Fukushima Japan;* [c]*Himorogi Psychiatric Institute, 2-31-3 Ichigayatamachi, Shinjuku, Tokyo, Japan;* [d]*Sumiyoshikaiseikai Sumiyoshi Hospital, 4-10-32 Sumiyoshi, Kohu, Yamanashi, Japan;* [e]*Department of Hospital Pharmaceutics, Faculty of Pharmaceutical Sciences, Showa University, 1-5-8 Hatanodai, Shinagawa, Tokyo 142-8555, Japan*

Received September 1, 2025; Accepted November 10, 2025

Objective: Attention-deficit/hyperactivity disorder (ADHD) is a common neurodevelopmental disorder with early onset. Sleep disturbances in children with ADHD may impair attention and learning and exacerbate symptoms. Maintaining good sleep is crucial in ADHD treatment. This study investigated the effects of ADHD medications on subjective and objective sleep in children under 18, employing actigraphy and a questionnaire. Methods: This single-centre prospective observational study enrolled patients under 18 receiving methylphenidate (MPH), lisdexamfetamine (LDX), atomoxetine (ATX), or guanfacine (GXR) between June 1 and August 31, 2022. Patients using other drugs were excluded. Subjective sleep was assessed using the Athens Insomnia Scale (AIS), and objective sleep variables were analysed using an actigraph worn on the waist. Results: A total of 21 patients were enrolled. AIS total scores of 4 or more were significantly more common in GXR-treated patients ($P = 0.009$) than in ATX-treated patients. However, other variables were not statistically significant. Among patients receiving non-psychostimulant monotherapy, sleep time was longer ($P = 0.045$), and postural changes were more frequent ($P < 0.001$) than in those receiving combined psychostimulant and non-psychostimulant therapy. Conclusions: Findings suggest ATX may improve subjective sleep more effectively than GXR. A trend toward shorter sleep period time was observed in the combined group, likely due to the arousal effects of psychostimulants. Reduced postural changes in the combined group may indicate altered sleep structure.

Key words attention-deficit/hyperactivity disorder, guanfacine, atomoxetine, actigraph, sleep

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is a common early-onset neurodevelopmental disorder that affects cognitive, academic, behavioural, emotional, and social functioning.[1,2] Impulsivity and hyperactivity typically emerge around 4 years of age and peak in severity between 7 and 8 years of age.[3] In contrast, attention deficits often become apparent around ages 8 to 9, can persist throughout life, and may contribute to academic challenges.[4] The prevalence of ADHD has been reported to range from 3.5% to 7.1%.[5-7] Given its relatively high prevalence, ADHD is not a rare disorder, and many affected individuals seek clinical care.

Sleep disorders in youth are particularly significant, as they interfere with crucial developmental tasks, including academic performance, examinations, sports, and future employment. The prevalence of sleep disorders in typically developing children is reported to be 11% to 37%,[8,9] whereas in children with ADHD, it is approximately 70%.[10,11] Sleep disorders are significantly more prevalent in children with ADHD than in typically developing children. Furthermore, sleep disturbances in youth have been identified as a risk factor for depression onset,[12] suggesting potential long-term impacts on mental health.

Children with ADHD commonly experience difficulty falling asleep, nocturnal awakenings, sleep-disordered breathing, and excessive daytime sleepiness. Additionally, ADHD has been related to sleep disorder,[13] periodic limb movement disorder, obstructive sleep apnoea, and increased shallow sleep stages.[13-15] Recent studies suggest that the prevalence of sleep disturbances has increased due to coronavirus disease 2019 (COVID-19)-related curfew restrictions, which have disrupted sleep-wake cycles.[16] Given that sleep disturbances can exacerbate ADHD symptoms and impair attention and learning, maintaining good sleep hygiene is considered essential in ADHD management.[17]

*To whom correspondence should be addressed. e-mail: shuusuke.uekusa@phar.toho-u.ac.jp

Medications for ADHD are broadly classified into psychostimulants and non-psychostimulants. Methylphenidate (MPH) and lisdexamfetamine (LDX) are well-established psychostimulants. MPH is one of the most prescribed ADHD medications, accounting for approximately 90% of prescriptions in certain countries[18,19] and 58.8% in Japan.[20] However, insomnia is a frequently reported adverse effect, with incidence rates of 18.2% for MPH[21] and 14.4% for LDX.[22]

MPH has been associated with reduced total sleep time, prolonged sleep onset latency, and decreased sleep efficiency.[23,24] In contrast, LDX appears to have minimal impact on sleep variables.[25,26] Among non-psychostimulants, atomoxetine (ATX) and guanfacine (GXR) are widely used. ATX has the highest prescription rate among non-psychostimulants[20] and has been reported to improve sleep quality compared to MPH.[24,27] GXR, through its sedative effects mediated by adrenergic α2 receptor stimulation, may benefit sleep disorders; however, its impact on sleep, particularly as assessed using actigraphy, remains insufficiently characterised.

Therefore, this study aimed to compare subjective sleep assessments and objective sleep parameters between children with ADHD under 18 years of age receiving ATX and those receiving GXR, or receiving monotherapy with non-psychostimulant and those who receiving a combination of psychostimulants and non-psychostimulants, using actigraphy and sleep questionnaires.

METHODS

Participants This was a single-centre, prospective, observational study. The study protocol was approved by the Ethical Research Committee of the Himorogi Psychiatric Institute. After receiving a detailed explanation of the study, all participants provided written informed consent.

Children and adolescents under 18 years of age who were prescribed MPH, LDX, ATX, or GX for ADHD between June 1, 2022 and August 31, 2022 were enrolled in the study. Patients were excluded if they were prescribed any medications other than MPH, LDX, ATX, or GXR.

Data Collection The following demographic data were collected: age, body weight, height, and sex.

The Athens Insomnia Scale (AIS),[28] a widely used subjective sleep assessment tool, quantifies sleep disturbances based on International Classification of Diseases, 10th edition (ICD-10) criteria. It consists of eight items evaluating different aspects of sleep: sleep onset (AIS1), nighttime awakenings (AIS2), early morning awakening (AIS3), total sleep duration (AIS4), overall sleep quality (AIS5), daytime well-being (AIS6), daytime functioning (AIS7), and daytime sleepiness (AIS8). The AIS demonstrates high validity and reliability in assessing sleep disorders. AIS scores were obtained following informed consent from participants.

Physical activity was recorded using an actigraph (Acous, Maibara, Japan) which was securely positioned on the participants' waistbands with their consent. Data were collected at 2-min intervals. Only activity records that captured continuous data for at least one week, which included both weekends and weekdays, were included in the analysis. The activity data were processed using Sleep Sign® Act software (version 2.0; KISSEI COMTEC, Matsumoto, Japan). The following sleep parameters were assessed for objective sleep evaluation: total sleep time (TST), sleep onset latency (SL), bed-out latency, wake after sleep onset, sleep efficiency, number of postural changes during sleep, number of awakenings, time in bed, sleep period time (SPT), and bed-out time.

Statistical Analyses Sleep parameters were averaged over consecutive weeks during the measurement period. Continuous variables were expressed as medians with interquartile ranges (25th percentile [Q_1], 75th percentile [Q_3]). The Brunner–Munzel test was used to analyse continuous variables, while categorical variables were assessed using Fisher's exact test. All statistical analyses were performed using R software (version 4.4.0; R Foundation, Vienna, Austria, with statistical significance set at $P < 0.05$.

RESULTS

Demographic and Clinical Characteristics A total of 21 patients were enrolled in this study. All patients had been receiving treatment with ADHD medication for at least one year, and the medication regimen used at enrolment had been maintained at the same dosage and administration schedule for at least three months.

The frequency of ADHD medication prescriptions is represented in Fig. 1. Males accounted for 85.7% (18/21) of the study population. The median age, weight, and height were 12 years (10, 14), 44.5 kg (33.7, 54.0), and 151.0 cm (140.5, 160.0), respectively. The prescription rates for different medication regimens were as follows: ATX only, 28.6% (6/21); GXR only, 19.0% (4/21); a combination of ATX and MPH, 23.6% (5/21); a combination of ATX and LDX, 4.8% (1/21); a combination of GXR and MPH, 19.0% (4/21); and a combination of GXR and LDX, 4.8% (1/21). None of the patients in this study received MPH monotherapy, LDX monotherapy, or a two-drug combination of non-psychostimulants.

The distribution of AIS total scores is illustrated in Fig. 2. Nine patients had an AIS total score of ≥4, while only one patient had an AIS total score exceeding 10.

Comparison of Patients with ATX and Patients with GXR Table 1 provides a comparison between patients receiving ATX (either ATX monotherapy or a combination of ATX with MPH or LDX) and those receiving GXR (either GXR monotherapy or a combination of GXR with MPH or LDX). AIS total scores of ≥4 were significantly more frequent in patients treated with GXR ($P = 0.009$). However, no other variables evidenced significant differences between the two groups.

Comparison of Patients with Monotherapy of Non-Psychostimulants and Patients with Combined Psychostimulants and Non-Psychostimulants Table 2 provides a comparison between patients who received monotherapy with non-psychostimulants (ATX monotherapy and GXR monotherapy) and those who received a combination of psychostimulants and non-psychostimulants (a combination of ATX with MPH or LDX, and a combination of GXR with MPH or LDX). Among patients who received monotherapy with non-psychostimulants, SPT was significantly longer ($P = 0.045$), and the frequency of postural changes was significantly higher ($P < 0.001$) than in patients who received a combination of psychostimulants and non-psychostimulants.

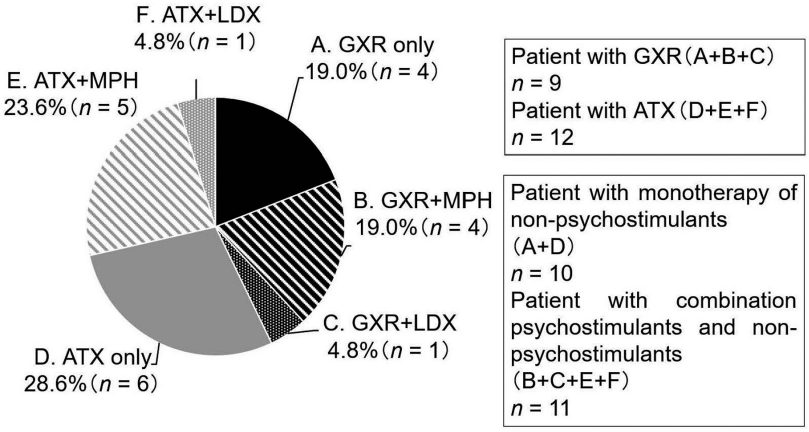

Fig. 1. Frequency of Prescribing ADHD Medication

ADHD: attention-deficit/hyperactivity disorder

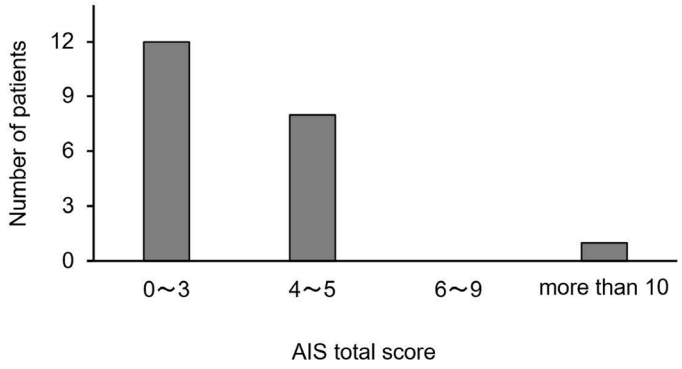

Fig. 2. AIS Total Score Distribution

AIS: Athens Insomnia Scale

DISCUSSION

Participants Were Reflective of the Broader ADHD Population To clarify the effects of ADHD medications on sleep, this study compared subjective sleep status—using AIS and sleep diary questionnaires—with objective sleep status based on actigraphy-derived sleep parameters in patients with ADHD.

In the current study, most participants were male (85.7%). Sex differences in ADHD prevalence are well documented, with male-to-female ratios ranging from 2:1 to 9:1, indicating a higher prevalence among males.[29-31] The male proportion in this study falls within this established range; therefore, we considered the sample to be representative of the patient population with ADHD.

With respect to age, height, and weight, the median age was 12 years, the median height was 151.0 cm, and the median weight was 44.5 kg. A survey conducted by the Ministry of Health, Labour and Welfare in Japan reported that the mean height and weight of 12-year-old males were 148.0 cm and 41.3 kg, respectively, while those of females were 150.9 cm and 41.9 kg.[32] The data from this study showed a trend toward slightly higher body weights compared to these reference values. Children with ADHD have been reported to have 1.10–1.22 times higher odds of obesity compared to children without ADHD.[33,34] This association is thought to be influenced by impulsivity and inattention, core symptoms of ADHD, which may contribute to dysregulated eating behaviours and lower physical activity levels. Therefore, the slightly higher body weight observed in this study may be attributable to the characteristics of the population with ADHD.

Patients Treated with ATX Had Lower Total AIS Scores without Altering Sleep Variables Total AIS scores were significantly higher in the GXR group, while no significant differences were observed in any of the actigraphy-derived sleep variables. This finding presents a discrepancy: subjective dissatisfaction with sleep onset was reported in the GXR group, but no objective differences in sleep parameters were detected. Currently, there are no existing studies directly comparing the effects of ATX and GXR on sleep, making this a new finding.

A study comparing ATX and MPH reported a shorter SL in the ATX group.[24] Additionally, a comparison between the ATX group and healthy controls suggested that ATX administration is associated with the expression of genes related to circadian rhythms, such as *BMAL1* and *PER2*, in human dermal fibroblasts, despite the absence of significant differences in sleep

Table 1. Comparison of Patients with ATX and GXR

Number of patients	with GXR (n = 9)	with ATX (n = 12)	P
Sex (male/female)	8/1	10/2	1.000
with MPH (+/-)	4/5	5/7	1.000
with LDX (+/-)	1/8	1/11	1.000
AIS1 (≥1/0)	7/2	4/8	0.081
AIS2 (≥1/0)	2/7	3/9	1.000
AIS3 (≥1/0)	4/5	2/10	0.331
AIS4 (≥1/0)	4/5	3/9	0.397
AIS5 (≥1/0)	5/4	4/8	0.396
AIS6 (≥1/0)	4/5	1/11	0.119
AIS7 (≥1/0)	3/6	1/11	0.272
AIS8 (≥1/0)	7/2	11/1	0.553
AIS total score (≥4/<4)	7/2	2/10	0.009
	Median [Q_1, Q_3]	Median [Q_1, Q_3]	
Height (cm)	156.8 [146.5, 160.0]	144.3 [138.9, 156.0]	0.204
BW (kg)	50.9 [40.7, 54.4]	38.1 [31.1, 51.2]	0.388
Age (y)	12 [11, 14]	12 [9.75, 14.25]	0.339
GXR dose (mg/day)	3 [3, 5]	0	NA
GXR dose per BW (mg/kg/day)	0.08 [0.06, 0.11]	0	NA
ATX dose (mg/day)	0	62.5 [43.75, 80]	NA
ATX dose per BW (mg/kg/day)	0	1.58 [1.45, 1.71]	NA
MPH dose (mg/day)	0 [0, 27]	0 [0, 29.25]	0.937
MPH dose per BW (mg/kg/day)	0 [0, 0.53]	0 [0, 0.66]	0.969
SPT (min)	453.7 [447.1, 460.0]	422 [375.6, 496.4]	0.305
TST (min)	336.0 [316.9, 371.1]	305.7 [257.2, 368.6]	0.359
SE (%)	76.8 [68.7, 79.8]	71.7 [61.0, 76.7]	0.424
WASO (min)	95.7 [78.3, 127.7]	108.0 [88.9, 140.4]	0.668
awakening (times)	14.0 [11.6, 16.4]	13.1 [10.8, 14.9]	0.647
posture change (times)	20.6 [15.7, 26.1]	24.2 [19.6, 25.9]	0.762
BOL (min)	8.0 [6.0, 9.4]	8.6 [7.9, 9.5]	0.704
SL (min)	15.1 [7.4, 19.4]	11.4 [9.5, 13.7]	0.580
TIB (hr:min)	22:33 [22:19, 23:45]	23:16 [22:48, 0:28]	0.240
BOT (hr:min)	6:43 [6:14, 7:12]	6:57 [6:14, 7:12]	0.787

Abbreviations: MPH: methylphenidate, LDX: lisdexamfetamine, AIS: athens insomnia scale, Q_1: 25th percentile, Q_3: 75th percentile, BW: body weight, ATX: atomoxetine, GXR: guanfacine, SPT: sleep period time, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset, BOL: bed out latency, SL: sleep onset latency, TIB: time in bed, BOT: bed out time

variables.[35] However, the effects of GXR on sleep have not yet been investigated using actigraphy. A polysomnographic study comparing GXR to placebo reported a decrease in TST, rapid eye movement (REM) sleep, non-REM sleep, and slow-wave sleep time, as well as an increase in wake time after sleep onset in the GXR group.[36] Dexmedetomidine (DEX), which shares a similar mechanism of action with GXR, is an adrenergic α2 receptor agonist used as a sedative during artificial respiration, surgery, and medical procedures. DEX inhibits noradrenaline release, leading to gamma-aminobutyric acid output from the ventral lateral preoptic nucleus, which is thought to contribute to the generation of non-REM sleep patterns.[37] Additionally, studies have reported that DEX administration alters sleep architecture by increasing the proportion of deep non-REM sleep stages (N2) while reducing the shallow sleep stages (N1) of REM and non-REM sleep.[38,39] Given these findings, it is possible that sleep structural changes induced by GXR may resemble those observed with DEX. This suggests that ATX and GXR may exert distinct effects on sleep.

The findings of this study suggest that ATX may be more beneficial for subjective sleep outcomes; however, the study did not clarify differences in the effects of ATX and GXR on objective sleep parameters. Further research is warranted to elucidate these differences.

Combined Psychostimulants and Non-Psychostimulants Shortens SPT A comparison between a single non-psychostimulant group and a combination of non-psychostimulants and psychostimulants showed a trend toward shorter SPT in the combination group. Similarly, a meta-analysis comparing MPH and placebo reported a significantly shorter TST in the MPH group.[40] Considering these reports, in the present study, the reduction in sleep duration associated with the arousal effects of psychostimulants was observed even when non-psychostimulants were co-administered. Additionally, the suppression of sleep-related movements previously reported in adults was observed in children. However, studies suggest that MPH may increase TST.[41] Furthermore, in a previous study, variations in the effects of sleep variables were observed depending on ADHD symptoms.[42] The present study did not assess ADHD symptoms, and it cannot be ruled out that ADHD symptoms may have influenced sleep.

Combined Psychostimulants and Non-Psychostimulants Reduces Postural Changes A comparison between a single non-psychostimulant group and a combination of non-psychostimulants and psychostimulants showed a trend toward

Table 2. Comparison of patients with monotherapy of non-psychostimulants and patients with combination psychostimulants and non-psychostimulants

Number of patients	with monotherapy of non-psychostimulants (n = 10)	with combination psychostimulants and non-psychostimulants (n = 11)	P
Sex (male/female)	9 / 1	9 / 2	1.000
with ATX (+/-)	6 / 4	6 / 5	1.000
with GXR (+/-)	4 / 6	5 / 6	1.000
AIS1 (≥1/0)	5 / 5	6 / 5	1.000
AIS2 (≥1/0)	3 / 7	2 / 9	0.635
AIS3 (≥1/0)	3 / 7	3 / 8	1.000
AIS4 (≥1/0)	1 / 9	6 / 5	0.063
AIS5 (≥1/0)	5 / 5	4 / 7	1.000
AIS6 (≥1/0)	2 / 8	3 / 8	1.000
AIS7 (≥1/0)	2 / 8	2 / 9	1.000
AIS8 (≥1/0)	9 / 1	9 / 2	1.000
AIS total score (≥4/<4)	4 / 6	5 / 6	1.000
	Median [Q_1, Q_3]	Median [Q_1, Q_3]	
Height (cm)	144.3 [141.1, 155.4]	153.2 [138.9, 156.0]	0.385
BW (kg)	44.4 [33.4, 53.3]	44.5 [36.1, 54.7]	0.647
Age (y)	11.5 [9.5, 12]	13 [10.5, 14.5]	0.159
GXR dose (mg/day)	0 [0, 2.5]	0 [0, 3]	0.845
GXR dose per BW (mg/kg/day)	0 [0, 0.05]	0 [0, 0.07]	0.585
ATX dose (mg/day)	37.5 [0, 48.75]	40 [0, 77.5]	0.686
ATX dose per BW (mg/kg/day)	1.28 [0, 1.67]	1.36 [0, 1.58]	0.769
MPH dose (mg/day)	0	27 [18, 40.5]	NA
MPH dose per BW (mg/kg/day)	0	0.66 [0.46, 0.72]	NA
SPT (min)	458.6 [434.9, 507.6]	431.4 [380.7, 452.6]	0.045
TST (min)	332.1 [273.9, 411.9]	327.7 [300.1, 364.6]	0.800
SE (%)	68.5 [59.8, 77.8]	75.7 [69.5, 78.6]	0.355
WASO (min)	129.3 [98.6, 160.1]	91.1 [76.9, 118.7]	0.091
awakening (times)	16.2 [12.9, 16.6]	11.6 [10.8, 13.9]	0.071
posture change (times)	25.9 [24.3, 26.1]	18.6 [12.7, 21.4]	<0.001
BOL (min)	8.6 [6.9, 10.1]	8.3 [6.7, 9.4]	0.660
SL (min)	11.4 [8.9, 17.9]	12.0 [10.4, 15.9]	0.873
TIB (hr:min)	22:48 [22:04, 23:16]	0:00 [22:33, 1:26]	0.053
BOT (hr:min)	6:43 [6:43, 7:12]	7:12 [6:14, 8:09]	0.651

Abbreviations: ATX: atomoxetine, GXR: guanfacine, AIS: athens insomnia scale, Q_1: 25th percentile, Q_3: 75th percentile, BW: body weight, MPH: methylphenidate, SPT: sleep period time, TST: total sleep time, SE: sleep efficiency, WASO: wake after sleep onset, BOL: bed out latency, SL: sleep onset latency, TIB: time in bed, BOT: bed out time

reduced postural change in the combination group. In a previous study, psychostimulants were shown to suppress movements during sleep.[42] Additionally, rhythmic movements during sleep are observed from infancy onward and are thought to persist in individuals with ADHD, where they manifest as rhythmic movement disorder. These sleep-related movements can appear as large, coarse body movements during REM sleep or as smaller rocking or fine body movements during non-REM sleep.[43] Although no significant difference was observed, MPH has been reported to reduce REM sleep.[23] In present study, we hypothesised that the reduction in the number of postural changes observed in the combination group was due to a decrease in gross body movement, potentially caused by a reduction in REM sleep. Furthermore, since crude body movements typically occur when a major change in sleep state takes place,[44] it is possible that sleep architecture differs between the monotherapy and combination groups. To clarify these effects, a detailed investigation of sleep structure is warranted. We believe that an electroencephalography-based assessment, such as polysomnography, is necessary for further evaluation.

LDX, a psychostimulant, was used in only two cases in this study; therefore, LDX and MPH could not be analysed separately. However, previous studies have reported that LDX has no significant effect on sleep as measured by either polysomnography or actigraphy.[26] Since LDX has only recently been introduced in Japan, further case series data must be collected and analysed in the future.

Additionally, treatment with low-dose melatonin may be beneficial for patients experiencing subjective sleep disturbances, even while taking ADHD medications.[45] In this study, patients receiving concomitant medications other than ADHD treatments were excluded from the comparison of sleep variables. As a result, the potential effects of these additional medications were not assessed but should be explored in future research.

Limitations The current study has certain limitations. First, the number of patients included was relatively small (n = 21). As a result, the study may not have had sufficient statistical power to detect significant differences in inherently variable measures. Additionally, while an ideal comparison would involve analysing GXR and ATX monotherapy separately, the sample size in this study was minimal to facilitate such an analysis. We believe that increasing the sample size in future studies will be necessary to address this limitation.

Second, we were unable to assess treatment efficacy. In

clinical practice, treatment selection must consider efficacy and safety to determine the optimal therapeutic approach for each patient. Furthermore, differences in treatment effectiveness associated with ADHD medication selection may influence sleep patterns.

Third, we were unable to compare daytime activity levels. Many of the patients in this study were school-aged and were reluctant to wear actigraphy devices at school, leading to insufficient data for assessing daily activity levels. Consequently, we were unable to analyse potential relationships between daytime activity and sleep parameters. Actigraphs can assess sleep when worn on a part of the body, making them highly useful for continuous evaluation. Additionally, while not applicable to this study, their ability to monitor daytime activity levels is an advantage. It is necessary to measure activity levels during the day and night and conduct research going forward.

Fourth, this study did not include comparisons with children without ADHD or those not receiving ADHD medication. Future research should incorporate data from children without ADHD and those not undergoing pharmacological treatment to facilitate a more comprehensive comparison.

Conclusion Findings suggest that ATX may improve subjective sleep more effectively than GXR. A trend toward shorter SPT was observed in the combined group, likely due to the arousal effects of psychostimulants. Reduced postural changes in the combined group may indicate altered sleep structure.

Conflict of interest The authors declare no conflict of interest.

REFERENCES

1) Parenti I, Rabaneda LG, Schoen H, Novarino G. Neurodevelopmental disorders: from genetics to functional pathways. *Trends Neurosci.*, **43**, 608–621 (2020).
2) American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. American Psychiatric Association, Arlington, 2013.
3) Applegate B, Lahey BB, Hart EL, Biederman J, Hynd GW, Barkley RA, Ollendick T, Frick PJ, Greenhill L, McBurnett K, Newcorn JH, Kerdyk L, Garfinkel B, Waldman I, Shaffer D. Validity of the age-of-onset criterion for ADHD: A report from the DSM-IV field trials. *J. Am. Acad. Child Adolesc. Psychiatry*, **36**, 1211–1221 (1997).
4) Holbrook JR, Cuffe SP, Cai B, Visser SN, Forthofer MS, Bottai M, Ortaglia A, McKeown RE. Persistence of parent-reported ADHD symptoms from childhood through adolescence in a community sample. *J. Atten. Disord.*, **20**, 11–20 (2016).
5) Canals J, Morales-Hidalgo P, Jané MC, Domènech E. ADHD prevalence in Spanish preschoolers: comorbidity, socio-demographic factors, and functional consequences. *J. Atten. Disord.*, **22**, 143–153 (2018).
6) Wang KY. Updated findings on neurodevelopmental disorders in Taiwan: impact of the institutionalized national healthcare system on prevalence and health outcomes. *Curr. Opin. Psychiatry*, **29**, 144–148 (2016).
7) Yallop L, Brownell M, Chateau D, Walker J, Warren M, Bailis D, Lebow M. Lifetime prevalence of attention-deficit hyperactivity disorder in young adults: examining variations in the socioeconomic gradient. *Can. J. Psychiatry*, **60**, 432–440 (2015).
8) Owens JA, Spirito A, McGuinn M, Nobile C. Sleep habits and sleep disturbance in elementary school-aged children. *J. Dev. Behav. Pediatr.*, **21**, 27–36 (2000).
9) Stein MA, Mendelsohn J, Obermeyer WH, Amromin J, Benca R. Sleep and behavior problems in school-aged children. *Pediatrics*, **107**, E60 (2001).
10) Becker SP, Pfiffner LJ, Stein MA, Burns GL, McBurnett K. Sleep habits in children with attention-deficit/hyperactivity disorder predominantly inattentive type and associations with comorbid psychopathology symptoms. *Sleep Med.*, **21**, 151–159 (2016).
11) Sung V, Hiscock H, Sciberras E, Efron D. Sleep problems in children with attention-deficit/hyperactivity disorder: prevalence and the effect on the child and family. *Arch. Pediatr. Adolesc. Med.*, **162**, 336–342 (2008).
12) Chang PP, Ford DE, Mead LA, Cooper-Patrick L, Klag MJ. Insomnia in young men and subsequent depression. The Johns Hopkins Precursors Study. *Am. J. Epidemiol.*, **146**, 105–114 (1997).
13) Cortese S, Faraone SV, Konofal E, Lecendreux M. Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. *J. Am. Acad. Child Adolesc. Psychiatry*, **48**, 894–908 (2009).
14) Cortese S, Konofal E, Yateman N, Mouren MC, Lecendreux M. Sleep and alertness in children with attention-deficit/hyperactivity disorder: a systematic review of the literature. *Sleep*, **29**, 504–511 (2006).
15) Golan N, Shahar E, Ravid S, Pillar G. Sleep disorders and daytime sleepiness in children with attention-deficit/hyperactive disorder. *Sleep*, **27**, 261–266 (2004).
16) Becker SP, Epstein JN, Tamm L, Tilford AA, Tischner CM, Isaacson PA, Simon JO, Beebe DW. Shortened sleep duration causes sleepiness, inattention, and oppositionality in adolescents with attention-deficit/hyperactivity disorder: findings from a crossover sleep restriction/extension study. *J. Am. Acad. Child Adolesc. Psychiatry*, **58**, 433–442 (2019).
17) Bruni O, Giallonardo M, Sacco R, Ferri R, Melegari MG. The impact of lockdown on sleep patterns of children and adolescents with ADHD. *J. Clin. Sleep Med.*, **17**, 1759–1765 (2021).
18) Beau-Lejdstrom R, Douglas I, Evans SJW, Smeeth L. Latest trends in ADHD drug prescribing patterns in children in the UK: prevalence, incidence and persistence. *BMJ Open*, **6**, e010508 (2016).
19) Furu K, Karlstad Ø, Zoega H, Martikainen JE, Bahmanyar S, Kieler H, Pottegård A. Utilization of stimulants and atomoxetine for attention-deficit/hyperactivity disorder among 5.4 million children using population-based longitudinal data. *Basic Clin. Pharmacol. Toxicol.*, **120**, 373–379 (2017).
20) Okumura Y, Usami M, Okada T, Saito T, Negoro H, Tsujii N, Fujita J, Iida J. Prevalence, incidence and persistence of ADHD drug use in Japan. *Epidemiol. Psychiatr. Sci.*, **28**, 692–696 (2019).
21) Janssen Pharmaceutical (2024). *K.K. Concerta® Tablets, package insert*
22) Coghill D, Banaschewski T, Lecendreux M, Soutullo C, Johnson M, Zuddas A, Anderson C, Civil R, Higgins N, Lyne A, Squires L. European, randomized, phase 3 study of lisdexamfetamine dimesylate in children and adolescents with attention-deficit/hyperactivity disorder. *Eur. Neuropsychopharmacol.*, **23**, 1208–1218 (2013).
23) Galland BC, Tripp EG, Taylor BJ. The sleep of children with attention deficit hyperactivity disorder on and off methylphenidate: a matched case-control study. *J. Sleep Res.*, **19**, 366–373 (2010).
24) Sangal RB, Owens J, Allen AJ, Sutton V, Schuh K, Kelsey D. Effects of atomoxetine and methylphenidate on sleep in children with ADHD. *Sleep*, **29**, 1573–1585 (2006).
25) Adler LA, Goodman D, Weisler R, Hamdani M, Roth T. Effect of lisdexamfetamine dimesylate on sleep in adults with attention-deficit/hyperactivity disorder. *Behav. Brain Funct.*, **5**, 34 (2009).
26) Giblin JM, Strobel AL. Effect of lisdexamfetamine dimesylate on sleep in children with ADHD. *J. Atten. Disord.*, **15**, 491–498 (2011).
27) Cheng JYW, Chen RYL, Ko JSN, Ng EML. Efficacy and safety of atomoxetine for attention-deficit/hyperactivity disorder in children and adolescents–meta-analysis and meta-regression analysis. *Psychopharmacology (Berl.)*, **194**, 197–209 (2007).
28) Soldatos CR, Dikeos DG, Paparrigopoulos TJ. Athens Insomnia Scale: validation of an instrument based on ICD-10 criteria. *J. Psychosom. Res.*, **48**, 555–560 (2000).
29) Bauermeister JJ, Shrout PE, Chávez L, Rubio-Stipec M, Ramírez R, Padilla L, Anderson A, García P, Canino G. ADHD and gender: are risks and sequela of ADHD the same for boys and girls? *J. Child Psy-*

chol. Psychiatry, **48**, 831–839 (2007).
30) Huss M, Hölling H, Kurth BM, Schlack R. How often are German children and adolescents diagnosed with ADHD? Prevalence based on the judgment of health care professionals: results of the German health and examination survey (KiGGS). *Eur. Child Adolesc. Psychiatry*, **17**, 52–58 (2008).
31) Rucklidge JJ. Gender differences in attention-deficit/hyperactivity disorder. *Psychiatr. Clin. North Am.*, **33**, 357–373 (2010).
32) Ministry of Health. Labour and Welfare. "National health and nutrition survey." <http://www.mhlw.go.jp/toukei/itiran/gaiyo/k-eisei.html>, cited 1st September 2025.
33) Cortese S, Moreira-Maia CR, St Fleur D, Morcillo-Peñalver C, Rohde LA, Faraone SV. Association between ADHD and obesity: a systematic review and meta-analysis. *Am. J. Psychiatry*, **173**, 34–43 (2016).
34) Nigg JT, Johnstone JM, Musser ED, Long HG, Willoughby MT, Shannon J. Attention-deficit/hyperactivity disorder (ADHD) and being overweight/obesity: new data and meta-analysis. *Clin. Psychol. Rev.*, **43**, 67–79 (2016).
35) Faltraco F, Palm D, Uzoni A, Simon F, Tucha O, Thome J. Atomoxetine and circadian gene expression in human dermal fibroblasts from study participants with a diagnosis of attention-deficit hyperactivity disorder. *J. Neural Transm. (Vienna)*, **128**, 1121–1133 (2021).
36) Rugino TA. Effect on primary sleep disorders when children with ADHD are administered guanfacine extended release. *J. Atten. Disord.*, **22**, 14–24 (2018).
37) Nelson LE, Lu J, Guo T, Saper CB, Franks NP, Maze M. The alpha2-adrenoceptor agonist dexmedetomidine converges on an endogenous sleep-promoting pathway to exert its sedative effects. *Anesthesiology*, **98**, 428–436 (2003).
38) Liu H, Wei H, Qian S, Liu J, Xu W, Luo X, Fang J, Liu Q, Cai F. Effects of dexmedetomidine on postoperative sleep quality: a systematic review and meta-analysis of randomized controlled trials. *BMC Anesthesiol.*, **23**, 88 (2023).
39) Zhang Z-F, Su X, Zhao Y, Zhong C-L, Mo X-Q, Zhang R, Wang K, Zhu S-N, Shen Y-E, Zhang C, Wang D-X. Effect of mini-dose dexmedetomidine supplemented intravenous analgesia on sleep structure in older patients after major noncardiac surgery: a randomized trial. *Sleep Med.*, **102**, 9–18 (2023).
40) De Crescenzo F, Armando M, Mazzone L, Ciliberto M, Sciannamea M, Figueroa C, Janiri L, Quested D, Vicari S. The use of actigraphy in the monitoring of methylphenidate versus placebo in ADHD: a meta-analysis. *Atten. Defic. Hyperact. Disord.*, **6**, 49–58 (2014).
41) Chin W-C, Huang Y-S, Chou Y-H, Wang C-H, Chen K-T, Hsu J-F, Hsu S-C. Subjective and objective assessments of sleep problems in children with attention deficit/hyperactivity disorder and the effects of methylphenidate treatment. *Biomed. J.*, **41**, 356–363 (2018).
42) Surman CBH, Walsh DM. Understanding the impact of stimulants on sleep in ADHD: evidence from systematic assessment of sleep in adults. *CNS Drugs*, **36**, 253–260 (2022).
43) Prihodova I, Skibova J, Nevsimalova S. Sleep-related rhythmic movements and rhythmic movement disorder beyond early childhood. *Sleep Med.*, **64**, 112–115 (2019).
44) Masaya K, Hiroshi H. Extraction of body movement characteristics during sleep by measuring at different body sites. *Trans. Jpn. Soc Med. Biol. Eng.*, **52**, 175–180 (2014).
45) Checa-Ros A, Muñoz-Hoyos A, Molina-Carballo A, Viejo-Boyano I, Chacín M, Bermúdez V, D'Marco L. Low doses of melatonin to improve sleep in children with ADHD: an open-label trial. *Children (Basel)*, **10**, 1121 (2023).