Association Between Attention-Deficit/Hyperactivity Disorder and Sleep Impairment in Adulthood: Evidence From a Large Controlled Study

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Objective: To examine whether sleep impairment is associated with attention-deficit/hyperactivity disorder (ADHD) in adults.

Method: In a study conducted from 1998 to 2003, we identified sleep characteristics in a community sample of 182 cases of *DSM-IV* ADHD or ADHD not otherwise specified and 117 non-ADHD controls aged 18 to 55 years. Attention-deficit/hyperactivity disorder status, current and lifetime psychiatric comorbidity, and pharmacologic treatment of ADHD were identified with the Structured Clinical Interview for *DSM-IV* and with modules from the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Epidemiologic Version. Sleep problems were characterized by self-report. We separately accounted for the contribution of age at ADHD onset, ADHD pharmacotherapy, lifetime bipolar disorder, and the following lifetime and current comorbidities: depression, generalized anxiety, substance abuse, and multiple anxiety disorders.

Results: Adults with ADHD went to bed later than control subjects and had a wider range of bedtimes (mean ± SD = 18 ± 92 min vs 54 ± 69 min before midnight; $P < .001$), were more likely to take over an hour to fall asleep (OR = 5.22, $P = .001$), and were more likely ($P < .003$) to experience difficulty going to bed, going to sleep, sleeping restfully, or waking in the morning. Adults with ADHD experienced daytime sleepiness more often (OR = 2.23, $P = .003$) and reported more sleep problems (mean ± SD = 6.7 ± 2.5 vs 4.3 ± 2.2; $P < .001$) than controls. All sleep impairments were significantly associated with ADHD independent of contributions to sleep disruption from ADHD pharmacotherapy, comorbidities likely to contribute to sleep disturbance, and age at ADHD onset.

Conclusion: Sleep disturbances that are not attributable to comorbid mental health conditions or ADHD pharmacotherapy are associated with ADHD in adulthood. Clinicians and researchers should consider the potential contribution of sleep disruption to the clinical presentation of adults with ADHD.

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Sleep disorders and attention-deficit/hyperactivity disorder (ADHD) are common causes of functional impairment in the general adult population. Three percent to four percent of adults in the United States may have ADHD,[1–3] and 24% of individuals aged 18 years or older contacted in the 2005 Sleep in America Survey reported having sleep problems impacting daytime functioning.[4] Prior reports preliminarily suggest that there may be an association between ADHD and sleep disturbance in children.[5–9] Because the functional manifestations of sleep impairment and ADHD may overlap, and because adults are at heightened risk for sleep disorders, clarification of whether these entities are associated in adulthood would have significant clinical implications.[10,11]

Surveys of adults suggest an association between ADHD and sleep disruption. For example, 219 adults with clinical diagnoses of *DSM-IV* ADHD recalled frequent difficulty falling asleep (72%) and disrupted sleep (83%) prior to starting stimulant treatment.[12] Another survey[13] administered a validated screen for ADHD to 2,284 Taiwanese college students. It found that students highly likely to have ADHD were more likely to report current and lifetime sleep problems than were those not likely to have ADHD.[13] These surveys, however, did not account for the possible contribution of comorbid mental health disorders, which are common in adults with ADHD,[2,14–16] or pharmacotherapy for ADHD, which may impact sleep.

Studies of adults that partially accounted for the contribution of comorbidity or pharmacotherapy also suggest an association between ADHD and sleep disruption. In a sample of 120 adults meeting *DSM-IV* criteria for ADHD, Schredl et al[17] found that comorbidity and depressive symptoms were associated with insomnia, but this study did not report systematic methods for identifying mental health diagnoses. Sixty-one of these 120 adults with ADHD were

classified as not having mental health comorbidity or ADHD pharmacotherapy and reported poorer sleep quality and feeling less refreshed in the morning than did control subjects.[17] Boonstra et al[18] controlled for level of current depression and anxiety symptoms in their analysis of actigraphic data from 33 individuals with ADHD fulfilling a research definition of ADHD (requiring 5 rather than 6 current symptoms in the inattentive or impulsive-hyperactive category). They demonstrated that these adults had significantly greater sleep onset latency, lower sleep efficiency, and shorter periods of uninterrupted sleep than did control subjects.[18]

Two small investigations[19,20] of sleep in adults with ADHD that accounted for comorbidity and pharmacotherapy effects report systematic characterization of diagnoses. Actigraphic assessments over 6 days in 8 adults with systematically identified *DSM-IV* ADHD who were not receiving ADHD pharmacotherapy found higher nighttime activity in comparison to control subjects, differences that were not accounted for by comorbid Axis I *DSM-IV* conditions. However, sleep-log data revealed no differences between the ADHD and control participants in this study, and reports of worse sleep quality in ADHD participants were accounted for by the presence of comorbidity.[19] The only controlled polysomnographic study[20] of adults with ADHD reported to date included 20 individuals meeting *DSM-IV* and *ICD-10* criteria for ADHD, excluding individuals with sleep apnea or current comorbid psychiatric diagnoses. The ADHD subjects in this study reported, relative to control subjects, worse overall sleep quality during sleep study nights, and during a 2-week period reported both worse overall sleep quality and worse total sleep time. These findings were not replicated on polysomnography, which demonstrated, relative to control subjects, that ADHD subjects had greater total sleep time and greater sleep efficiency despite significantly higher nighttime motor activity and arousals associated with periodic leg movements.[20]

While findings to date are consistent with a possible association of sleep impairment with ADHD in adulthood, very limited data are available from studies that systematically accounted for contributions of mental health comorbidity and pharmacotherapy. To clarify whether sleep disruption is associated with ADHD in adulthood, we characterized sleep in a large community sample of adults with and without *DSM-IV* ADHD, utilizing systematic methods of identifying diagnoses and ADHD treatment status. We hypothesized that adults with ADHD would be more likely to report sleep disruption than would adults without ADHD but that comorbid mental health conditions and pharmacotherapy would partially account for this association.

METHOD

Participants

Men and women between the ages of 18 and 55 were ascertained as probands in a family study that was designed to systematically characterize adults with and without ADHD.[21] The study was conducted from 1998 to 2003 and was approved by the institutional review board at Massachusetts General Hospital. Subjects with major sensorimotor handicaps, psychosis, inadequate facility with English, or a full-scale intelligence quotient (IQ) less than 80 (as measured by the IQ estimated from the block design and vocabulary subtests of the Wechsler Adult Intelligence Scale-Revised[22]) were excluded. Subjects with and without ADHD were recruited via advertisements in the greater Boston area. Subjects with ADHD were also ascertained from referrals to psychiatric clinics at the Massachusetts General Hospital. After complete description of the study was given to the subjects, written informed consent was obtained.

The ADHD subjects included 75 persons with *late-onset* ADHD (after age 7), defined as we have previously described.[21] Eighty-three percent of such late-onset subjects experienced ADHD symptoms by age 12. All other ADHD subjects were classified as *full* ADHD, defined as we previously have described,[21] and experienced onset by age 7. We previously demonstrated few differences in the psychopathology or the ADHD characteristics distinguishing these 2 ADHD groups from non-ADHD control subjects. Forty-one subjects whom we previously classified as *subthreshold* ADHD[21] were excluded from analysis because our prior work suggests that they comprise a mix of ADHD and non-ADHD patients.[21,23–25]

Diagnostic Interviews

Lay interviewers, trained as previously described,[21] administered the Structured Clinical Interview for *DSM-IV*[26] and modules from the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Epidemiologic Version,[27] remaining blind to ascertainment status. When childhood disorders were reviewed, subjects were first queried about childhood symptoms and, if present, were asked about continuation of these symptoms into adulthood and the emergence of other symptoms. Age at onset was defined as the first emergence of impairing symptoms.

Board-certified child and adolescent psychiatrists or licensed psychologists supervised the interviewers and formed a committee that reviewed structured interview data presented by the interviewers. The committee remained blind to each subject's ascertainment group. Best-estimate diagnoses, as described by Leckman et al,[28] were made for lifetime (prior to the past month) and current (past month) intervals. The median κ coefficient of agreement for diagnoses between diagnostic committee members was 0.98 for 500 audiotaped assessments. The κ coefficients for individual diagnoses were the following: ADHD (0.88), major depressive disorder (MDD) (1.0), mania (0.95), separation anxiety (1.0), agoraphobia (1.0), panic disorder (0.95), obsessive-compulsive disorder (OCD) (1.0), generalized anxiety disorder (GAD) (0.95), specific phobia (0.95),

posttraumatic stress disorder (1.0), social phobia (1.0), and substance use disorder (SUD) (1.0). Definite diagnoses were assigned if consensus was achieved that diagnostic criteria were met to a clinically concerning degree.

Sleep Assessment

Participants were administered a self-report survey of sleep disturbance. This survey included the 22 questions from the Children's Sleep Behavior Scale,[29] reviewing the past 6 months. Twenty-one of these questions have answer options of "Never," "Rarely (once)," "Occasionally (2 or 3 times)," "Quite Often (4 or 5 times)," "Often (6 times or more)," and "Don't Know" and ask about the following: going to bed willingly, restless sleep, smiling during sleep, waking during the night, talking during sleep, sleep walking, sitting up while asleep, grinding teeth while asleep, laughing in sleep, having a frightening dream, repetitive actions during sleep, problems with bed wetting, falling asleep easily, having nightmares that were forgotten, fear of sleeping in the dark, waking easily in the morning, having really scary nightmares, crying in sleep, having a pleasant dream, difficulty going to sleep, and getting up to go to the bathroom. Another question asks about time slept per night with answer options of "4–5 hours," "6–7 hours," "8–9 hours," "10–11 hours," or "greater than 11 hours." Binary measures were created for each item, coded positive if the subject reported "Quite Often" or "Often," except for queries regarding going to bed willingly, falling asleep easily, and waking easily in the morning, which were coded positive if the subject reported "Never" or "Rarely." Time slept per night was coded positive if less than 8 hours of sleep was reported. We assessed total sleep dysfunction by calculating the total number of positive dysfunctional responses to these 22 sleep-behavior scale items. "Don't Know" responses were treated as missing data.

In addition, we also asked participants the time they usually went to bed, how long it took them to get to sleep once they were in bed, whether they awoke during the night (and if so how many times), what time they awoke in the morning, whether they took naps during the day, whether they ever seemed to need less sleep than other people their age, whether they were usually the first person up in the morning, and whether they ever experienced daytime sleepiness.

Statistical Analyses

We compared the control and ADHD groups on potentially confounding demographic variables, using the Pearson χ^2 test for sex and the Student *t* test for age. We used logistic regression to assess binary sleep questionnaire items and negative binomial regression to assess the total number of sleep problems. Dummy variables indicating group membership were the independent variables, along with any additional covariates, in all regressions. We used a Bonferroni-adjusted α level of .003 when comparing groups on sleep questionnaire items and an α level of .05 elsewhere (eg, sleep characteristics); all statistical tests were 2-tailed.

Table 1. Demographic Characteristics of Adults With and Without ADHD (N = 299)

Variable	Control Group, n = 117	ADHD Group, n = 182	Statistic	*df*	*P* Value
Age, mean ± SD, y	29.38 ± 8.60	36.26 ± 10.80	$t = 5.82$	297	< .001
Gender, male, n (%)	55 (47)	94 (52)	$\chi^2 = 0.61$	1	.43

Abbreviation: ADHD = attention-deficit/hyperactivity disorder.

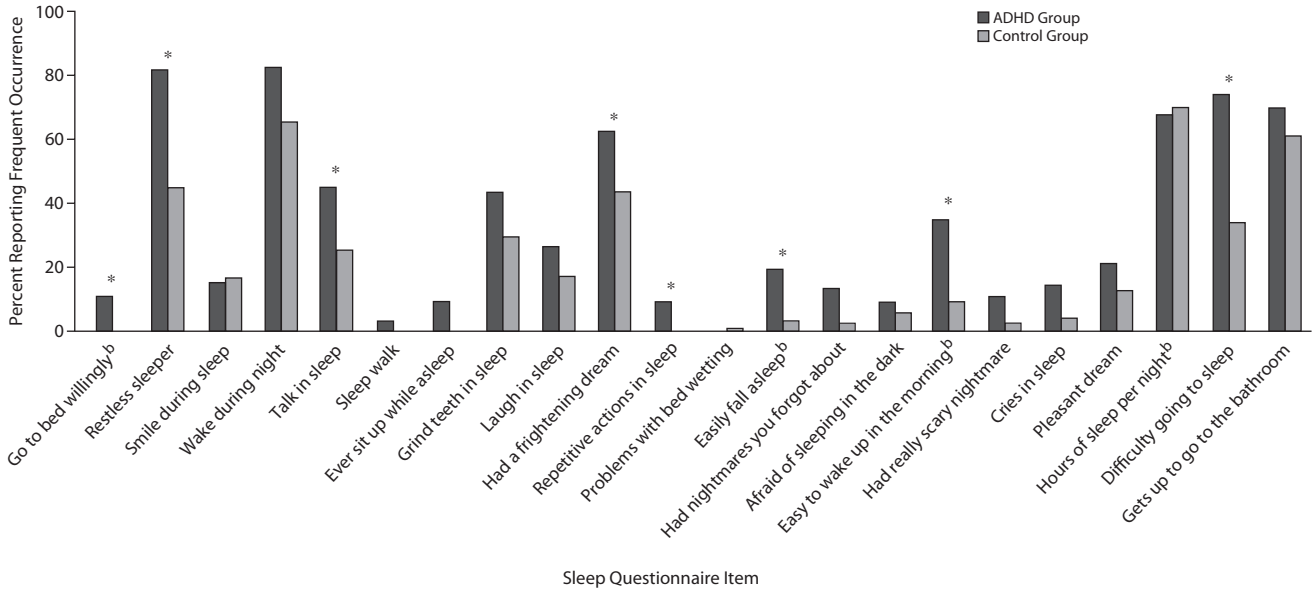
RESULTS

We obtained sleep questionnaire data from 299 adult subjects (117 control subjects, 182 ADHD subjects). We found a significant difference in mean age but not gender (Table 1). All further comparisons of control and ADHD subjects control for age.

Figure 1 shows the frequency of reports of disturbed sleep on sleep questionnaire items controlling for subject age. Subjects with ADHD were significantly more likely to report restless sleeping, talking in sleep, having frightening dreams, repetitive actions in sleep, and difficulty going to sleep. Subjects with ADHD were significantly less likely to report going to bed willingly (ie, reported "Never" or "Rarely"), easily falling asleep, and waking easily in the morning. We repeated the analyses in Figure 1 with only full ADHD cases compared to control subjects, and all significant results maintained significance.

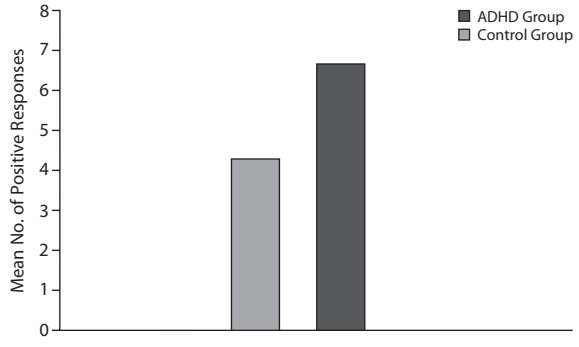
Since psychiatric comorbidity secondary to ADHD may lead to sleep disturbance, we performed the above analysis controlling, separately, for current (past month) and lifetime manifestation of MDD, SUD, GAD, or multiple anxiety disorders (ie, 2 or more anxiety disorders). Talking in sleep lost significance when analyses controlled for lifetime SUD, lifetime MDD, current MDD, or lifetime multiple anxiety disorders. Having a frightening dream was no longer significant after controlling for lifetime SUD, lifetime MDD, current MDD, lifetime GAD, current GAD, or lifetime multiple anxiety disorders. Performing repetitive actions in sleep was no longer significant after controlling for lifetime SUD, current SUD, current MDD, lifetime GAD, lifetime multiple anxiety disorders, or current multiple anxiety disorders. When analyses controlled for current MDD, falling asleep easily lost significance. Difficulty going to bed willingly, sleeping restfully, waking up in the morning, and going to sleep always remained significant when controlling for each comorbid disorder. We also tested whether significant results were accounted for by comorbid bipolar disorder by removing subjects who endorsed lifetime bipolar disorder. All results remained significant. Sixty-three ADHD subjects had pharmacologic treatment of ADHD within the year prior to the study (n = 57 for stimulants, n = 4 for nonstimulants, n = 2 for missing). We tested whether pharmacologic

Figure 1. Rates and Types of Frequent Sleep Disruption in Adults With and Without ADHD (N = 299)[a]



[a]Analysis controlled for age.
[b]Ratings of "often" or "very often" were considered frequent—except for footnoted items, coded as frequently impaired if subjects reported "never" or "rarely," or if they reported < 8 hours for "hours of sleep per night."
*$P < .003$.
Abbreviation: ADHD = attention-deficit/hyperactivity disorder.

Figure 2. Total Sleep Questionnaire Score in Adults With and Without ADHD (N = 299)[a]



[a]$P < .001$.
Abbreviation: ADHD = attention-deficit/hyperactivity disorder.

ADHD treatment affected frequency of questionnaire responses by testing 2-by-2 contingency tables of "Rarely" versus "Frequently" responses between currently treated (within the past year) and currently untreated ADHD subjects. Adult ADHD subjects with current pharmacologic treatment (n = 50) were more likely to report having really scary nightmares than were those without current pharmacologic treatment (n = 96; Pearson χ^2 test: $\chi^2_1 = 6.4$, $P = .01$). No other sleep questionnaire item was significantly associated with ADHD treatment.

ADHD subjects reported significantly more sleep problems (mean ± SD = 6.7 ± 2.5) compared to controls (mean ± SD = 4.3 ± 2.2; $z = 7.59$, $P < .001$; Figure 2). This result maintained significance when, in separate analyses, we removed any subjects endorsing bipolar disorder, included only full ADHD, and controlled for current or lifetime manifestation of GAD, multiple anxiety disorders, MDD, or SUD. We found no difference in overall sleep dysfunction score between subjects with ADHD pharmacotherapy (n = 63; mean ± SD = 6.6 ± 2.7) and subjects without ADHD pharmacotherapy (n = 119; mean ± SD = 6.7 ± 2.5; $z = -0.28$, $P = .78$).

Using linear regression and controlling for age, we found that ADHD subjects reported significantly later bedtimes (mean ± SD = 11:45 pm ± 93 minutes), by more than half an hour, than control subjects (mean ± SD = 11:09 pm ± 68 minutes; $t_{290} = 5.81$, $P < .001$). A significantly larger proportion of ADHD subjects reported more than 1 hour in bed before falling asleep (Table 2). Subjects with ADHD were also significantly more likely to have been awakened during the night compared to controls and reported more daytime sleepiness than did controls but did not have a significantly higher frequency of napping during the day, needing less sleep than others, or being the first person up in the morning. We repeated all of the above analyses of sleep characteristics controlling for lifetime or current GAD, multiple anxiety disorders, MDD, and SUD, excluding subjects with late-onset ADHD and subjects with lifetime bipolar

Table 2. Characteristics of Sleep in Control and ADHD Subjects (N = 299)[a]

Variable	Control Group, n = 117, n (%)[b]	ADHD Group, n = 182, n (%)[b]	OR	95% CI	*z*	*P* Value
Time to fall asleep[c]	5 (4)	30 (17)	5.22	1.91–14.28	3.22	.001
Awaken during night	67 (59)	135 (77)	1.84	1.07–3.16	2.20	.03
Nap during day	24 (21)	56 (31)	1.62	0.91–2.89	1.64	.10
Need less sleep	27 (23)	62 (35)	1.44	0.82–2.51	1.27	.20
First person up	41 (37)	82 (47)	1.11	0.65–1.87	0.37	.71
Daytime sleepiness	35 (30)	83 (47)	2.23	1.32–3.78	3.00	.003

[a]Logistic regression controlling for age.
[b]Sample sizes range from 111 to 116 for controls and 173 to 179 for ADHD due to missing data.
[c]Positive response indicates > 1 hour in bed before falling asleep.
Abbreviation: ADHD = attention-deficit/hyperactivity disorder.

disorder. Awakening during the night lost significance when subjects with bipolar disorder were excluded and when controlling for lifetime and current GAD, lifetime and current multiple anxiety disorders, and lifetime and current MDD. None of the other sleep characteristics from Table 2 lost significance. Within the ADHD group, pharmacologic treatment was not significantly associated with any of the sleep characteristics (all $P > .20$).

DISCUSSION

In a large, systematically characterized sample, we found that adults with ADHD were significantly more likely to report sleep-related disturbances than were adults without ADHD. We also found that sleep dysfunction maintained its association with ADHD after accounting for contributions of ADHD pharmacotherapy, ADHD onset age, and current or lifetime major mental health comorbidities likely to manifest in sleep disturbance. On average, individuals with ADHD went to bed more than half an hour later than control subjects and had a wider range of bedtimes. Other sleep disturbances that were more common in ADHD subjects included difficulty going to bed, difficulty going to sleep, taking longer than an hour to fall asleep, restless sleep, difficulty waking in the morning, and daytime sleepiness. Subjects with ADHD also reported significantly higher overall sleep dysfunction compared to controls. To our knowledge, ours is the first evaluation of parasomnia traits in individuals with ADHD—none of the parasomnia traits examined maintained association with ADHD in our analyses.

Prior smaller studies, which accounted in varying degrees for the contribution of comorbidity and pharmacotherapy to sleep in adults with ADHD, echo our finding that deficits in sleep initiation, sleep quality, and daytime alertness are associated with ADHD in adulthood. Boonstra et al[18] reported actigraphic evidence of longer delay to sleep onset in adults with ADHD relative to control subjects after analytically accounting for concurrent mood and anxiety symptoms. Their study and that of Philipsen et al[20] found that adults with ADHD had worse sleep continuity than did control subjects. Philipsen et al[20] and Schredl et al[17] both excluded ADHD subjects with current comorbidity or ADHD pharmacotherapy and found poorer sleep quality in adults with ADHD than in controls. Schredl et al[17] also echo our finding that *DSM-IV* ADHD is associated with poorly refreshing sleep in adults.

We found association between ADHD pharmacotherapy and only 1 sleep disturbance symptom, having scary nightmares, but prior studies have implicated stimulants in different patterns of sleep impact in adults with ADHD. One prior study[18] found that when taking methylphenidate, ADHD subjects had fewer nocturnal awakenings and fewer interruptions in sleep as measured by actigraphy but also had later bedtimes, later sleep onset, and shorter sleep duration, findings that were not accounted for by self-reported depression and anxiety symptoms. Kooij et al[19] found that methylphenidate treatment was associated with evidence of improved sleep in the form of decreased nighttime actigraphic activity as well as reports of improved sleep quality in ADHD adults relative to control subjects. This latter report is more consistent with the clinical findings of Dodson and Zhang,[12] who found that stimulant treatment can be associated with significant improvements in initial insomnia and less sleep disruption.

We asked participants questions that would identify major patterns of sleep disruption in adults. A portion of the questions we asked came from the Children's Sleep Behavior Scale, which has not been validated for use in adults and includes a few items with a pediatric orientation. However, our assessment of sleep disturbance was not dependent on responses to these pediatric items, and our questionnaire allowed comparison of reported sleep disturbance in adults with and without ADHD. While there may be contributions to sleep disturbances in our study sample from comorbid conditions or alerting/sedating agents that we did not account for, by accounting for lifetime incidence of comorbidities we also accounted for predisposition to subthreshold manifestation of, and pharmacotherapy for, these comorbidities. We may in fact have overcontrolled for the contribution of comorbidity or pharmacotherapy to sleep disruption by accounting for these variables over a longer interval (lifetime and last year) than the interval used to measure sleep characteristics (last 6 months).

Our findings suggest that ADHD in adulthood may be associated with problems of sleep initiation, sleep quality, and awaking/alertness but are not sufficient to implicate particular comorbid sleep diagnoses. Studies[30,31] have found high rates of symptoms of ADHD in patients with hypersomnia[30] and of *DSM-IV* ADHD clinical diagnoses in patients with restless leg syndrome.[31] Cases of sleep-disordered breathing have also been reported in individuals with clinically diagnosed[32,33] and systematically identified *DSM-IV* ADHD.[34] However, research to date has not clarified whether ADHD

is associated with a particular sleep disorder at a rate greater than that expected by chance alone.

Sleep impairment compromises cognitive and behavioral function, and studies provide preliminary evidence that sleepiness may be correlated with ADHD traits. In one study,[35] self-reports of daytime sleepiness and sleep disruption correlated with inattentive and hyperactive traits in young adults. Another study[30] found that self-reported sleepiness correlated with extent of inattentive symptoms in adults with *DSM-IV* ADHD. The recent large Taiwanese survey[13] of ADHD and sleep traits in young adults found that inattention, but not hyperactivity, was associated with greater sleep need and greater difference between sleep need and self-estimated sleep duration. In contrast, a smaller study[36] of 18 adults with clinical diagnoses of *DSM-IV* ADHD or ADHD not otherwise specified did not find correlation between self-reported sleepiness and current inattentive symptoms.

Our study suggests that adults with ADHD are more likely than adults without ADHD to report sleep problems and that their sleep impairments are strongly associated with ADHD independent of mental health comorbidity and ADHD pharmacotherapy. We suggest that clinicians take care to evaluate adults with ADHD for clinically significant sleep impairment and comorbid sleep disorders. Large studies comprehensively characterizing sleep and ADHD may clarify the clinical significance of sleep impairment in adults with ADHD, identify whether specific sleep disorders are associated with ADHD in adulthood, and explore whether common pathophysiology underlies the association of ADHD with sleep disorders.

Drug name: methylphenidate (Daytrana, Ritalin, and others).

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