Sleep in Adults with Attention Deficit Hyperactivity Disorder (ADHD) Before and During Treatment with Methylphenidate: A Controlled Polysomnographic Study

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Study Objectives: Sleep problems are frequently associated with childhood ADHD, as indicated by numerous polysomnographic investigations showing increased nocturnal movements, reduced sleep efficiency, and decreased percentage of REM sleep (although findings are not consistent over all studies). Data on objective and subjective sleep parameters in adults with ADHD are sparse, and to date the impact of stimulants, the most widely used pharmacological treatment for ADHD, on sleep in adults with ADHD has not been examined. Thus the objectives of our study were to assess objective and subjective sleep parameters in adults with ADHD and the impact of stimulant medication on sleep.

Design: Two-group comparison and open-label therapy study.

Participants: We enrolled 34 nonmedicated patients with ADHD, of whom 24 were without current comorbid psychiatric disorders, and 34 sex- and gender-matched control subjects without current psychiatric disorders or psychotropic medication.

Interventions: Ten patients were treated with methylphenidate over ≥26 days with a mean daily dose of 36.7 ± 11.2 mg.

Measurements: Polysomnographic recording over 2 consecutive nights as well as assessments of subjective sleep parameters were performed in all patients and controls before treatment and reassessed in those patients receiving methylphenidate.

Results: Compared to controls untreated patients showed increased nocturnal activity, reduced sleep efficiency, more nocturnal awakenings and reduced percentage of REM sleep. Treatment with methylphenidate resulted in increased sleep efficiency as well as a subjective feeling of improved restorative value of sleep.

Conclusions: Sleep problems in patients with ADHD continue from childhood to adulthood, with similar objective sleep characteristics in adults and children with ADHD. Medication with methylphenidate appears to have beneficial effects on sleep parameters in adults with ADHD.

Keywords: Attention deficit hyperactivity disorder, polysomnography, sleep, methylphenidate

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ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD) WAS LONG CONSIDERED AS A DISORDER PREVALENT ONLY IN CHILDREN AND ADOLESCENTS. MORE recently, however, ADHD has been conceptualized as a lifelong disorder prevalent in most afflicted individuals from childhood to adulthood. Data from independent longitudinal studies clearly provide evidence of a continuation of the disorder into adulthood in up to 60% of afflicted children.[1,2] Additionally, the results of the National Comorbidity Survey Replication show a prevalence of ADHD among the general adult U.S. population to be 4.4%[3].

Due to the clinical observation that sleep problems are common in children with ADHD and the former inclusion of excessive movements during sleep in the diagnostic criteria according to DSM-III,[4] sleep quality and disturbances have been the topic of numerous studies carried out in children with ADHD (for review see reference 5). Studies assessing subjective sleep disturbances consistently revealed more problems with falling asleep along with longer sleep latencies, more bedtime struggles, nocturnal awakenings, restless sleep, daytime sleepiness, and a higher rate of enuresis compared to control children without ADHD, indicating an approximately fivefold increase in the rate of sleep problems in children with ADHD.[5,6] Although conflicting in some aspects, investigations of objective sleep parameters have quite consistently shown reduced REM sleep, more nocturnal movements, increased frequency of periodic limb movements (PLMS) and PLMS-associated arousal as well as elevated daytime somnolence in children with ADHD when compared to controls.[7-11]

While sleep problems are also common in the clinical practice of adult ADHD, studies examining sleep in adults with ADHD are relatively sparse. To the best of our knowledge there are 3 questionnaire studies (n = 219, n = 141, n = 120), one controlled actigraphic (n = 8) and one controlled polysomnographic (n = 20) study assessing sleep parameters in adults with ADHD.[12-17] As a common finding the cited questionnaire studies consistently report high rates of sleep problems in up to 83% of the assessed adults, including sleep onset problems, restless sleep, and insufficient restorative value of sleep.[12-14] Both studies assessing objective sleep parameters report significantly more nocturnal periodic leg movements and an elevated movement level during sleep, whereas no differences in sleep architecture or efficiency were found between patients with ADHD and healthy controls.[15,16]

Disclosure Statement

This was not an industry supported study. Dr. Sobanski participated in studies for methylphenidate and has participated in speaking engagements for Eli Lilly and Janssen-Cilag, Ltd. Dr. Alm participated in studies for methylphenidate and has participated in speaking engagements for Eli Lilly and Wyeth. The other authors have indicated no financial conflicts of interest.

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While the influence of stimulants, the most widely used pharmacological treatment for ADHD, on sleep parameters has been extensively studied in children[18-26] there is currently only one small actigraphic study assessing the effect of stimulant medication on sleep patterns and quality in adults with ADHD.[15]

The aim of our study was to investigate the following topics.

As the results of the only available polysomnographic study on sleep in adults with ADHD differ in some aspects from data obtained in polysomnographic studies in children we wanted to assess objective (polysomnographic) and subjective (self-rated sleep questionnaires) sleep parameters in an independent sample of adults with ADHD. As the majority of studies in children with ADHD found a reduction of REM sleep, which was not the case in the polysomnographic study in adults with ADHD,[16] we were especially interested to see, if our study would confirm this finding. We expected to observe a reduction in the percentage of REM sleep in adult patients as previously been described in children with ADHD.

As there is no polysomnographic or corresponding subjective data on the influence of stimulant medication on sleep parameters in adults with ADHD, we wanted to assess the impact of treatment with methylphenidate on objective and subjective sleep parameters. According to the preliminary results of the actigraphic study we expected a reduction of nocturnal movement level and improved subjective sleep quality.

METHODS

Subjects

The study was approved by the local ethics committee; all participants gave written informed consent before participating in the study. Thirty-four adult patients with ADHD recruited from consecutive referrals to the ADHD outpatient specialty clinic at the Central Institute of Mental Health in Mannheim, Germany, and 34 age- and gender-matched medication-free controls without psychiatric or sleep disorders were included in the study.

All patients met the following inclusion criteria:

- ADHD during childhood and at present according to DSM-IV criteria[27] as assessed in a structured clinical interview.
- Chronic course of the disorder from childhood to adulthood, defined as clinically assessed evidence for ongoing presence of ADHD symptoms since onset, i. e., functional impairment caused by hyperactivity/impulsivity and/or inattention.
- Consensus of a senior psychiatrist (B. A.) and a senior child- and adolescent psychiatrist (E. S.) experienced in the field of ADHD about diagnosis of child and adult ADHD.
- At least 30 points in the short version of the Wender Utah Rating Scale.[28]
- At least 50 points in the Brown Attention Deficit Disorder Scales.[29]
- Healthy on the basis of physical examination.
- Results of routine blood testing (blood count, renal, hepatic, and thyroid function) within normal limits.
- Negative urinary drug screen (including barbiturates, benzodiazepines, cannabinoids, amphetamines, MDMA, cocaine, and opiates).
- Free from psychotropic medication including methylphenidate for the last 4 weeks.

All patients with ADHD who met the following criteria were excluded from study participation:

- Comorbid axis-I disorders, as assessed in a semi-structured clinical interview, which required being treated with priority or could explain the assessed symptoms.
- Comorbid substance abuse/dependency.
- Working on night shift.
- Patients with apnea index >5 in adaptation night.
- Patients with obstructive snoring.
- Contraindication to methylphenidate treatment, e.g., hypertension, hyperthyroidism.

None of the control subjects were suffering from psychiatric or sleep disorders; no subjects were taking psychotropic medication. They participated in different sleep studies.[30-33]

Sleep Recordings

Each patient and control subject spent two consecutive nights (adaptation, baseline) in our sleep laboratory for polysomnographic recording. The first night served as adaptation night and for the exclusion of sleep related breathing disorders (apnea index >5). Data from the baseline night will be presented in the results section. Polysomnography encompassed EEG (C3-A2, C4-A1), horizontal and vertical eye movements, submental and leg electromyogram (left and right anterior tibial muscles), and electrocardiogram. Respiration (oral and nasal air flow, thoracoabdominal respiratory movements, and oxygen saturation) was recorded during the first night only. PLMS were scored according to standard criteria,[34] i.e., if they were part of a series of 4 or more movements lasting ≥5 sec. All recordings were carried out from 23:00 (lights out) to 07:00 (lights on). All sleep recordings were scored in 30-sec epochs, according to Rechtschaffen and Kales criteria.[35]

The following sleep parameters were determined: total time in bed (in minutes); sleep onset latency (min); sleep efficiency (total sleep time/time in bed*100); REM sleep latency (time between sleep onset and first epoch of REM sleep); REM sleep density (ratio of 3-sec mini-epochs of eye movements per REM period including ≥1 REM to the total number of 3-sec mini-epochs per REM sleep*100%); number of awakenings; duration of first REM sleep period (min); REM density of first REM sleep period; percentage wakefulness after sleep onset (time spent awake between sleep onset and final end of sleep); percentage NREM1, NREM2, slow wave sleep (defined as stages NREM3 or NREM4), and REM sleep of total sleep time; PLMS index (number of PLMS/h total sleep time); PLMS arousal index (number of PLMS associated with arousals/h total sleep time, PLMS-A).

Subjective Sleep Parameters

To determine subjective sleep parameters, we administered the self-rated questionnaires Schlaffragebogen A and B,[36,37] which are well-validated instruments widely used in Germany for scientific and clinical purposes. The Schlaffragebogen A (SF-A) comprises 22 items in total and was administered each morning after polysomnographic recording under baseline and medication condition. It provides information about the following 5 composite scores: sleep quality (9 items), restorative value of sleep (8 items), evening mood (5 items), fatigue in

the evening (5 items) and psychosomatic symptoms (5 items). The estimates refer to the previous night. The composite scores range from 1 to 5, since most scales of the sleep questionnaire are constructed as 5-point Likert Scales (1 = not present, 5 = strongly). The item sleep latency is assessed with a 6-point scale (1 = <5 min; 2 = 5 to 10 min, 3 = 10 to 20 min, 4 = 20 to 30 min, 5 = 30 to 60 min, 6 = >1 h) and the item nocturnal awakenings with a 5-point scale (1 = no, 5 = more than 3 times). The Schlaffragebogen-B (SF-B) assesses subjective sleep quality over the previous 2 weeks and comprises the same composite scores as SF-A. It was also administered before polysomnographic recording under baseline and medication condition. The inter-item consistency for the composite scores range from r = 0.77 to r = 0.87 and the retest reliability (4 weeks) is about r = 0.79. Construct validity was shown in several factor analyses, and comparisons with expert ratings were satisfying, e.g., r = 0.78 between nocturnal awakenings and the diagnosis of insomnia.[36]

ADHD Assessments

Wender-Utah-Rating Scale, Short Version

The Wender-Utah-Rating scale, short version (Wurs-k) is a retrospective measure of ADHD symptoms. Using a cutoff score of 30 points its sensitivity and specificity for detection of childhood ADHD is 86% and 80% respectively.[28]

Brown Attention Deficit Disorder Scales

The Brown Attention Deficit Disorder Scales (BADDS) assesses current ADHD-symptoms on the basis of 40 self-rated items encompassing the symptom cluster organizing and activating, sustaining attention, sustaining effort, managing affective interference, and working memory.[29] It has been shown that using a cutoff score of 50 points, its sensitivity was 96% while its specificity for detection of adult ADHD was 94%.[38]

Statistics

Statistical analyses were carried out with SAS for Windows (Version 8.02) software package. Unpaired and paired *t*-tests were computed. Significance level was set to $P < 0.05$.

RESULTS

Subject Characteristics

The total ADHD-sample comprised 34 nonmedicated patients (n = 21 males, n = 13 females; n = 28 ADHD, combined and n = 6 ADHD, predominately inattentive type.) with a mean age of 36.1 ± 9.3 years. The mean total Wurs-k score was 51.1 ± 12.3; the mean total BADDS score was 89.8 ± 20.4 points. Ten patients were suffering from comorbid axis-I disorders, namely combined motor and vocal tic disorder (n = 3), anxiety disorders primarily social phobia (n = 6) and dysthymia (n = 2). None of the comorbid disorders required a priori clinical intervention, and all were judged as mild. The 24 patients with ADHD only did not differ in gender ratio (16 males, 8 females), mean age (36.2 ± 8.9 years), or symptom scores (mean total Wurs-k score: 51.4 ± 12.0 points; mean total BADDS score: 91.7 ± 24.2 points) from the total ADHD sample but comprised a comparatively higher proportion of ADHD combined (n = 21) vs. inattentive type (n = 3) than the total sample.

Patients Treated with Methylphenidate

Under treatment with methylphenidate, 10 patients were reassessed with polysomnographic recording and sleep questionnaires. All reassessed patients (n = 6 combined, n = 4 inattentive type) were male; they had a mean age of 35.0 ± 8.7 years and a mean body weight of 77.5 ± 11.1 kg. They were treated with methylphenidate over a minimum of 26 days, starting with 5 to 10 mg twice daily. Individual doses were adjusted depending on efficacy and side effects to achieve optimal medication effects with a mean daily dose of 36.7 ± 11.2 (20-60) mg.

Sleep Data

Polysomnography in Nonmedicated Patients

Compared to the control group, all subjects in our ADHD sample (n = 34) displayed reduced sleep efficiency, with longer sleep onset latency and more nocturnal awakenings; they had altered sleep architecture, with a higher percentage of stage 1 and reduced percentage of REM sleep. Patients also showed a trend toward a reduced total REM density and elevated percentage of wakefulness after sleep onset. In the ADHD group the PLMS index was 5.5 ± 8.1, the PLMS-A index 0.3 ± 0.4. All other sleep parameters showed no significant difference between ADHD patients and controls (Table 1).

Our results in ADHD patients without comorbidity (n=24) did not differ from those obtained in the total sample. Patients with ADHD only showed reduced sleep efficiency with more nocturnal awakenings and altered sleep architecture, with reduced percentage of REM sleep and REM density compared with the control group. In the ADHD group the PLMS index was 4.6 ± 5.6, the PLMS-A index 0.3 ± 0.5. Other sleep parameters did not differ significantly between ADHD patients and controls (Table 2).

Subjective Sleep Measures

The results of the SF-A completed after the baseline night in the sleep laboratory are depicted in Table 3. Similar to the polysomnographic findings, patients reported significant longer sleep latencies and more frequent nocturnal awakenings (statistical trend). No differences were found for sleep quality or the feeling of being refreshed in the morning between patients and controls. Evening mood was more positive in the patient group.

Polysomnography During Treatment with Methylphenidate

When treated with methylphenidate patients showed a significant reduction in sleep onset latency and improved sleep efficiency. All other sleep parameters remained unchanged (Table 4).

Subjective Sleep Measures During Treatment with Methylphenidate

Table 1—Polysomnographic Results in all Non-Medicated Patients with ADHD Including Patients Currently Suffering from Comorbid Disorders (n=34) and Gender- and Age Matched Healthy Controls (n=34)

	ADHD (n=34)	Controls (n=34)	*t* =	P =
Total time in bed (min)	462.3 ± 34.1	463.9 ± 19.0	0.2	0.8135
Sleep onset latency (min)	26.1 ± 21.7	17.4 ± 13.0	-2.0	0.0501
Sleep efficiency (%)	85.0 ± 7.3	89.4 ± 9.3	2.2	0.0308*
REM latency (min)	80.7 ± 48.7	97.3 ± 56.1	1.3	0.1891
Total REM density	16.2 ± 8.1	19.1 ± 6.9	1.6	0.1151
Number of awakenings	32.1 ± 18.1	12.0 ± 7.2	-6.0	<0.0001***
Duration of first REM period	16.4 ± 9.3	20.2 ± 12.8	1.4	0.1696
Density of first REM period	13.2 ± 10.5	13.6 ± 8.3	0.2	0.8709
Sleep Stage (% of SPT)				
% Wake	9.0 ± 6.6	5.9 ± 8.6	-1.7	0.1009
% Stage 1	11.9 ± 7.2	8.5 ± 3.4	-2.5	0.0153*
% Stage 2	55.7 ± 8.6	56.0 ± 6.8	0.2	0.8568
% Slow wave sleep	5.5 ± 6.9	7.1 ± 6.9	1.0	0.3421
% REM	17.9 ± 4.9	21.8 ± 5.1	3.2	0.0019**

*<0.05; **<0.01; ***<0.0001

Table 2—Polysomnographic Results in Nonmedicated Patients with ADHD Only Without Current Comorbid Psychiatric Disorders (n=24) and Controls (n=24)

	ADHD (n=24)	Controls (n=24)	*t* =	P =
Total time in bed (min)	461.2 ± 37.7	462.0 ± 21.1	0.1	0.9234
Sleep onset latency (min)	26.5 ± 20.5	18.5 ± 14.7	-1.6	0.1253
Sleep efficiency (%)	84.7 ± 7.9	90.1 ± 7.1	2.5	0.0150*
REM latency (min)	79.7 ± 35.7	94.2 ± 43.1	1.3	0.1967
Total REM density	15.3 ± 6.7	19.3 ± 6.7	2.1	0.0435*
Number of awakenings	31.5 ± 14.6	12.7 ± 8.2	-5.0	< 0.0001***
Duration of first REM period	16.9 ± 8.3	22.2 ± 13.0	1.7	0.1029
Density of first REM period	12.1 ± 8.0	14.7 ± 8.8	1.1	0.2876
Sleep Stage (% of SPT)				
% Wake	9.4 ± 7.1	5.4 ± 5.6	-2.2	0.0344*
% Stage 1	10.2 ± 5.6	9.0 ± 3.5	-0.9	0.3598
% Stage 2	56.1 ± 7.7	56.2 ± 5.1	0.1	0.9525
% Slow wave sleep	6.2 ± 7.5	6.0 ± 5.4	-0.1	0.9316
% REM	18.0 ± 4.8	22.5 ± 5.0	3.2	0.0023**

*<0.05; **<0.01; ***<0.0001

Under treatment with methylphenidate patients reported improved evening mood, less psychosomatic symptoms while falling asleep, reduced sleep latency, and fewer nocturnal awakenings during the night spent in our sleeping laboratory (SF-A), though statistically significant only at the trend. For the 2 weeks at home preceeding their polysomnographic investigation (SF-B) patients reported significantly better restorative value of sleep and a trend for less nocturnal awakenings compared to baseline. Details are provided in Tables 5 and 6.

DISCUSSION

In contrast to Philipsen et al.,[16] we found polysomnographic differences between ADHD patients and healthy controls, with patients experiencing reduced sleep efficiency along with an elevated number of awakenings and percentage wakefulness after sleep onset. This is in accordance with results from studies assessing objective sleep parameters in children with ADHD, which also found reduced sleep efficiency[39] and more nocturnal awakenings.[10,40,41] These results, however, conflict with some studies showing no differences in sleep efficiency and number of nocturnal awakenings[42,43] between children with ADHD and healthy controls.

Consistent with our hypothesis and paralleling the results of polysomnographic studies in children with ADHD,[5,9,40,41] we observed a reduced percentage of REM sleep in our adult patients with ADHD, as compared to controls. Although the clinical significance and correlates of this REM reduction in ADHD are unknown, REM sleep has been associated with learning and performance, particularly with measures of executive functions, attention, memory, and language; a decrease in REM percentage has been correlated with deficits in these functions.[45]

Data from polysomnographic studies, e.g., Philipsen et al., also show that adult ADHD is associated with increased movements during sleep. The PLMS index in our total ADHD sample was 5.3 ± 5.7, corresponding with the PLMS index found

Table 3—Subjective Sleep Measures During Baseline Night in Sleeping Laboratory (SF-A) in Nonmedicated Patients with ADHD Only (n=24) and Controls (n=24)

	ADHD (n=24)	Controls (n=24)	*t* =	P =
Sleep quality	3.03 ± 0.66	2.97 ± 0.30	-0.3	0.7427
Restorative value of sleep	2.94 ± 0.68	2.60 ± 0.72	-1.3	0.2071
Evening mood	3.14 ± 0.72	2.39 ± 0.90	-2.5	0.0216*
Fatigue in the evening	2.70 ± 0.94	2.96 ± 0.67	0.8	0.4061
Psychosomatic symptoms during sleep onset	1.71 ± 0.59	1.43 ± 0.41	-1.4	0.1656
Sleep latency	3.29 ± 1.33	2.00 ± 0.96	-2.9	0.0068**
Nocturnal awakenings	3.50 ± 1.29	2.71 ± 1.07	-1.8	0.0905‡

‡<0.1; *<0.05; **<0.01; ***<0.0001.

Table 4—Polysomnographic Results in ADHD-Patients (n=10) Before and Under Treatment with Methylphenidate

	Baseline (n=10)	Treatment (n=10)	*t* =	P =
Total time in bed (min)	441.3 ± 42.9	435.3 ± 54.4	-0.3	0.7717
Sleep onset latency (min)	40.4 ± 30.5	12.7 ± 6.1	-2.7	0.0237*
Sleep efficiency (%)	82.0 ±10.4	89.5 ± 7.4	2.5	0.0354*
REM latency (min)	79.0 ± 33.7	99.2 ± 49.7	1.2	0.2510
Total REM density	15.6 ± 9.0	15.4 ± 6.4	-0.1	0.9486
Number of awakenings	24.0 ± 22.9	25.3 ± 23.9	0.4	0.6916
Duration of first REM period	15.2 ± 7.1	21.1 ± 14.2	1.6	0.1566
Density of first REM period	12.8 ± 12.2	10.7 ± 7.9	-0.8	0.4532
Sleep Stage (% of SPT)				
% Wake	8.3 ± 9.7	7.2 ± 7.4	-0.5	0.6378
% Stage 1	9.7 ± 8.0	8.0 ± 5.9	-1.0	0.332
% Stage 2	58.2 ± 9.9	60.4 ± 8.1	1.2	0.2757
% Slow wave sleep	5.9 ± 9.1	4.8 ±7.1	-1.3	0.2362
% REM	17.8 ± 6.3	19.3 ± 7.6	1.0	0.3480
PLMS Index	5.5 ± 6.1	4.1 ± 4.6	-1.1	0.3008
PLMS-A Index	0.3 ± 0.5	0.4 ± 0.6	0.3	0.7505

*<0.05; **<0.01; ***<0.0001.

by Philipsen et al.,[16] which was 5.18 ± 5.92 (significantly elevated compared to control subjects, whose PLMS-index was 1.66 ± 3.25). Contrary to Philipsen et al.,[16] the PLMS-A index in our patients was 0.3 ± 0.4, much lower than that reported by Philipsen et al., (1.56 ± 2.19 in ADHD patients compared to 0.31 ± 0.54 in controls).[16]

Though our findings regarding subjective sleep parameters during the baseline night parallel polysomnographic findings (prolonged sleep latency, more nocturnal awakenings) the effects were not as pronounced as reported by Philipsen et al.[16] and Kooij et al.[15]

In accordance with our hypothesis, our results furthermore show that medication with methylphenidate has a significant positive effect on sleep, with improved sleep efficiency and substantially shortened sleep onset latencies compared to baseline without medication. Sleep architecture and number of PLMS with and without arousal remained unchanged. The unchanged number of PLMS under stimulant medication did not support our hypothesis of a reduction of movements during sleep due to stimulants; it also did not correspond with the findings of the actigraphic study of Kooij et al.[15] reporting a significant reduction in nocturnal activity in treated patients compared to baseline. A major difference between the two studies lies in the different doses of methylphenidate, with a mean dosage of 36.7 mg/day in our study and 51 mg/day in the actigraphic study. Further studies are needed to clarify whether methylphenidate exerts a marked effect on periodic limb movements during sleep.

The positive effect of stimulant treatment on sleep was also present in patients' subjective sleep estimates both the home (SF-B) and in the laboratory setting (SF-A). Compared to baseline without medication, patients reported a subjective feeling of shortened sleep latency and improved restorative value of sleep. Thus, our findings are in line with the results by Kooij et al.[15] who also reported improved subjective sleep quality under stimulant medication. Interestingly, the most significant effect of treatment on sleep was obtained for the restorative value of sleep. In our correlational study,[14] we found this variable to correspond most closely to the severity of ADHD symptoms during the day. Thus it would be most interesting to look for parallels between improvement of daytime ADHD symptoms due to stimulants and changes in subjective and objective sleep parameters.

Studies assessing the effect of methylphenidate in children with ADHD provide inconsistent and conflicting findings. While some studies parallel the results obtained in our study by also showing reduced latency of sleep onset in medicated compared to stimulant-free children with ADHD,[18,19] other studies report

Table 5—Subjective Sleep Measures (SF-A) for the Night in Sleep Laboratory Under Baseline and Medication Condition

	ADHD baseline (n=10)	ADHD treatment (n=10)	*t* =	P =
Sleep quality	2.81 ± 0.52	3.22 ± 0.73	1.7	0.1224
Restorative value of sleep	2.76 ± 0.66	2.81 ± 0.80	0.2	0.8292
Evening mood	2.98 ± 0.49	3.34 ± 0.66	2.1	0.0609‡
Fatigue in the evening	2.42 ± 0.72	2.75 ± 0.80	1.0	0.3588
Psychosomatic symptoms during sleep	1.93 ± 0.58	1.60 ± 0.45	-1.9	0.0961‡
Sleep latency	3.9 ± 1.45	3.1 ± 1.52	-2.2	0.0528‡
Nocturnal awakenings	3.4 ± 1.43	2.7 ± 1.42	-1.1	0.0886‡

‡<0.1; *<0.05; **<0.01; ***<0.0001.

Table 5—Subjective Sleep Measures (SF-B) for the 2 Weeks Before Baseline and Medication Polysomnographic Recording

	ADHD baseline (n=10)	ADHD treatment (n=10)	*t* =	P =
Sleep quality	3.52 ± 0.55	3.57 ± 0.65	0.9	0.3829
Restorative value of sleep	2.4 ± 0.72	2.95 ± 0.71	2.9	0.0174*
Evening mood	3.39 ± 0.61	3.29 ± 0.78	-0.6	0.5957
Fatigue in the evening	4.00 ± 0.74	3.70 ± 0.79	-1.7	0.1212
Psychosomatic symptoms during sleep	1.93 ± 0.59	1.88 ± 0.84	0.3	0.7854
Sleep latency	2.7 ± 1.57	2.5 ± 1.35	-1.0	0.3434
Nocturnal awakenings	2.90 ± 1.10	2.33 ± 1.00	-2.0	0.0805‡

‡<0.1; *<0.05; **<0.01; ***<0.0001.

no differences in sleep quantity.[20,21,24] The same applies for findings concerning changes in sleep architecture under stimulant medication. While one study reports no significant changes in the percentage of REM sleep,[24] another study using a twice daily dosing of methylphenidate notes an increased number of REM periods and activity,[42] while yet another using a t.i.d. dosing of dextroamphetamine with additional nighttime applications found a decrease in percentage of REM sleep and REM periods as well as an increased REM onset latency when comparing medicated to unmedicated children with ADHD.[26] Taken together, these data suggest that medication schedule and type of stimulant has an influence on sleep parameters, though it is still far from clear by what physiological mechanism methylphenidate influences sleep in ADHD. Given the short plasma half-life of stimulants it is not probable that improved sleep-quality is a direct effect of methylphenidate on ADHD symptoms during the night. A possible explanation is that stimulants influence chronobiological brain functions resulting in improved sleep. Another possibility is that overall better adjustment during the day due to medication also has a beneficial influence on sleep during the night.

When interpreting the results of our study, we must keep limitations in mind. First, our study was conducted in a psychiatric hospital setting, and a selection bias of patients must be considered as all patients were recruited from our ADHD-outpatient clinic (i.e., we studied ADHD patients seeking help because their daytime functioning was impaired by their symptoms). Additionally, the effect of methylphenidate treatment was assessed in a relatively small patient sample using an open-label design, which requires a verification of the results by randomized placebo-controlled trials with sufficiently powered sample size. Our positive findings in the retest polysomnography might, for example, be partly explained by habituation to the sleep laboratory setting, although we applied the standard procedure of including an adaptation night in laboratory before each measurement night.

Despite these limitations the findings of our study show that sleep characteristics and problems in adults with ADHD are similar to those in children and add evidence to the hypothesis that sleep problems related to ADHD continue during patients' life span. They also suggest that medication with methylphenidate has beneficial effects on sleep parameters resulting in improved sleep efficiency and improved restorative value of sleep.

REFERENCES

1. Manuzza S, Klein RG, Bessler, A et al. Adult outcome of hyperactive boys. Educational achievement, occupational rank, and psychiatric status. Arch Gen Psychiatry 1993;50:565-7.
2. Weiss G, Hechtman L, Milroy T, et al. Psychiatric status of hyperactives as adults: a controlled prospective 15-year follow-up of 63 hyperactive children. J Am Acad Child Adolesc Psychiatry 1985;24:211-23.
3. Kessler RC, Adler L, Barkley R, O et al. The prevalence and correlates of adult ADHD in the United States: Results from the National Comorbidity Survey Replication (NCS-R). Am J Psychiatry 2006;163:716-23.
4. Diagnostic and Statistical Manual of Mental Disorders III (DSM-III) Washington DC: American Psychiatric Association; 1980.
5. Cohen-Zion M, Anconi-Israel S. Sleep in children with attention-deficit hyperactivity disorder (ADHD): a review of naturalistic and stimulant intervention studies. Sleep Med Rev 2004;8:379-402.
6. Corkum P, Tannock R, Moldofsky H. Sleep disturbances in chil-

dren with attention-deficit/hyperactivity disorder. J Am Acad Child Adolesc Psychiatry 1998;37:637-46
7. Lecendreux M, Konofal E, Bouvard M, Fallsiard B, Mouren-Simeoni M. Sleep and alertness in children with ADHD. J Psychol Psychiatry 2000;41:803-12.
8. Golan N, Shahar E, Ravid G. Sleep disorders and daytime sleepiness in children with attention deficit hyperactivity disorder. Sleep 2004;27:261-6.
9. Picchietti DL, Underwood DJ, Farris WA, et al. Further studies on periodic limb movement disorders and restless legs syndrome in children with attention-deficit hyperactivity disorder. Mov Disord 1999;14:1000-7.
10. Picchietti DL, England S, Walters A, et al. Periodic limb movement disorder and restless legs syndrome in children with attention-deficit hyperactivity disorder. J Child Neurol 1998;13:588-94.
11. O'Brien LM, Ivanenko A, Crabtree VM, et al. Sleep disturbances in children with attention deficit hyperactivity disorder. Pediatr Res 2003;54:237-43.
12. Dodson WW, Zhang Y. Sleep disturbances associated with adult ADHD In: New research program and abstracts of the 152nd annual meeting of the American Psychiatric Association 1999; Abstract NR216:124
13. Kooij JJS, Aeckerlin Lp, Buitelaar JJ. Funtioneren, comorbiditeit en behandeling van 141 volwassenen met aandachtstekort-hyperactiviteit-stoornis (ADHD) op een algemene poliklineik Psychiatrie [Functioning, comorbidity and treatment of 141 adults with ADHD at a psychiatric outpatients' department] Ned Tijdschr Geneeskd 2001;145:1498-1501.
14. Schredl M, Alm B, Sobanski E. Sleep quality in adult patients with attention deficit hyperactivity disorder (ADHD). Eur Arch Psychiatry and Clin Neurosci 2007; 257:164-8.
15. Kooij JJS, Middelkoop HAM, vanGils K, Buitelaar JK. The effect of stimulants on nocturnal activity abd sleep quality in adults with ADHD: an open-label case-control study. J Clin Psychiatry 2001;62:952-6.
16. Philipsen A, Feige B, Hesslinger B, et al. Sleep in adults with attention-deficit/hyperactivity disorder: a controlled polysmonographic study including spectral analysis of the sleep EEG. Sleep 2005;28:738-45.
17. Philipsen A, Hornyak M, Riemann D. Sleep and sleep disorders in adults with attention deficit/ hyperactivity disorder. Sleep Med Rev 2006;10:399-405.
18. Tirosh E, Sadeh A, Munvez R, Lavie P. Effects of methylphenidate on sleep in children with attention-deficit hyperactivity disorder. Am J Dis Child 1993;147:1313-5.
19. Busby K, Plivik RT. Auditory arousal thresholds during sleep in hyperkinetic children. Sleep 1985;8:332-41.
20. Greenhill L, Puig-Antich J, Goetz R, Hanlon C, Davies M. Sleep architecture and REM sleep measures in prepubertal children with attention deficit with hyperactivity. Sleep 1983;6:91-101.
21. Stein MA, Blondis TA, Schnitzler ER, et al. Methylphenidate dosing twice daily versus three times daily. Pediatrics 1996;98:748-56.
22. Haig JR, Schroeder CS, Schroeder SR. Effects of methylphenidate on hyperactive's children sleep. Psychopharmacologia 1974;37:185-8.
23. Nahas-AD, Krynicki V. Effects of methylphenidate on sleep stages and ultradian rhythms in hyperactive children. J Nerv Ment Dis 1977;164:66-9.
24. O'Brien LM, Ivanenko A, McLaughlin, et al. The effect of stimulants on sleep characteristics in children with attention deficit hyperactivity disorder. Sleep Med 2003;4:309-16.
25. Small A, Hibi S, Feinberg I. Effects of dexamphetamine sulphate on EEG sleep patterns of hyperactive children. Arch Gen Psychiatry 1971;25:369-80.
26. Chatoor I, Wells KC, Conners CK, Seidel WT, Shaw D. The effects of nocturnally administered stimulant medication on EEG sleep and behaviour in hyperactive children. J Am Acad Child Adolesc Psychiatry 1983;22:337-42.
27. Diagnostic and Statistical Manual of Mental Disorders, 4th ed. Washington, DC: American Psychiatric Association, 1994.
28. Retz-Junginger P, Retz W, Blocher D, et al. Validity and reliability of the German short version of the Wender-Utah rating scale for the retrospective assessment of attention-deficit/hyperactivity disorder. Nervenarzt 2003;74:987-93.
29 Brown TE. Brown Attention-Deficit Disorder Scales Manual. San Antonio: The Psychological Corporation; 1996.
30. Dreßing H, Riemann D, Löw H, Schredl M, Reh C, Laux P, Müller E. Baldrian-Melisse-Kombinationen versus Benzodiazepin: Bei Schlafstörungen gleichwertig? Therapiewoche 1992;42:726-36.
31. Gann H, Riemann D, Hohagen F, Müller WE, Berger M. The influence of carbamazepine on sleep EEG and the clonidine test in healthy subjects: results of a preliminary study. Biol Psychiatry 1994;35:893-6.
32. Riemann D, Gann H, Dressing H, Müller WE, Aldenhoff JB. Influence of the cholinesterase inhibitor galanthamine hydrobromide on normal sleep. Psychiatry Res 1994;51:253-67.
33. Voderholzer U, Al-Shajlawi A, Weske G, Feige B, Riemann D. Are there gender differences in objective and subjective sleep measures? A study of insomniacs and healthy controls. Depress Anxiety 2003;17:162-72.
34. The Atlas Task Force. Recording and scoring leg movements. Sleep 1993;16:748-59.
35. Rechtschaffen A, Kales A. A manual of standardized terminology, techniques and scoring systems for sleep stages of human subjects. US Government Printing Office 1968. Washington DC
36. Görtelmeier R. Schlaffragebogen SF-A und SF-B. In: Collegium Internationale Psychiatriae Scolarum (CIPS). Internationale Skalen für Psychiatrie. Weinheim: Beltz, 1986
37. Görtelmeier R. On the development of a standardized sleep inventory fort he assessment of sleep. In: Kubicki S, Herrmann WM (Eds) Methods of sleep research. New York: Gustav Fischer; 1985:93-8
38. Faraone SV, Biederman J. Neurobiology of attention-deficit hyperactivity disorder; Biol Psychiatry 1998;44:951-8.
39. Dagan Y, Zeevi-Luria S, Sever Y, et al: Sleep quality in children with attention deficit hyperactivity disorder. An actigraphic study. Psychiatry Clin Neurosci 1997;51:383-6.
40. Ramos Platos MJ, Bueno AV, Sierra JE, Kales S. Hypopolygraphic alternation in attention deficit disorder children. Int J Neurosci 1990;53:87-101.
41. O'Brien LM, Ivanenko A, McLaughlin, JL et al. Sleep disturbances in children with attention deficit hyperactivity disorder. Pediatric Res 2003;54:237-43.
42. Greenhill L, Pig-Antich J, Goetz R, Hanlon C, Davies M. Sleep architecture and REM sleep measures in prepubertal children with hyperactivity. Sleep 1983;6:91-1001.
43. Busby K, Firestone P, Pivik RT. Sleep pattern in hyperkinetic and normal children. Sleep 1981;4:366-83.
44. O'Brien LM, Holbrook CR, Mervis CB, et al. Sleep and neurobehavioral characteristics of 5- to 7-year-old children with parentally reported symptoms of attention-deficit hyperactivity disorder. Pediatrics 2003;111:554-63.
45. Siegel JM. The REM sleep-memory consolidation hypothesis. Science 2001; 294:1058-63.