Title: Sleep problems and daily functioning in children with ADHD: an investigation of the role of impairment, ADHD presentations and psychiatric comorbidity

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Abstract

Objective: In children with ADHD little systematic information is available regarding how sleep problems influence daytime functioning, just as the role of ADHD presentations and comorbidity is unclear.

Methods: Sleep problems were assessed in 397 children with the Children's Sleep Habits Questionnaire, whereas daily functioning and ADHD symptom level were evaluated with the Weiss Functional Impairment Rating Scale and the ADHD Rating Scale.

Results: We found a moderate, positive correlation between sleep problems and impaired functioning in both children with ADHD and in typically developed children. ADHD presentations did not differ significantly with respect to sleep problem profile. Children with ADHD and a comorbid internalising or autistic disorder had the highest sleep problem score.

Conclusions: Sleep problems and impaired daily functioning were more common in children with ADHD than in typically developing children, but the over-all association between sleep problems and impaired daily functioning was similar in clinical and non-clinical children. Internalising or autistic co-morbid disorders added significantly to the sleep problems.

Keywords: ADHD; sleep problems; daily functioning; ADHD presentations; comorbidity

Introduction

Attention deficit/hyperactivity disorder (ADHD) is a neuro-developmental disorder characterised by symptoms of inattention, hyperactivity and impulsivity, which can be categorised into either the combined, inattentive, or hyperactive/impulsive presentation. The symptoms must be present in a range of situations, and the functional level must be inconsistent with the child's developmental stage and cause impairment in two or more settings. ADHD is estimated to occur in about 5% of children in most cultures (American Psychiatric Association, 2013). Psychiatric comorbidity is reported in up to 75% of children with the disorder (Spencer, 2006).

For clinicians, symptoms of ADHD (i.e., inattention, hyperactivity and impulsivity) are commonly the main focus during the investigation of the referred child, but for parents, impaired daily functioning in social and educational settings is more often the reason for referral. The focus on a child's difficulties at different care sectors (health care, social and educational sectors) may be in conflict with the family experienced problems and difficulties. What is really important is the daily functional level of the individual, which could be systematically evaluated in clinical consultations. In addition, the evaluation of ADHD is generally focused on daytime symptoms. However, studies suggest that up to 70% of children with ADHD have sleep problems (Sung, Hiscock, Sciberras, & Efron, 2008). The sleep problems reported by parents and children include difficulties in falling asleep and maintaining sleep, tiredness when waking up, and daytime sleepiness (Cortese, Faraone, Konofal, & Lecendreux, 2009; Hvolby, Jorgensen, & Bilenberg, 2009; J. A. Owens, Maxim, Nobile, McGuinn, & Msall, 2000). Objective measures like actigraphy have supported the irregular pattern of sleep timing, whereas studies of the sleep structure using polysomnography have shown mixed results (Cortese et al., 2009). Differences between results from questionnaire-based studies and studies that include objective measures may arise because the two types of studies assess somewhat different sleep constructs, with questionnaires mainly addressing behaviour related to sleep, whereas objective investigations mainly assess sleep structure and related physiological patterns during sleep (Konofal, Lecendreux, & Cortese, 2010).

In general, an adequate amount of sleep is considered integral to good daytime functioning (Galland, Tripp,

& Taylor, 2010). Sleep quality and quantity have been shown to affect performance on working memory tasks in school-age children (Steenari et al., 2003), just as daily functioning and emotional regulation have been found to be impaired when sleep is inadequate (J. Owens et al., 2012; Sung et al., 2008; Yurumez & Kilic, 2013). Sleep problems in typically developed children are also strongly associated with poor quality of life, reduced daily functioning, and poorer school attendance (Sung et al., 2008). Consequently, nocturnal problems appear to deserve scrutiny when a child with ADHD is referred for an evaluation, because sleep problems appear to be an integral part of the child's impairment profile (Stores, 1996).

The ADHD presentation and the presence of comorbidity may further complicate the association between ADHD and sleep. The very few previous studies looking into presentations and sleep problems report varying results (LeBourgeois, Avis, Mixon, Olmi, & Harsh, 2004; Mayes et al., 2009; Surman et al., 2009; Yoon, Jain, & Shapiro, 2013). One study found that children with the inattentive presentation have no night-related sleep problems but report significant daytime sleepiness compared to peers, whereas the combined presentation report more night-related sleep problems compared to peers (Mayes et al., 2009). Another study found no significant difference between presentations, but the inattentive presentation had the most sleep problems (LeBourgeois et al., 2004). In adults with the inattentive presentation of ADHD poorer sleep quality and more fatigue has been reported than in adults with the combined presentation (Yoon et al., 2013). Having comorbidity in addition to ADHD appears to add to the total reported sleep problem score (Mayes et al., 2009) and may function as a key mediating variable (Cortese et al., 2009); especially emotional disorders seem to have a high correlation with sleep problems (Dahl & Harvey, 2007), but systematic evidence in the literature is lacking. Potential differences in sleep problems for children with different presentations or comorbid profiles are important to detect because they may influence the type of assessment and intervention needed.

To summarize, the presence of sleep related problems in children with ADHD appears to be well established (Cortese et al., 2009). Previous studies of sleep and ADHD have primarily focused on the prevalence of sleep problems in ADHD, as compared to typically developing groups or groups with other psychiatric disorders (Hvolby et al., 2009). Aetiological factors such as delayed melatonin secretion (Van der Heijden, Smits, Van Someren, & Gunning, 2005), have been explored and a link to hypocretin deficiency, as seen in

narcolepsy, has been proposed (Cortese, Konofal, & Lecendreux, 2008). However, as of yet no unequivocal conclusion has been reached regarding the relation between ADHD and sleep. We do not yet know the aetiology of ADHD nor of the sleep related problems and how the neural pathways interact or even overlap. Furthermore, sleep problems are not subjectively reported or objectively measured in all children with ADHD so exploratory research into the different phenotypes may help detect the aetiology of ADHD and sleep.

To date, little attention has been paid to the degree of impairment caused by sleep problems in children with ADHD. If the functional level is correlated with the amount of reported sleep problems, the emphasis on early intervention in treating the sleep related problems could be essential for the child and the family. Sleep hygiene has been shown to relieve some of the sleep-related problems in a child with ADHD (Weiss, Wasdell, Bomben, Rea, & Freeman, 2006), thereby potentially avoiding some of the impairment related to poor sleep. Another matter with existing studies is the question of generalisability: many samples include selected patients with clinical diagnoses, no co-morbidity, and unclear medication status. As such, obtaining evidence from large naturalistic cohorts combining child characteristics, including presentation and comorbidity, and examining the association between sleep and clinically relevant parameters, impairment of daily functioning and ADHD symptoms are warranted in order to obtain knowledge about how sleep problems impact children with ADHD.

The overall purpose of the present study is to examine the association between sleep problems and impaired daily functioning in children with and without ADHD and to investigate the association between ADHD presentations and comorbidity in sleep related problems. Specifically, we aimed to 1) Assess sleep problems and daily function in children with ADHD and typically developing age-matched peers and 2) Investigate the associations between comorbidity and ADHD presentations with sleep and daily functioning.

We hypothesised that children with ADHD would have more sleep problems than their typically developing peers and that there would be an association between reported sleep problems and impaired daily functioning in the ADHD group. Due to the paucity of studies on ADHD presentations, comorbidity, and sleep; and

previous ambiguous results, analyses in the present study involving presentation and comorbidity are exploratory.

Methods

Participants and procedures

The Danish Regional Ethics Committee and the Danish Data Protection Agency approved the study.

Clinical children

All patients consecutively referred from 1 January 2011 to the 1 January 2013 to a public child and adolescent psychiatric hospital were included in the study (n = 209). Inclusion criteria were age 6-13 years and a diagnosis of ADHD. Exclusion criteria were former treatment with stimulants and IQ below 70 measured with the Wechsler Intelligence Scale for Children – Third Edition (Wechsler, 1991). (Figure 1).

(FIGURE 1 IN CLOSE RELATION TO THIS SECTION)

ADHD diagnoses were based on the Development and Well-Being Assessment (DAWBA) (Goodman, Ford, Richards, Gatward, & Meltzer, 2000). The DAWBA is a standardised assessment for DSM-IV psychiatric diagnoses and integrates information from parents (structured interview) and teachers (questionnaire). The parent interview was administered by telephone, whereas the teacher questionnaire was administered via mail to the child's primary teacher. A child and adolescent psychiatrist assessed the DAWBA, and any uncertainty about diagnoses was discussed with a second child and adolescent psychiatrist until consensus was achieved. Parents completed the following questionnaires: Children's Sleep Habits Questionnaire (CSHQ) (J. A. Owens, Spirito, & McGuinn, 2000) for sleep-problems assessment, Weiss Functional Impairment Rating Scale (WFIRS) (Weiss, 2011) for daily functioning and Attention Deficit Hyperactive Disorder Rating Scale (ADHD-rs) (Barkley, 1999) for a symptom score. All questionnaires were mailed to the parents and completed before the actual clinical investigation, so parents and interviewer were unaware of the final clinical diagnosis.

Based on the results from the DAWBA, children were grouped according to ADHD presentation and the presence of comorbidity. If more than one comorbid condition in addition to the ADHD diagnosis was

present, the diagnostic groups were categorized so that the patient was present in only one category. The categories from first to last order were as follows: autism spectrum disease, internalising disorders, externalizing disorders and tics/Tourette syndrome. Five groups emerged: ADHD with no comorbidity, ADHD with internalising comorbidity (depression, anxiety, obsessive compulsive disorder), ADHD with externalising comorbidity (conduct disorder, oppositional defiant disorder), ADHD with autism, and ADHD with Tourette syndrome and tics.

Typically developing children

Typically developing children were recruited from local community schools (3^{rd} – 6^{th} grade). Envelopes with information about the study and questionnaires were distributed in classrooms. In addition to the same questionnaires completed by the clinical group, the parents in the control group also completed the hyperactivity/inattention subscale from the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 2001). This subscale was included to examine whether any of the children in the control group were above the cut-off for hyperactivity and inattention. Children above the cut-off were not excluded from analyses, because the study aimed to include a control sample of non-referred children regardless of symptomatology. Returned questionnaires had to be complete for a child to be enrolled in the study. Controls treated with ADHD medication were excluded as well as were children with other diseases of the central nervous system (Figure 1).

Measures

The CSHQ is a 1-week recall parent questionnaire developed as a screening instrument for children aged 4–12 years. Parents rate the occurrence of 33 sleep habits or sleep problems in the most recent typical week. The questionnaire provides a total score (33–99 points) and eight subscale scores: Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Waking, Parasomnia, Sleep Disordered Breathing and Daytime Sleepiness. A total score > 41 yields adequate sensitivity (0.80) and specificity (0.70) in differentiating children with and without sleep disturbances (J. A. Owens et al., 2000). The questionnaire was translated into Danish using traditional back-translation procedures and used with permission from the

original author. In this study the CSHQ had an acceptable internal consistency (Cronbach's α range: 0.62 – 0.73).

The WFIRS is developed to assess impairment in daily functioning in children with ADHD. Parents fill in the 50-item questionnaire (0–3 points). The score is divided into subdomains of possible impairment (family, school, life skills, self-concept, social activities and risky activities). The measure has been psychometrically validated (Weiss, 2011). The scale can be scored by looking at the total score or by creating a mean score for the total score divided by the number items for each domain, omitting those rated not applicable (Weiss, 2011). The questionnaire was translated into Danish using traditional back-translation procedures and used with permission from the original author. Cronbach's α displayed good internal consistency (0.88 – 0.90).

The ADHD-rs modified by Barkley is a 26-item questionnaire including the 18 original ADHD-RS-IV items supplemented with 8 conduct problem items. The total score (0–78) and 3 subscales: inattentive scale, hyperactive/impulsive scale, and conduct scale can all be calculated from the item scores. The questionnaire was previously translated into Danish and validated in a Danish nationwide multicenter study (Szomlaiski, 2009). Cronbach's α range: 0.82 – 0.90.

Statistical analyses

Analyses were conducted using the statistical software program Stata 13. Data were plotted for normal distribution. Because WFIRS and the ADHD-rs are developed for children with attention problems, data from the control group were not normally distributed and data were log transformed to fit assumptions. Raw scores are presented in the tables. Summary statistic, effect sizes (Cohen's d), and linear regression models were applied. All analyses were carried out with an adjustment for age and gender. An alpha level was set at .05 in all statistical analyses.

Results

Response rate on the DAWBA was 92%; 22 interviews were not completed due to language problems (*n* = 7), refusal (*n* = 2) or unavailability (*n* = 13). Response rates in the clinical group to the questionnaires were 85% for the CSHQ, 85% for the WFIRS, and 89% for the ADHD-rs. The overall response rate in the control group was 35% and after exclusion 32% (revisit Figure 1). In the control group three children (2%) were above the cut-off on the SDQ hyperactivity/inattention scale.

Clinical and non-clinical groups did not differ significantly with respect to age, albeit there were significantly more males in the clinical group than in the non-clinical group (79 % versus 52%, respectively) (Table 1). (TABLE 1 IN CLOSE RELATION TO THIS SECTION)

Children with ADHD and typically developing children obtained significantly different scores on the specific questionnaires addressing sleep, daily functioning, and ADHD symptoms. Effect sizes for the total scores on the CSHQ, WFIRS, and the ADHD-rs were large (Table 1). In general, children with ADHD had more problems than typically developing counterparts. The results were unaffected by whether the mother or the father filled in the questionnaire. The reported prevalence of sleep problems in the present study was 68 % of children with ADHD (75 % in children with comorbidity versus 59 % without comorbidity) compared 26 % the control group.

Correlating the sleep score with daily functioning (Figure 2) in patients and controls resulted in similar correlation coefficients in the two groups, $r = 0.50$ (0.38–0.60) in the ADHD group and $r = 0.46$ (0.31–0.57) in the control group. To further test whether the slopes differed between the two group-correlates, we applied a logistic regression model testing for co-linearity, which showed that the two slopes did not differ significantly.

(FIGURE 2+3 IN CLOSE RELATION TO THIS SECTION)

Of the 209 children who had an ADHD diagnosis, 79% met criteria for the combined presentation, 18% the inattentive presentation, and 2% the hyperactive/impulsive presentation. Within the presentations of ADHD, the inattentive presentation had a lower functional impairment score and less ADHD symptomatology than

the combined type. The sleep score did not differ significantly between presentations. The correlation coefficients between sleep problems and daily functioning were, r = 0.57 (0.45–0.67), for the combined type, r = 0.95 (0.42–1.0), for the hyperactive/impulsive type, and r = 0.34 (-0.01–0.62), for the inattentive type.

Fifty-five percent had one comorbid condition and 14% two or more comorbid conditions. The comorbidities were pooled into four categories: externalising disorders (57%), internalising disorders (24%), autism spectrum disorders (8%), and tics and Tourette syndrome (11%) (Table 2). The presence of comorbidity contributed to a higher score on all scales in children with ADHD compared to children with no comorbidity. The total sleep score increased significantly by having an autistic or an internalising comorbid disorder compared to having externalising, tics and Tourette, or no comorbid disorder. In the different groups of comorbidities, the correlation coefficients between sleep problems and daily functioning were, r = 0.38 (0.17–0.56), in the no-comorbidity group, r = 0.30 (-0.14–0.64), in the internalising group, r = 0.54 (0.32–0.70), for the externalising group, r = 0.95 (0.76–0.99) for autism, and r = 0.64 (0.14–0.88) in the tics/Tourette syndrome group. (TABLE 2 IN CLOSE RELATION TO THIS SECTION)

Discussion

The present study examined the association between sleep problems and impaired daily functioning in a large cross-sectional sample of consecutively clinic-referred school-age children with ADHD and non-clinical counterparts. Furthermore, the correlations of ADHD presentation and comorbidity with reported sleep problems were examined in the clinical group.

The results from the present study suggest that children with ADHD and controls differ significantly with respect to level of sleep problems and impaired daily functioning. Overall, children with ADHD reported more sleep problems and more impaired daily functioning than did age-matched controls. The results correspond well with previous results (Yurumez & Kilic, 2013). Sleep problems were associated with impaired daily functioning in both patients with ADHD and controls. This suggests that sleep problems impair daily functioning regardless of diagnostic status. The correlation between reported sleep problems and daily functioning remained positive across presentations and comorbid groups.

By grouping children with ADHD according to DSM-5 presentation or comorbid condition, a more nuanced picture emerged. We found that the inattentive presentation had more sleep problems than the combined type (although the result was not statistically significant), which is consistent with previous studies examining school-age (LeBourgeois et al., 2004) as well as adult samples (LeBourgeois et al., 2004; Yoon, Jain, & Shapiro, ; Yoon et al., ; Yoon et al., 2013), but different from another study that included a childhood sample (Mayes et al., 2009). Both studies examining childhood populations included medicated and non-medicated children and in the latter, sleep problems were measures based on a retrospective collection of 10 sleep items from the Paediatric Behaviour Scale (Lindgren & Koeppl, 1987). The varying results most likely reflect methodological differences between studies. The hyperactive/impulsive presentation showed a strong correlation between sleep problems and daily functional level; however, the number of included subjects was limited (n = 5). Even though we did not find any statistically significant difference in sleep scores within the ADHD presentations, it can be speculated whether combined ADHD and inattentive ADHD reflect different disorders of endogenous sleep and arousal regulation.

Children with ADHD and a co-occurring disorder presented higher scores on all measures, and the children with autism or internalising disorders had statistically significantly higher scores on the CSHQ as well as on the WFIRS than did the other groups. This additive effect was expected because children with autism as well as internalising disorders are known to have severe sleep problems (Hansen, Skirbekk, Oerbeck, Wentzel-Larsen, & Kristensen, 2013; Ivanenko & Johnson, 2008; Kirov, Kinkelbur, Banaschewski, & Rothenberger, 2007). The group with comorbid autism showed large correlation coefficients; however, the number of included subjects was limited (n = 9).

A major strength of the present study was the inclusion of consecutively clinic-referred children during a 2-year period to avoid selection bias. Only a few (22 out of 272) patients did not complete the diagnostic interview, which optimises the generalisability. Exclusion of patients previously treated with central stimulants or with a low IQ, thereby removing potential confounders, also strengthened the design. Because we categorised presentations and comorbidities, it was possible to take a detailed look at the role of sleep in these groups, even though some of the groups included relatively few children. To eliminate possible information bias, questionnaires addressing sleep and impaired daily functioning were completed before the

clinical examination of the referred child. Furthermore, rating scales provided valuable information about the degree to which a child's ADHD-related behaviours differ from peers of the same age and gender. Therefore it is of outmost importance that the questionnaires possess adequate levels of reliability and validity (DuPaul, Power, McGoey, Ikeda, & Anastopoulos, 1998).

Limitations of the study include a low response rate in the control group (32%). Control-children often come from highly functional families with fewer problems than the average family, which may underestimate the true prevalence of the targeted problems. On the other hand, overestimation is also possible as likelihood to participate in studies increases if sleep problems are present. We found that 2% of the control group were above the cut-off for symptoms of ADHD on the SDQ. This number corresponds to previous epidemiologic findings regarding ADHD (Petersen, Bilenberg, Hoerder, & Gillberg, 2006; Scott et al., 2013), suggesting that the group was in fact representative. On the other hand, parents of a referred child may be more stressed and may over-report symptoms including sleep-related problems. In the present study we were interested in the pure prevalence rate of sleep problems prior to intervention, which is why we sent out the questionnaires before the clinical evaluation. Parents completed all questionnaires in the study and thereby only the parent's perspective is represented in the study. Future studies should include an objective measure of sleep to support the findings and to rule out primary sleep disorders.

Whether ADHD and the sleep-related problems share a common aetiology remains unknown. The present study suggests a high prevalence of sleep problems among children with ADHD and a strong association between sleep problems and functional impairment. ADHD and many other neuro-developmental disorders are heterogeneous conditions that probably arise from the additive and interactive effects of multiple heritable aetiologies and environmental risk factors including sleep routines (Willcutt et al., 2010) and the endogenous regulation of sleep (Lecendreux, Konofal, Bouvard, Falissard, & Mouren-Simeoni, 2000). Future studies are needed to address why and how problems with sleep cause daily functional impairment. We have shown that having an internalising or autistic disorder comorbid in addition to ADHD augments the sleep score and the daily functioning score significantly. However, further objective measures of sleep within comorbid conditions are warranted.

Our results add to the current literature by drawing attention to the observation that the majority of children with ADHD have sleep problems, and that certain comorbid disorders have an additive effect on these problems, and that sleep is very important for daily function in all children. A thorough diagnostic procedure is warranted in order to assess all psychiatric diagnosis in a referred child because, as our data suggests, an autistic or internalising disorders appears to worsen both sleep and functional level. We also speculate that the therapeutic success within a family including a higher daily functional level may depend on whether additional comorbidity or a sleep problem exists, is diagnosed, and treated.

Conclusion: Sleep problems are more frequently reported in children with ADHD and generally related to daytime functioning in these children as well as in controls. This underlines the importance of sleep for daytime functioning in children, and that an awareness of sleep history is important in the psychiatric evaluation of children. The correlations between sleep and daily functioning show that daily functioning is especially important in the case of ADHD both with and without additional comorbidity so not only a thorough sleep history is important but also the psychiatric evaluation must be accurate in order to treat adequately and help improving the daily functional level for the children and their families.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders, fifth edition. arlington, VA, american psychiatric association, 2013*

Barkley, R. (1999). *Defiant Teens.a Clinician's Manual for Assessment and Family Intervention.,*

Cortese, S., Faraone, S. V., Konofal, E., & Lecendreux, M. (2009). Sleep in children with attention-deficit/hyperactivity disorder: Meta-analysis of subjective and objective studies. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(9), 894-908.

Cortese, S., Konofal, E., & Lecendreux, M. (2008). Alertness and feeding behaviors in ADHD: Does the hypocretin/orexin system play a role? *Medical Hypotheses, 71*(5), 770-775.

Dahl, R. E., & Harvey, A. G. (2007). Sleep in children and adolescents with behavioral and emotional disorders. *Sleep Medicine Clinics, 2*(3), 501-511.

DuPaul, G. J., Power, T. J., McGoey, K. E., Ikeda, M. J., & Anastopoulos, A. D. (1998). Reliability and validity of parent and teacher ratings of attention-deficit/hyperactivity disorder symptoms. *Journal of Psychoeducational Assessment, 16*(1), 55-68.

Galland, B. C., Tripp, E. G., & Taylor, B. J. (2010). The sleep of children with attention deficit hyperactivity disorder on and off methylphenidate: A matched case-control study. *Journal of Sleep Research, 19*(2), 366-373.

Goodman, R. (2001). Psychometric properties of the strengths and difficulties questionnaire. *Journal of the American Academy of Child and Adolescent Psychiatry, 40*(11), 1337-1345.

Goodman, R., Ford, T., Richards, H., Gatward, R., & Meltzer, H. (2000). The development and well-being assessment: Description and initial validation of an integrated assessement of child and adolescent psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 41*(5), 645-655.

Hansen, B. H., Skirbekk, B., Oerbeck, B., Wentzel-Larsen, T., & Kristensen, H. (2013). Associations between sleep problems and attentional and behavioral functioning in children with anxiety disorders and ADHD. *Behavioral Sleep Medicine,*

Hvolby, A., Jorgensen, J., & Bilenberg, N. (2009). Parental rating of sleep in children with attention deficit/hyperactivity disorder. *European Child & Adolescent Psychiatry, 18*(7), 429-438.

Ivanenko, A., & Johnson, K. (2008). Sleep disturbances in children with psychiatric disorders. *Seminars in Pediatric Neurology, 15*(2), 70-78.

Kirov, R., Kinkelbur, J., Banaschewski, T., & Rothenberger, A. (2007). Sleep patterns in children with attention-deficit/hyperactivity disorder, tic disorder, and comorbidity. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*(6), 561-570.

Konofal, E., Lecendreux, M., & Cortese, S. (2010). Sleep and ADHD. *Sleep Medicine, 11*(7), 652-658.

LeBourgeois, M. K., Avis, K., Mixon, M., Olmi, J., & Harsh, J. (2004). Snoring, sleep quality, and sleepiness across attention-deficit/ hyperactivity disorder subtypes. *Sleep, 27*(3), 520-525.

Lecendreux, M., Konofal, E., Bouvard, M., Falissard, B., & Mouren-Simeoni, M. C. (2000). Sleep and alertness in children with ADHD. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 41*(6), 803-812.

Lindgren, S. D., & Koeppl, G. K. (1987). Assessing child behavior problems in a medical setting: Development of the pediatric behavior scale. *Advances in Behavioral Assessment of Children and Families, 3,* 57-90.

Mayes, S. D., Calhoun, S. L., Bixler, E. O., Vgontzas, A. N., Mahr, F., Hillwig-Garcia, J., et al. (2009). ADHD subtypes and comorbid anxiety, depression, and oppositional-defiant disorder: Differences in sleep problems. *Journal of Pediatric Psychology, 34*(3), 328-337.

Owens, J. A., Maxim, R., Nobile, C., McGuinn, M., & Msall, M. (2000). Parental and self-report of sleep in children with attention- deficit/hyperactivity disorder. *Archives of Pediatrics and Adolescent Medicine, 154*(6), 549-555.

Owens, J. A., Spirito, A., & McGuinn, M. (2000). The children's sleep habits questionnaire (CSHQ): Psychometric properties of a survey instrument for school-aged children. *Sleep, 23*(8), 1043-1051.

Owens, J., Gruber, R., Brown, T., Corkum, P., Cortese, S., O'Brien, L., et al. (2012). *Future research directions in sleep and ADHD: Report of a consensus working group*

Petersen, D. J., Bilenberg, N., Hoerder, K., & Gillberg, C. (2006). The population prevalence of child psychiatric disorders in danish 8- to 9-year-old children. *European Child & Adolescent Psychiatry, 15*(2), 71-78.

Scott, N., Blair, P. S., Emond, A. M., Fleming, P. J., Humphreys, J. S., Henderson, J., et al. (2013). Sleep patterns in children with ADHD: A population-based cohort study from birth to 11 years. *Journal of Sleep Research, 22*(2), 121-128.

Spencer, T. J. (2006). ADHD and comorbidity in childhood. *Journal of Clinical Psychiatry, 67*(SUPPL. 8), 27-31.

Steenari, M. -., Vuontela, V., Paavonen, E. J., Carlson, S., Fjällberg, M., & Aronen, E. T. (2003). Working memory and sleep in 6- to 13-year-old schoolchildren. *Journal of the American Academy of Child and Adolescent Psychiatry, 42*(1), 85-92.

Stores, G. (1996). Practitioner review: Assessment and treatment of sleep disorders in children and adolescents. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 37*(8), 907-925.

Sung, V., Hiscock, H., Sciberras, E., & Efron, D. (2008). Sleep problems in children with attention-deficit/hyperactivity disorder: Prevalence and the effect on the child and family. *Archives of Pediatrics & Adolescent Medicine, 162*(4), 336-342.

Surman, C. B., Adamson, J. J., Petty, C., Biederman, J., Kenealy, D. C., Levine, M., et al. (2009). Association between attention-deficit/hyperactivity disorder and sleep impairment in adulthood: Evidence from a large controlled study. *The Journal of Clinical Psychiatry, 70*(11), 1523-1529.

Szomlaiski, N. (2009). Validity and clinical feasibility of the ADHD rating scale (ADHD-RS) A danish nationwide multicenter study validity and clinical feasibility of ADHD-RS. *Acta Pædiatrica (Oslo), 98*(2), 397; 397-402; 402.

Van der Heijden, K. B., Smits, M. G., Van Someren, E. J., & Gunning, W. B. (2005). Idiopathic chronic sleep onset insomnia in attention-deficit/hyperactivity disorder: A circadian rhythm sleep disorder. *Chronobiology International, 22*(3), 559-570.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children-Third Edition,*

Weiss, M. D. (2011) *Weiss functional impairment rating scale (WFIRS) instructions.* from http://www.caddra.ca/cms4/pdfs/caddraGuidelines2011WFIRSInstructions.pdf

Weiss, M. D., Wasdell, M. B., Bomben, M. M., Rea, K. J., & Freeman, R. D. (2006). Sleep hygiene and melatonin treatment for children and adolescents with ADHD and initial insomnia. *Journal of the American Academy of Child and Adolescent Psychiatry, 45*(5), 512-519.

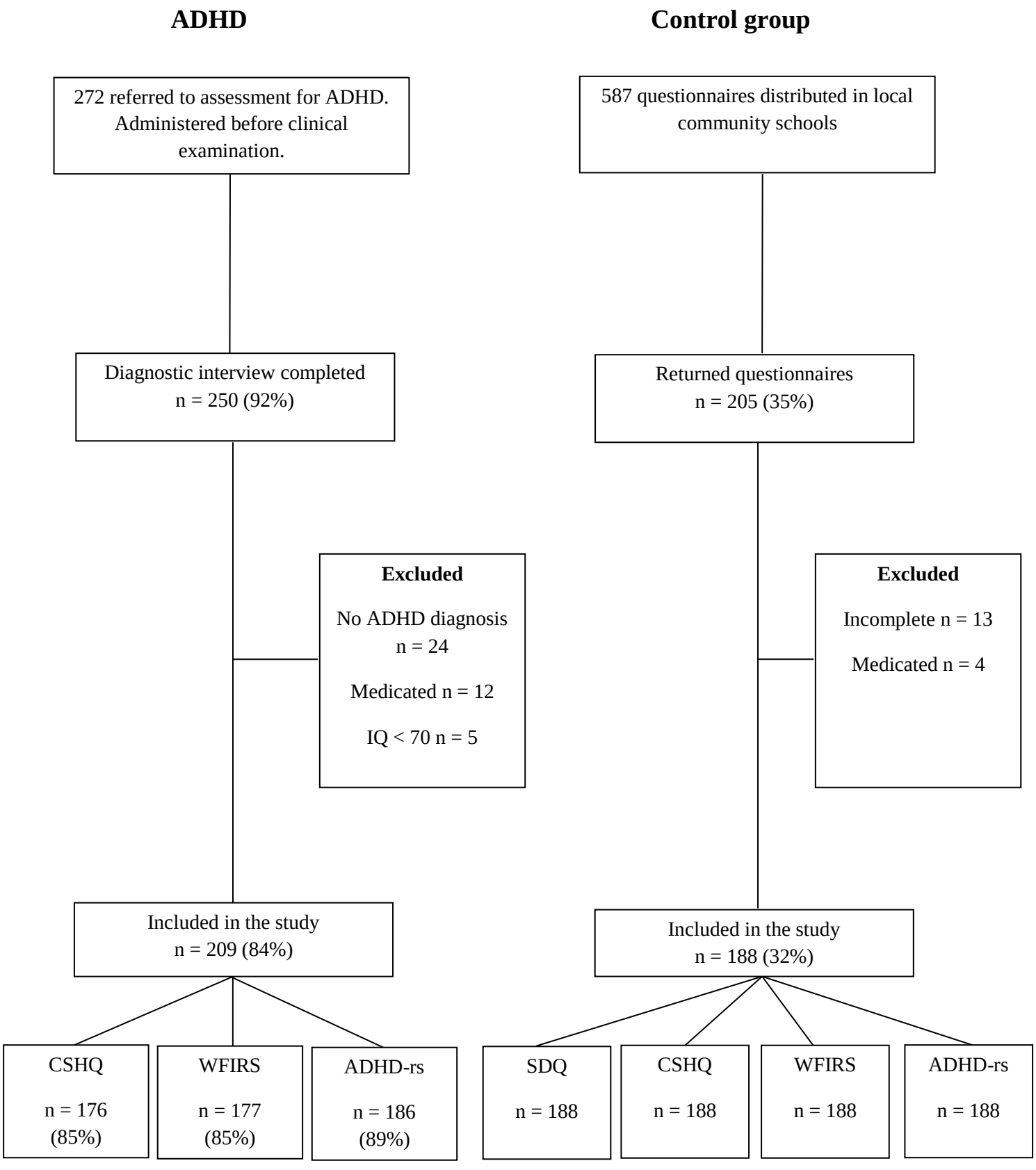
Willcutt, E. G., Pennington, B. F., Duncan, L., Smith, S. D., Keenan, J. M., Wadsworth, S., et al. (2010). Understanding the complex etiologies of developmental disorders: Behavioral and molecular genetic approaches. *Journal of Developmental and Behavioral Pediatrics : JDBP, 31*(7), 533-544.

Yoon, S. Y. R., Jain, U. R., & Shapiro, C. M. Sleep and daytime function in adults with attention-deficit/hyperactivity disorder: Subtype differences. *Sleep Medicine,* (0)

Yoon, S. Y. R., Jain, U. R., & Shapiro, C. M. (2013). Sleep and daytime function in adults with attention-deficit/hyperactivity disorder: Subtype differences. *Sleep Medicine, 14*(7), 648-655.

Yurumez, E., & Kilic, B. G. (2013). Relationship between sleep problems and quality of life in children with ADHD. *Journal of Attention Disorders,*

Figure 1: Recruitment flow chart



	Controls (SD)	Patients (SD)	Diff (95%-CI)	ES (95%-CI)
Age	**9.7 (1.5)**	**9.6 (1.9)**		
Gender (% male)	**52%**	**79%**		
CSHQ				
Total score	**40.6 (4.9)**	**47.5 (7.6)**	**6.8 (5.5-8.1) ***	**1.1 (0.9-1.3)**
Sub scales:				
1. Bedtime resistance	6.9 (1.7)	7.9 (2.3)	0.9 (0.5-1.3) *	0.5 (0.2-0.7)
2. Sleep onset disorder	1.4 (0.6)	1.9 (0.8)	0.5 (0.3-0.6) *	0.7 (0.5-0.9)
3. Sleep duration	3.5 (0.9)	4.6 (1.7)	1.1 (0.8-1.4) *	0.8 (0.6-1.0)
4. Sleep anxiety	4.7 (1.3)	5.7 (1.9)	1.0 (0.7-1.4) *	0.6 (0.4-0.8)
5. Night waking	3.5 (1.0)	3.9 (1.3)	0.4 (0.2-0.6) *	0.3 (0.1-0.6)
6. Parasomnias	7.8 (1.1)	8.8 (1.9)	1.1 (0.8-1.4) *	0.7 (0.5-0.9)
7. Sleep disordered breathing	3.2 (0.5)	3.5 (0.9)	0.3 (0.1-0.4) *	0.4 (0.2-0.6)
8. Daytime sleepiness	12.0 (2.2)	14.0 (3.3)	2.0 (1.4-2.5) *	0.7 (0.5-0.9)
WFIRS				
Total score	**0.1 (0.2)**	**0.8 (0.4)**	**0.7 (0.7-0.8)** *	**2.4 (2.2-2.7)**
Sub scales:				
A. Family	0.2 (0.2)	1.0 (0.6)	0.8 (0.7-0.9) *	1.6 (1.4-1.8)
B. Learning and school	0.0 (0.1)	0.9 (0.5)	0.9 (0.8-1.0) *	2.5 (2.2-2.8)
C. Life skills	0.2 (0.2)	0.9 (0.6)	0.7 (0.6-0.8) *	1.6 (1.4-1.8)
D. Child's self- concept	0.2 (0.3)	1.0 (0.7)	0.8 (0.7-1.0) *	1.5 (1.2-1.7)
E. Social activities	0.1 (0.2)	0.9 (0.6)	0.8 (0.7-0.9) *	1.9 (1.6-2.1)
F. Risky activities	0.0 (0.1)	0.3 (0.3)	0.3 (0.2-0.3) *	1.4 (1.1-1.6)
ADHD-rs				
Total score	**7.0 (7.1)**	**39.7 (14.2)**	**33.4 (31.0-35.8)** *	**2.9 (2.6-3.2)**
Sub scales				
1. Inattentive	3.3 (3.9)	16.9 (5.4)	13.5 (12.5-14.5) *	2.8 (2.5-3.1)
2. Hyperactive	2.3 (3.0)	14.3 (6.5)	12.0 (10.9-13.1) *	2.4 (2.1-2.6)
3. Conduct	1.3 (2.1)	8.0 (5.6)	7.7 (6.8-8.6) *	1.8 (1.6-2.1)

*=p<0.001

Table 1: Total scores and sub-scale scores on Children's Sleep Habits Questionnaire (CSHQ), Weiss Functional Impairment Rating Scale (WFIRS) and ADHD Rating Scale (ADHD-rs) in the control group and in the patient group. Standard deviations (SD)

Difference (diff), 95% confidence intervals (CI), and effect sizes (ES) are displayed.

Comorbidity						Presentations			Presentations (no co-morbidity)		
	ADHD no co-morbidity (n = 94)	ADHD +internalising co-morbidity (n = 27)	ADHD +externalising co-morbidity (n = 66)	ADHD +autism (n = 9)	ADHD +tics/ Tourette (n = 13)	ADHD combined (n = 166)	ADHD inattentive (n = 38)	ADHD hyp/imp (n = 5)	ADHD combined (n = 51-66)	ADHD inattentive (n = 21-26)	ADHD hyp/imp (n = 2)
CSHQ total score (SD)	**45.5 (7.0)**	**52.5 (6.5)***	**46.8 (7.0)**	**54.9 (9.9)***	**46.8 (6.8)**	**47.3 (13.9)**	**47.7 (8.6)**	**46.6 (8.2)**	**46(7.2)**	**45.0(6.9)**	**39.5(0.7)**
WFIRS total score (SD)	**0.7 (0.3)**	**0.9 (0.4)§**	**1.0 (0.4)***	**1.1 (0.5)***	**0.8 (0.4)**	**0.9 (0.4)**	**0.6 (0.3)***	**0.8 (0.3)**	**0.8(0.3)**	**0.5(0.2)§**	**0.5(0.1)**
ADHD-rs total score (SD)	**36.1 (13.0)**	**43.6 (14.1)§**	**44.4 (14.4)***	**37.9 (16.9)**	**39.1 (15.0)**	**47.4 (7.5)**	**28.7 (10.2)***	**31.3 (9.0)**	**36.5(12.6)**	**26.2(9.1)***	**25.5(7.8)**
*** = p < 0.001, §p = <0.05 compared to no comorbidity, adjusted for age and gender**						***= p <0.001, §p = <0.05 compared to ADHD combined type, adjusted for gender and age**					

Table 2: Total scores on the Children's Sleep Habits Questionnaire (CSHQ), the Weiss Functional Impairment Rating Scale (WFIRS), and the ADHD Rating Scale (ADHD-rs), in the control group and in the patient group. Comorbidity and presentations with and without comorbidity are displayed. Internalising comorbidity (depression, anxiety, obsessive compulsive disorder), externalising comorbidity (oppositional defiant disorder, conduct disorder). Hyperactive impulsive presentation (hyp/imp). Standard deviation (SD).

CSHQ and WFIRS

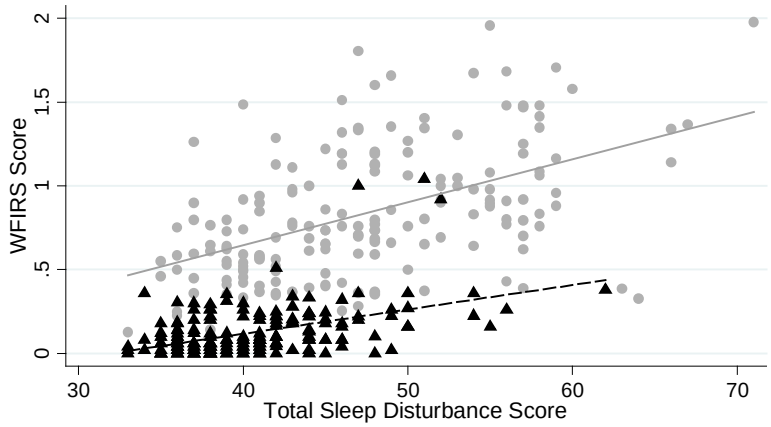


Figure 2: Correlation between total sleep disturbance score from the Children's Sleep Habits Questionnaire (CSHQ) and Weiss Functional Impairment Rating (WFIRS) in patients n = 176, (grey dots) and in controls n = 188, (black triangles). Patients: Correlation and 95% confidence interval (r = 0.50(0.38–0.60)). Controls: Correlation and 95% confidence interval (r = 0.46(0.31–0.57)).

CSHQ and ADHD-rs

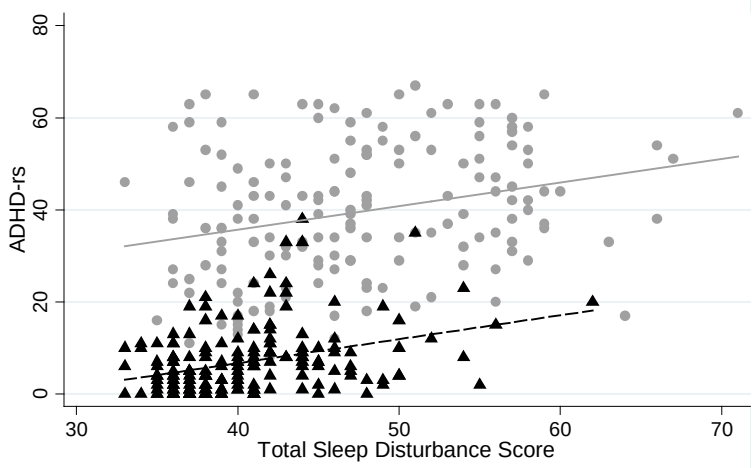


Figure 3: Correlation between total sleep disturbance score from the Children's Sleep Habits Questionnaire (CSHQ) and ADHD Rating Scale (rs) in patients n = 161 (grey dots) and in controls n = 188 (black triangles). Patients: Correlation and 95% confidence interval (r = 0.27(0.12–0.41)). Controls: Correlation and 95% confidence interval (r = 0.35(0.21–0.47)).