

## SCIENTIFIC INVESTIGATIONS

# The Association Between Insomnia and Sleep Duration in Adults With Attention-Deficit Hyperactivity Disorder: Results From a General Population Study

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**Study Objectives:** Insomnia and short or long sleep duration are important comorbid conditions in adults with attention-deficit hyperactivity disorder (ADHD), but reports of the association vary. In a general population study, we evaluated the relationship between ADHD symptom severity, insomnia symptoms, and sleep duration in adults.

**Methods:** Data were from the third wave of the Netherlands Mental Health Survey and Incidence Study-2 (NEMESIS-2; n = 4,618). ADHD symptom severity and symptom dimensions (hyperactivity and inattention) were assessed using the Adult ADHD Self-Report Scale screener. Self-reported insomnia symptoms (Insomnia Rating Scale; IRS) were defined as clinically relevant if IRS  $\geq$  9. Self-reported short sleep duration was defined as  $\leq$  6 hours, and long sleep duration as  $\geq$  10 hours.

**Results:** Within the group with clinically relevant ADHD symptoms, 43% reported significant insomnia symptoms (odds ratio [OR] = 2.66, 95% confidence interval [CI] 1.74–4.07); 41% short sleep duration (relative risk ratio [RRR] = 1.94, 95% CI 1.31–2.85) and 6% long sleep (RRR = 5.87, 95% CI 1.97–17.45). Increased inattention symptoms were associated with IRS  $\geq$  9, short and long sleep duration in fully adjusted models (OR = 1.10, 95% CI 1.06–1.14; RRR = 1.06, 95% CI 1.02–1.09; RRR = 1.16, 95% CI 1.05–1.28, respectively). Increased hyperactivity symptoms were associated with IRS  $\geq$  9 (OR = 1.17, 95% CI 1.11–1.23) and short sleep duration (RRR = 1.12, 95% CI 1.05–1.19).

**Conclusions:** Both clinically significant ADHD symptoms and inattention and hyperactivity symptom dimensions were consistently associated with insomnia symptoms and altered sleep duration. These associations confirm that sleep disturbances should be assessed and given appropriate clinical attention in adults with ADHD.

**Keywords:** ADHD, adults, attention-deficit hyperactivity disorder, general population survey, insomnia, sleep duration

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### BRIEF SUMMARY

**Current Knowledge/Study Rationale:** Insomnia and altered sleep duration are important comorbid conditions in adults with attention-deficit hyperactivity disorder (ADHD). Several cross-sectional clinical and population studies reported a prevalence of insomnia of 43% to 80% in adults with ADHD. One longitudinal study described an association between ADHD and insomnia; another did not. In a general population study, we evaluated the relationship between self-reported ADHD symptom severity, ADHD symptom dimensions, insomnia symptoms, and sleep duration in adults.

**Study Impact:** Clinically significant ADHD symptoms (four to six symptoms on the Adult ADHD Self-Report Screener) and the inattention and hyperactivity symptom dimensions were consistently associated with insomnia and altered sleep duration. We have confirmed that insomnia and altered sleep duration occur commonly in adults with ADHD; hence, they should be appropriately assessed and treated.

### INTRODUCTION

Attention-deficit hyperactivity disorder (ADHD) is a childhood-onset neurodevelopmental disorder that is marked by inattention and impulsivity, with or without hyperactivity.<sup>1</sup> ADHD persists into adulthood in two-thirds of children with ADHD,<sup>2</sup> where the cross-national estimated prevalence of ADHD is 2.8%.<sup>3</sup> Some researchers view ADHD as a dimensional disorder, where symptoms are best considered as continuous traits across the general population.<sup>4</sup> At a certain threshold of symptom severity, in combination with

significant dysfunction in daily life, a clinical diagnosis of ADHD may be made.<sup>1</sup> Adult ADHD is highly comorbid with other psychiatric disorders: 52% of adults with ADHD have any comorbid psychiatric disorder.<sup>3</sup> The most common comorbidities are anxiety, mood, behavioral, and sleep disorders.<sup>3</sup>

There is evidence for an increased prevalence of several sleep disorders in adult ADHD, including insomnia, circadian rhythm disturbances, restless legs syndrome, and obstructive sleep apnea, comprehensively reviewed by Instanes et al.<sup>5</sup> Several cross-sectional, clinical, and population

studies reported a prevalence of insomnia in adults with ADHD ranging from 43% to 80%.<sup>6–9</sup> Two longitudinal studies described conflicting findings; in one there was a significant association between persistent childhood ADHD and insomnia at age 18.<sup>10</sup> The other showed no association between childhood or adolescent ADHD and insomnia diagnosed at age 38 years.<sup>11</sup> ADHD symptom severity correlated with worsening of sleep quality in a small study among adults,<sup>12</sup> but a community study of young adults (aged 18–20 years) did not find this association.<sup>13</sup> Some studies within adult ADHD populations have examined insomnia symptoms, such as subjective sleep quality, which was reported as poorer in adults with ADHD than in controls (reviewed in Instanes et al.).<sup>5</sup>

Reports of sleep duration in adult ADHD vary, with the literature reporting no change as well as a combination of both short and long sleep duration. A very large population study ( $n = 30,858$ ; ADHD cases  $n = 1,122$ ) found that both increased and decreased sleep duration were associated with increasing odds of reporting ADHD symptoms.<sup>14</sup> Two other studies reported a mean total sleep duration less than 6 hours in adults with ADHD<sup>15,16</sup>; however, the latter included a very small ADHD sample ( $n = 24$ ). In contrast, in three small studies (ADHD samples  $n = 20–40$ ) measuring total sleep duration objectively using actigraphy or polysomnography, no significant difference in sleep duration was found between those with ADHD and healthy controls.<sup>17–19</sup> Two large studies using self-reported sleep duration also showed no difference in sleep duration in (young) adults with and without ADHD ( $n = 64$  and  $n = 175$ , respectively).<sup>13,20</sup>

The clinical implications of suboptimal sleep include worsening of ADHD symptoms, as sleep regulates learning and consolidation of memory.<sup>21</sup> Sleep loss in the general population is well known to impair performance on attention and executive control tasks.<sup>22</sup> These authors showed that 6 hours of sleep restriction for 14 days produced detrimental effects on sustained attention and working memory that were comparable to the effects of 2 nights of full sleep deprivation. In view of the deleterious effects of sleep loss on cognitive functioning, and the conflicting results in the literature, it is important to clarify the relationship between ADHD and sleep duration in a larger adult sample.

Two main symptom dimensions are present in ADHD: hyperactivity/impulsivity and inattention.<sup>1</sup> Research specifically investigating sleep disorders and these two symptom dimensions is preliminary and has given mixed results in adults, as reported in two reviews.<sup>5,23</sup> The relationship between specific ADHD symptom dimensions and sleep problems is important because patients with these separate clinical profiles may require different treatments.

In this study, we aimed to clarify if the burden of insomnia and disturbed sleep duration increases with higher ADHD symptom severity. We examined ADHD symptom severity, ADHD symptom dimensions, insomnia symptoms, and sleep duration among the Dutch general population, taking a range of sociodemographic and lifestyle factors, comorbid mental disorders, and medical conditions into account.

## METHODS

### Participants

Subjects (aged 18–64 years) participated in the Netherlands Mental Health Survey and Incidence Study-2 (NEMESIS-2), an epidemiological study of the prevalence, incidence, course, and consequences of psychiatric disorders in the Dutch general population. A full description of NEMESIS-2 has been reported elsewhere.<sup>24</sup> In short, NEMESIS-2 is based on a multistage, stratified, random sampling of households, with one respondent randomly selected from each household. Insufficient fluency in Dutch was an exclusion criterion.<sup>24</sup> The baseline wave included 6,646 subjects, and was conducted from November 2007 to July 2009. The response rate was 65.1%. The sample was nationally representative, although younger participants were somewhat underrepresented.<sup>24</sup> This study is based on wave 3, where 4,618 persons of the 5,303 who had completed wave 2 were interviewed (from November 2013 to June 2015). The response rate at wave 3 was 87.8%. Attrition at wave 3 was not significantly associated with all individual 12-month mental disorders at baseline after controlling for sociodemographics.<sup>25</sup> The research proposal was approved by a medical ethics committee. At each wave, all participants gave written informed consent at enrollment, after the study procedures had been fully explained.

### Measures

#### Adult ADHD Symptoms

At wave 3, the Adult ADHD Self-Report Scale (ASRS) Screener version 1.1<sup>26</sup> was used to assess adult ADHD symptoms. There are six items: four indicating inattention symptoms and two indicating hyperactivity symptoms. Symptom frequency was rated over the past 6 months, on a five-point Likert scale ranging from 0 (never) to 4 (very often). Scores on the six items were converted into binary values according to the official scoring system. The ASRS screener has been shown to have moderate sensitivity (68.7%), excellent specificity (99.5%), and excellent total classification accuracy (97.9%) for ADHD.<sup>26</sup> Internal consistency reliability of the ASRS Screener has been shown to fall in the range 0.63–0.72.<sup>27</sup> Compared to the 18-item version, the ASRS screener is more sensitive and specific, suggesting better classification accuracy.<sup>26,27</sup> In this study, severity of ADHD symptoms was determined by the number of scored ADHD symptoms on the ASRS screener, where 0 symptoms was labeled “none,” 1–3 symptoms as “few,” and 4–6 as “clinically relevant ADHD symptoms” which is an indication for a diagnosis of ADHD.<sup>27,28</sup> In addition, we assessed ADHD symptoms continuously, using a sum score of possible ratings on the six questions, (range 0–24). For this sum score, we allowed for a maximum of two missing items on the six questions. Where there were missing values, we used the mean of the responses of that individual for the other questions. The ADHD symptom dimensions of hyperactivity and inattention were assessed as continuous variables using a sum score, with a range of 0–8 for the hyperactivity (no missings imputed) and 0–16 for the inattention symptom dimensions (maximally one missing imputed by the mean), respectively.

## Sleep Measures

Insomnia symptoms were measured with the Women's Health Initiative Insomnia Rating Scale (IRS),<sup>29</sup> which consists of five questions addressing sleep in the past 4 weeks. These address difficulties initiating and maintaining sleep, early morning awakening (two questions), and overall sleep quality. Answers were on a five-point scale, ranging from 0 "less than once a week" to 4 "five times or more a week" for the first four questions, and the last question on sleep quality ranged from 0 "very sound or restful" to 4 "very restless." For each item, a score of 3 or 4 was considered to suggest pathology. The IRS has good test-retest reliability and has high convergent correlation with objective actigraphy sleep measures.<sup>30</sup> In all analyses, the total summary IRS score (0–20) was dichotomized at the cutoff point of 9 or higher, which indicated clinically significant insomnia symptoms.<sup>29</sup> We were interested in the contribution of each of the four domains of insomnia symptoms; hence, we examined these separately in relation to ADHD symptoms.

An additional question investigated total sleep duration. Participants were asked to estimate the average number of hours of sleep per night during the past 4 weeks. Answer options were: "10 or more hours," "9 hours," "8 hours," "7 hours," "6 hours," "5 or less hours." In all analyses, the single variable sleep duration was subcategorized into short ( $\leq 6$  h/night), normal (7–9 h/night), and long ( $\geq 10$  h/night), in accordance with the American Academy of Sleep Medicine and the Sleep Research Society's consensus statement on the recommended amount of sleep for healthy adults.<sup>31</sup>

## Covariates

Worse insomnia symptoms have previously been associated with increased age, female sex, partner status, and lower income.<sup>32</sup> Shorter sleep duration has been associated with worse health status, increased cardiovascular risk, presence of depression, and increased body mass index (BMI).<sup>33</sup> In the NEMESIS cohort, insomnia was found to be prevalent across different categories of mental disorders.<sup>34</sup> Therefore, in this study, we controlled for age, sex, living with a partner (yes/no), having a paid job (yes/no), chronic somatic disease (presence of one or more of 17 chronic physical disorders treated or monitored by a medical doctor in the previous 12 months, as assessed with a standard checklist), BMI, smoking last month (yes/no), exercise ( $< 1$  h/wk versus  $\geq 1$  h/wk); and the presence of any 12-month period of a mood, anxiety, or substance use disorder, as determined by the Composite International Diagnostic Interview, version 3.0—a fully structured, lay-administered diagnostic interview. Very few participants ( $n = 11$ , 0.2%) reported ADHD medication use. Therefore, we did not include ADHD medication use as a covariate.

## Statistical Analyses

We reported general characteristics of the sample using frequencies and percentages for categorical data, in terms of ADHD symptom severity (none, few, clinically relevant). Multivariate logistic regression analyses were performed to demonstrate how the sum scores of ADHD symptom severity and ADHD symptom subtype dimension (hyperactive or inattentive) were associated with the outcome, insomnia symptoms.

Multivariate multinomial regression analyses were performed to demonstrate how these associated with sleep duration. Results were adjusted for sex and age in model 1, and additionally for partner status, job status, any chronic somatic disorder, BMI, smoking last month, exercise last week, any 12-month mood, anxiety or substance use disorder in model 2. Results were expressed as adjusted odds ratios or relative risk ratios. All analyses were performed with STATA version 12.1 (Stata-Corp, College Station, Texas, United States), using weighted data to correct for differences in the response rates in several sociodemographic groups and differences in the probability of selection of respondents within households at baseline, with statistical significance inferred at  $\alpha < .05$ .

## RESULTS

**Table 1** describes the sample characteristics of the total sample, across ADHD symptom severity categories (none, few, and clinically relevant). No ADHD symptoms were found in 43% of the sample, 51% reported few symptoms, and 6% reported clinically relevant ADHD symptoms. Clinically relevant ADHD symptoms were significantly associated with female sex ( $P = .017$ ), younger age group ( $P < .001$ ), living without a partner ( $P < .001$ ), not having a paid job ( $P < .005$ ), smoking in the past month ( $P < .001$ ), and any 12-month mood/anxiety/substance use disorder (all  $P < .001$ ).

The prevalence of insomnia symptoms and sleep duration across the three ADHD symptom severity groups is described in **Table 2**. The group with clinically relevant ADHD symptoms had the highest prevalence of clinically significant insomnia symptoms (IRS  $\geq 9$ ): 43% reported significant insomnia symptoms, as opposed to 18% in the group with no ADHD symptoms. Those with clinically relevant ADHD symptoms also had the highest prevalence of the separate symptoms defining insomnia (difficulty initiating and maintaining sleep, early morning awakening, poor sleep quality); all  $P < .001$ . They also reported longer sleep duration as well as shorter sleep duration more often.

When we tested the associations between the insomnia variables and ADHD symptom severity groups (with no symptoms as the reference) in partially and fully adjusted logistic regression analyses, the groups with few and clinically relevant ADHD symptoms were significantly associated with all outcome variables in both models (**Table 3**). The  $P$  for trend was also significant for each outcome variable, meaning that across the three categories of increasing ADHD symptom severity (none, few, clinically relevant), there was a significant increase in the odds ratios for insomnia symptoms and relative risk ratios of short and long sleep duration. In the fully adjusted models, the group with clinically relevant ADHD symptoms had more than double the risk of insomnia symptoms and almost double the risk of short sleep duration, compared to the group with no ADHD symptoms.

The prevalence of both short ( $\leq 6$  h/night) and long ( $\geq 10$  h/night) sleep duration was highest in subjects with clinically relevant ADHD symptoms: 6% had long sleep duration, and 41% had short sleep duration (**Table 2**). An unexpected finding was

**Table 1**—Sociodemographic and health characteristics of the total Dutch general population sample (n = 4,618) and across ADHD symptom severity categories (none, few and clinically relevant).

	n (%) *	ADHD Symptoms			P
		None (n = 2,104, 42.8%)	Few (n = 2,278, 51.2%)	Clinically Relevant (n = 236, 6.0%)	
		%	%	%	
<b>Sex</b>					.017
Male	2,059 (49.8)	51.9	49.3	39.5	
Female	2,559 (50.2)	48.1	50.7	60.5	
<b>Age</b>					< .001
23–37 years	767 (26.0)	17.7	31.9	34.5	
38–47 years	1,079 (22.7)	22.2	22.8	26.6	
48–57 years	1,178 (24.2)	25.8	22.5	26.8	
58–70 years	1,594 (27.1)	34.3	22.8	12.1	
<b>Education</b>					.085
Primary or lower secondary education	1,379 (29.2)	30.0	28.0	33.4	
Higher secondary education	1,479 (41.3)	42.4	39.9	44.8	
Higher professional education, or university	1,760 (29.5)	27.6	32.1	21.8	
<b>Living Without Partner</b>	1,268 (27.8)	25.6	27.8	43.5	< .001
<b>Without Paid Job</b>	1,471 (28.2)	29.2	26.2	38.9	.005
<b>Any Chronic Somatic Disease</b>	2,016 (40.9)	40.7	40.6	44.5	.644
<b>BMI</b>					.082
Underweight (< 18.5 kg/m <sup>2</sup> )	55 (1.4)	0.9	1.4	4.1	
Normal (18.5–24.9 kg/m <sup>2</sup> )	2,237 (48.1)	46.1	49.6	49.6	
Overweight (25–29.9 kg/m <sup>2</sup> )	1,674 (36.4)	38.2	35.1	34.0	
Obese (≥ 30 kg/m <sup>2</sup> )	645 (14.2)	14.8	13.9	12.3	
<b>Smoking Last Month</b>	1,076 (25.4)	23.1	25.8	37.9	< .001
<b>Exercise &lt; 1 h/wk</b>	1,709 (37.2)	35.5	38.0	42.0	.241
<b>Any 12-Month Mood Disorder</b>	238 (5.4)	1.5	6.0	29.5	< .001
<b>Any 12-Month Anxiety Disorder</b>	270 (6.8)	3.2	7.9	24.4	< .001
<b>Any 12-Month Substance Use Disorder</b>	131 (4.1)	2.4	4.8	10.4	< .001

\* = in unweighted numbers and weighted percentages. ADHD = attention-deficit hyperactivity disorder.

**Table 2**—Percentages of insomnia symptoms and other sleeping problems across ADHD symptom severity categories (none, few and clinically relevant) in the general Dutch population sample (n = 4,618).

	n (%) *	ADHD Symptoms			P
		None	Few	Clinically Relevant	
		%	%	%	
<b>Insomnia Rating Scale ≥ 9</b>	1,109 (22.9)	17.9	24.7	42.9	< .001
<b>Difficulty Initiating Sleep</b>	379 (8.3)	5.5	9.0	22.2	< .001
<b>Difficulty Maintaining Sleep</b>	1,439 (29.7)	26.9	30.3	44.8	< .001
<b>Early Morning Awakening</b>	1,074 (22.6)	19.1	23.5	40.0	< .001
<b>Poor Sleep Quality</b>	574 (11.7)	8.2	12.8	28.5	< .001
<b>Total Sleep Duration</b>					< .001
Short (≤ 6 h/night)	1,376 (29.7)	27.4	30.3	41.2	
Normal (7–9 h/night)	3,170 (68.9)	71.7	68.5	52.8	
Long (≥ 10 h/night)	70 (1.4)	0.9	1.3	5.9	

\* = in unweighted numbers and weighted percentages. ADHD = attention-deficit hyperactivity disorder.

the significant relationship between clinically relevant ADHD symptoms and long sleep duration (≥ 10 h/night), although the significance level was less strong and the confidence interval

quite large (for this specific category  $P < .01$ ). Overall, these findings as well as those in **Table 3** suggest that worsening ADHD symptom severity is significantly associated with



**Table 3**—Ratios of insomnia symptoms and other sleeping problems across ADHD symptom severity categories (none, few, and clinically relevant) in the general Dutch population sample (n = 4,618), using partly and fully adjusted models.

	ADHD Symptoms (Ref = None)			ADHD Symptoms (Ref = None)		
	Few	Clinically Relevant	P for trend	Few	Clinically Relevant	P for trend
<b>Insomnia Rating Scale ≥ 9</b>	1.69 (1.39–2.05)***	4.01 (2.74–5.87)***	< .001	1.51 (1.24–1.84)***	2.66 (1.74–4.07)***	< .001
<b>Difficulty Initiating Sleep</b>	1.81 (1.36–2.39)***	5.14 (3.37–7.84)***	< .001	1.40 (1.06–1.85)**	2.03 (1.09–3.80)**	.009
<b>Difficulty Maintaining Sleep</b>	1.41 (1.18–1.69)***	2.87 (1.91–4.32)*	< .001	1.30 (1.08–1.58)*	2.17 (1.35–3.48)*	< .001
<b>Early Morning Awakening</b>	1.41 (1.15–1.74)*	3.11 (2.23–4.35)***	< .001	1.28 (1.03–1.58)*	2.21 (1.50–3.26)***	< .001
<b>Poor Sleep Quality</b>	1.74 (1.36–2.22)***	4.70 (3.26–6.79)***	< .001	1.46 (1.14–1.87)*	2.60 (1.65–4.09)***	< .001
<b>Total Sleep Duration</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>P for trend</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>P for trend</b>
Short (≤ 6 h/night)	1.24 (1.06–1.44)*	2.29 (1.56–3.35)***	< .001	1.18 (1.01–1.38)*	1.94 (1.31–2.85)***	.001
Normal (7–9 h/night)	Ref	Ref	Ref	Ref	Ref	Ref
Long (≥ 10 h/night)	1.72 (0.80–3.67)	12.04 (4.83–30.02)***	< .001	1.44 (0.63–3.27)	5.87 (1.97–17.45)**	.015

Asterisks indicate statistical significance: \* =  $P < .05$ , \*\* =  $P < .01$ , \*\*\* =  $P < .001$ . Model 1 is adjusted OR/RRR for sex and age. Model 2 is adjusted for the factors in Model 1 and additionally adjusted for partner status, job status, any chronic somatic disorder, body mass index, smoking last month, exercise last week, any 12-month mood, anxiety or substance use disorder. ADHD = attention-deficit hyperactivity disorder, CI = confidence interval, OR = odds ratio, Ref = reference, RRR = relative risk ratio.

**Table 4**—Ratios of insomnia symptoms and other sleeping problems across total ADHD symptoms, hyperactivity and inattention as continuous ADHD dimension variables, in the general Dutch population sample (n = 4,618), using partly and fully adjusted models.

	Total ADHD Symptoms		ADHD Hyperactivity Dimension		ADHD Inattention Dimension	
	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
<b>Insomnia Rating Scale ≥ 9</b>	1.12 (1.10–1.15)***	1.09 (1.06–1.13)***	1.20 (1.15–1.26)***	1.17 (1.11–1.23)***	1.14 (1.11–1.18)***	1.10 (1.06–1.14)***
<b>Difficulty Initiating Sleep</b>	1.15 (1.12–1.18)***	1.08 (1.04–1.12)***	1.25 (1.16–1.34)***	1.16 (1.07–1.25)***	1.18 (1.14–1.22)***	1.08 (1.04–1.13)***
<b>Difficulty Maintaining Sleep</b>	1.07 (1.05–1.10)***	1.06 (1.03–1.08)***	1.16 (1.10–1.21)***	1.14 (1.08–1.19)***	1.08 (1.04–1.11)***	1.05 (1.01–1.09)*
<b>Early Morning Awakening</b>	1.09 (1.07–1.12)***	1.07 (1.04–1.09)***	1.18 (1.13–1.24)***	1.15 (1.09–1.21)***	1.10 (1.06–1.13)***	1.06 (1.02–1.10)**
<b>Poor Sleep Quality</b>	1.16 (1.13–1.19)***	1.12 (1.08–1.15)***	1.28 (1.20–1.36)***	1.21 (1.14–1.30)***	1.19 (1.15–1.23)***	1.13 (1.09–1.17)***
<b>Total Sleep Duration</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>	<b>RRR (95% CI)</b>
Short (≤ 6 h/night)	1.07 (1.04–1.10)***	1.06 (1.03–1.09)***	1.13 (1.07–1.20)***	1.12 (1.05–1.19)***	1.07 (1.04–1.11)***	1.06 (1.02–1.09)**
Normal (7–9 h/night)	Ref	Ref	Ref	Ref	Ref	Ref
Long (≥ 10 h/night)	1.17 (1.07–1.28)**	1.10 (1.01–1.20)*	1.18 (0.92–1.53)	1.05 (0.84–1.32)	1.25 (1.14–1.37)***	1.16 (1.05–1.28)**

Asterisks indicate statistical significance: \* =  $P < .05$ , \*\* =  $P < .01$ , \*\*\* =  $P < .001$ . Model 1 is adjusted for sex and age. Model 2 is adjusted for the factors in Model 1 and additionally adjusted for partner status, job status, any chronic somatic disorder, body mass index, smoking last month, exercise last week, any 12-month mood, anxiety or substance use disorder. ADHD = attention-deficit hyperactivity disorder, CI = confidence interval, OR = odds ratio, Ref = reference, RRR = relative risk ratio.

insomnia symptoms and altered sleep duration, after adjustment for a wide range of possible confounders, indicating a dose-response association.

**Table 4** describes the associations between insomnia symptoms, sleep duration, total ADHD symptom score, and the two symptom dimensions hyperactivity and inattention. Again, the continuous variables for ADHD symptoms, including hyperactivity and inattention, all show a strongly significant relationship with clinically significant insomnia symptoms in the fully adjusted models (all  $P < .001$ ). All the separate symptoms defining insomnia showed a significant relationship with ADHD symptoms, hyperactivity and inattention dimensions, assessed continuously, in both models. The predictor variables for all insomnia and sleep duration outcomes did not change

markedly with full correction in model 2, demonstrating that the association between ADHD and sleep disturbance is robust, and not attributable to confounding factors. The hyperactivity dimension was significantly associated with short sleep, but not related to long sleep duration.

## DISCUSSION

In this study, we evaluated the independent association between adult ADHD symptom severity, ADHD symptom dimensions, insomnia symptoms, and sleep duration. Our results showed two main findings. First, clinically significant insomnia symptoms were strongly and consistently associated with

increasing severity of ADHD symptoms, and with the symptom dimensions of hyperactivity and inattention. There was a dose-response relationship between insomnia symptoms and ADHD symptom severity and ADHD symptom dimensions. Second, although self-reported short sleep duration was significantly associated with both inattentive and hyperactive symptom dimensions, long sleep duration was only associated with inattention and not with hyperactivity. After correcting for comorbid psychiatric disorders in the past year (mood, anxiety, and substance use disorders), these associations remained significant. This is noteworthy, because it indicates that even in the general population, these relationships are not attributable to another comorbid disorder.

A dose-response relationship between ADHD symptom severity and insomnia was also found in two large studies<sup>8,35</sup> and one smaller clinical study.<sup>12</sup> Ours and these three studies included adults aged up to 74 years.<sup>8,12,35</sup> However, in a community study of young adults (18–20 years), Gau et al. found no such dose response relationship ( $n = 2,284$ ).<sup>13</sup> The study of Gau et al. may indicate that in young adults, there is less difference in insomnia between those with and without ADHD. Our larger age range may account for more variability in self-reported ADHD and insomnia symptoms. It is also recognized that ADHD persisting into adulthood causes more severe impairment.<sup>36</sup> Similarly, insomnia symptoms worsen with increasing age<sup>37</sup> and poorer sleep quality in adult ADHD has been attributed to the presence of depressive symptoms.<sup>35</sup> We therefore also adjusted for mood and anxiety disorders and yet still found a dose-response relationship between increasing ADHD symptom severity and insomnia.

In terms of the ADHD symptom dimensions and insomnia symptoms, we found that clinically significant insomnia symptoms correlated strongly and significantly with both inattention and hyperactivity symptom dimensions. The research on ADHD subtypes and sleep disturbance to date has been mixed. Insomnia symptoms have been associated with: (1) the number of hyperactivity/impulsivity symptoms<sup>12</sup>; (2) the combined ADHD and inattentive subtype<sup>8</sup>; (3) inattentive symptoms only.<sup>7,13,38,39</sup> However, one study reported no association.<sup>6</sup> We found that insomnia correlated strongly with both inattentive and hyperactive symptoms, even after adjusting for multiple possible confounders, and despite using a population sample, where symptoms tend to be milder than in clinical studies. The clinical study by Fisher et al. (1,163 adults with ADHD) also demonstrated a strong association between adults with ADHD and insomnia, in both ADHD subtypes.<sup>6</sup>

Our second significant finding was that ADHD symptoms were associated with self-reported short and long sleep duration, as opposed to normal sleep. Our finding replicates the large population study of Bogdan and Reeves, although they did not correct for comorbid affective disorder.<sup>14</sup> In other clinical studies, ADHD patients reported shorter sleep duration than controls.<sup>40,41</sup> When sleep duration was objectively measured, it was found to be normal in three studies.<sup>17–19</sup> Normal sleep duration was also found in two studies using self-report measures.<sup>13,20</sup> It is possible that findings for altered sleep duration are less strong when objective sleep measures are used. Finally, a study of 22 adults with ADHD

found no correlation between number of ADHD symptoms and sleep duration, a negative finding that may be explained by the small sample size.<sup>12</sup>

Short sleep duration has been well described in the ADHD literature. Some authors have related it to increased nocturnal motor activity, as measured objectively by polysomnography,<sup>17,42–44</sup> although one study did not confirm this.<sup>45</sup> Our results significantly associated short sleep and ADHD symptoms. This relationship may be also explained by the presence of a comorbid delayed circadian rhythm disorder, such as delayed sleep phase syndrome.<sup>5</sup> Generally, delayed sleep phase syndrome is characterized by a preference for sleep onset after midnight, with consequent difficulty awaking, daytime sleepiness, and impaired functioning.<sup>1</sup> Individuals with delayed sleep phase syndrome have sleep onset insomnia when trying to fall asleep early.<sup>46</sup> When early rising is necessary, a cumulative sleep debt may arise—meaning that total sleep duration is shorter.

In terms of long sleep in ADHD, we found a strong and significant association with ADHD symptom severity and the inattention symptom dimension, showing a dose-response relationship. Long sleep was far less prevalent than short sleep duration in the ADHD group.

A first possible way to explain long sleep duration associated with ADHD is the presence of an (undiagnosed) comorbid disorder.<sup>14</sup> In general, sleep duration shows a U-shaped association with overall mortality, cardiovascular disease, obesity, and diabetes.<sup>47</sup> Hence, both short and long sleep duration are detrimental to health. In ADHD, such a comorbid disorder might include hypersomnia, affective disorder, or medical illness. Just as it is important to control for comorbid disorders when investigating insomnia (as mentioned previously), this is also true when investigating sleep duration. We did correct for mood, anxiety, substance, and somatic disorders in the past year, unlike some other studies.<sup>12,14,19,48,49</sup> Still, we found that ADHD symptoms and long sleep duration were significantly associated. This implies that an (atypical) subgroup of those with ADHD may exist on the continuum of adult ADHD. Hypersomnia, characterized by excessive daytime sleepiness and prolonged night time sleep, is increased in adults with ADHD compared to controls.<sup>5</sup> Hypersomnia may be misdiagnosed as ADHD.<sup>5</sup> Hence, where ADHD patients present with long sleep duration, hypersomnia should be excluded or treated. In general, the group with ADHD and long sleep may be at increased risk for overall mortality.<sup>47</sup>

A second possible explanation for long sleep in ADHD comes from the pediatric literature, where some authors have proposed that instability of the sleep-wake system is a characteristic of children with ADHD.<sup>50</sup> This instability (some with long sleep duration, some with short) may also be present in adult ADHD.

Regarding the two ADHD symptom dimensions and sleep duration in adults, there is a dearth of literature. Concurring with two studies, we found that short sleep duration was significantly associated with hyperactivity symptoms.<sup>12,13</sup> In a minority of subjects, long sleep duration was significantly associated with both hyperactive and inattentive symptoms. Regarding insomnia symptoms, significant findings in hyperactivity and inattention dimensions were very similar.

A question we were unable to address in our study is whether the treatment of sleep problems in those with ADHD improves the symptoms of inattention and hyperactivity. The cross-sectional nature of our analysis prevented us from analyzing this; however, future studies should examine this important clinical outcome.

Another striking finding was that 60.5% of those with clinically significant ADHD symptoms were females, as opposed to 39.5% males. This result contrasts with findings from the pediatric literature, where male children are more than twice as likely to have ADHD than female children.<sup>51</sup> However, ADHD in adult females has been described as underdiagnosed because the symptoms are less overt.<sup>52</sup> It has also been shown that the higher prevalence of ADHD in males tends to decrease with increasing age.<sup>52</sup> A recent study using the ASRS showed that although more males screened positive for ADHD, a difference between the sexes was not statistically significant.<sup>52</sup> Beyond this, we are unable to explain the increased prevalence of clinically relevant ADHD symptoms in females.

Despite the strengths of our study, several limitations should be noted. First, as this study is based on the third wave only and thus uses cross-sectional analyses, a clear causal direction of the relationships found cannot be demonstrated. Second, we relied on retrospective self-reports for ADHD symptoms present over the past 6 months using the Adult ADHD Self-Report Scale screener, which did not include a question about childhood onset of the symptoms. We used retrospective self-reporting for insomnia symptoms (present over the past 4 weeks). According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition diagnostic criteria, insomnia occurs when symptoms occur at least 3 nights/wk over a period of 3 months.<sup>1</sup> The IRS does not take duration of symptoms into account; therefore, we probably studied subjects with less severe symptoms, yet still we found significant associations between ADHD and insomnia symptoms. Sleep duration in the past 4 weeks were self-reported measures, where the categories of sleep duration may have limited variability. Yet, previous studies using both self-report measures and polysomnography indicate that long sleepers overestimate and short sleepers underestimate their true sleep duration.<sup>47</sup> Third, we controlled for anxiety, depressive, and bipolar disorders but we did not explore the potential overlap between ADHD and bipolar disorders. Bipolar disorder 2 can remain undiagnosed for years and exhibit similar symptoms to ADHD. In NEMESIS-2, the prevalence of all bipolar disorders was 0.8% in the past 12 months.<sup>53</sup> The 12-month prevalence of bipolar 2 disorder was 0.6%. This potential overlap would be interesting to investigate further. Fourth, regarding concomitant medication use, very few subjects used ADHD medication (0.2%), so we did not correct for them because we thought the results would not be meaningful. Neither did we correct for medications treating insomnia or hypersomnia. It would be interesting to note whether treatment of sleep disturbance in ADHD improves the core symptoms of this disorder. Finally, in terms of the ADHD symptom dimensions, hyperactivity was determined by only two questions and there was no assessment of impulsivity, a component of ADHD, meaning that we are unable to

comment on the relationship between impulsivity symptoms and insomnia/sleep duration.

In conclusion, we have confirmed that increasing symptom severity of ADHD is significantly associated with clinically significant insomnia symptoms, long and short sleep duration, after correction for a range of potential confounders. Both long and short sleep duration were also significantly associated with inattentive symptoms, in fully adjusted models, whereas hyperactive symptoms were associated with short sleep duration only. Adult ADHD and sleep disturbance symptoms are therefore linked with consistent and strong associations. This has serious implications for morbidity in ADHD, as insomnia, short and long sleep duration are all associated with significantly worse daily functioning<sup>34</sup> and adverse health outcomes<sup>33,47</sup> Where the comorbidities of adult ADHD are unrecognized and untreated, it has been shown that treatment costs increase and patients suffer more adverse long-term outcomes.<sup>54</sup> Sleep deprivation also worsens cognitive function.<sup>22</sup> In adult ADHD, attention and executive control are already compromised; therefore, insomnia should be recognized and treated. Insomnia can be successfully managed pharmacologically<sup>55</sup> and with cognitive behavioral therapy and light therapy.<sup>56,57</sup> Such treatments could be used to ameliorate the sleep disturbance we have found to be so prevalent in ADHD. Comorbid insomnia and altered sleep duration should be considered by clinicians treating these complex patients, to reduce suffering and improve functioning.

## ABBREVIATIONS

ADHD, attention-deficit hyperactivity disorder  
 ASRS, Adult ADHD Self-Report Scale Screener, version 1.1  
 BMI, body mass index  
 IRS, Women's Health Initiative Insomnia Rating Scale  
 NEMESIS-2, Netherlands Mental Health Survey and Incidence Study-2

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## SUBMISSION & CORRESPONDENCE INFORMATION

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## DISCLOSURE STATEMENT

Work for this study was performed at PsyQ Expertise Center Adult ADHD, The Hague and Trimbos Institute, Utrecht. All authors have seen and approve of the manuscript. The Netherlands Mental Health Survey and Incidence Study-2 (NEMESIS-2) is conducted by the Netherlands Institute of Mental Health and Addiction (Trimbos Institute) in Utrecht, The Netherlands. Financial support has been received from the Ministry of Health, Welfare and Sport, with supplemental support from the Netherlands Organization for Health Research and Development (ZonMw) and the Genetic Risk and Outcome of Psychosis (GROUP) investigators. These organizations had no further role in study design, collection, analysis and interpretation of data, writing of the report, and in the decision to submit the paper for publication. D. Wynchank has served on the advisory boards of Janssen BV, Novartis and Eli Lilly for activities outside the scope of this paper (2009–2014). Dr. Lamers has received funding from the European Union Seventh Framework Program (FP7/2007-2013) under grant agreement n° PCIG12-GA-2012-334065 for other activities outside the scope of this paper. Prof. Penninx has received research grants from Johnson & Johnson, Boehringer Ingelheim, NWO, BBRMI-NL, NIMH, and the EU-FP7 program (2014–2021) for research in the Netherlands Study of Depression and Anxiety (NESDA), activities outside the scope of this paper. Prof. Beekman has received funds through the speakers' bureau of Lundbeck and Eli Lilly. Dr. Kooij, Dr. Bijlenga, Dr. ten Have, and Dr. de Graaf declare no financial or other relationship relevant to the subject of this article.