

## The relationship between insomnia symptoms and school performance among 4966 adolescents in Shanghai, China ☆☆☆☆☆

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### ABSTRACT

**Purpose:** Insomnia symptoms are common in adolescents. This study examined the associations of insomnia symptoms with school performance among adolescents in Shanghai, China.

**Methods:** A total of 4966 adolescents aged 11–20 years participated in a cross-sectional survey during November of 2009. The Adolescent Sleep Disturbance Questionnaire was used to examine insomnia symptoms, and the Teacher School Achievement Form was applied to evaluate adolescents' school performance. **Results:** The results demonstrated that, after adjusting for possible confounders, all 3 dimensions of insomnia symptoms were associated with adolescents' school performance. Difficulty falling asleep problem was associated with poor attention and concentration (odds ratio [OR] = 1.30, 95% confidence interval [CI] 1.11–1.52,  $P = .001$ ), academic frustration (OR = 1.24, 95% CI: 1.06–1.45,  $P = .007$ ), and poor school relationships (OR = 1.26, 95% CI: 1.08–1.48,  $P = .003$ ); maintaining sleep problem was associated with poor attention and concentration (OR = 1.25, 95% CI: 1.06–1.46,  $P = .007$ ) and poor interest and motivation (OR = 1.22, 95% CI: 1.04–1.44,  $P = .017$ ); and reinitiating sleep problem was related to poor interest and motivation (OR = 1.20, 95% CI: 1.00–1.45,  $P = .048$ ). Coexisting insomnia symptoms were associated with poorer school performance, especially in maintaining attention and concentration.

**Conclusions:** The findings of this study highlight the importance of sleep in the social and cognitive development of adolescents.

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Accumulating evidence suggests that sleep plays a crucial role in pubertal physical and psychological development.<sup>1</sup> It has been found that a remarkably high prevalence of insomnia and insomnia symptoms occurred in adolescents.<sup>2–5</sup> A cross-sectional study among 6919 Portuguese adolescents aged 12–18 years reported that approximately one-fourth of participants suffered from insomnia symptoms with a frequency of at least 3 times per week.<sup>2,5</sup> Previous

studies have confirmed that sleep was involved in a wide spectrum of daytime functioning, including behavior, mood, and cognitive performance.<sup>6–8</sup> For adolescents, school performance could be a good indicator for daytime functioning because most of their daytime is spent in school. Therefore, it is natural to raise the question: are insomnia symptoms significant contributors to school performance among adolescents?

☆ Implications and contribution: Sleep appears to play a significant role in social and cognitive development. Adolescence is a susceptible period for sleep problems, and it is important to ensure sufficient sleep and reduce the occurrence of insomnia among adolescents.

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To the best of our knowledge, only 3 studies specifically explored the associations of insomnia symptoms with school performance among adolescents.<sup>3,4,9</sup> These studies mainly focused on the impact of insomnia symptoms on academic achievement, one aspect of school performance. Based on a holistic understanding of school performance, it should be a multidimensional condition.<sup>10–12</sup> Therefore, a more comprehensive evaluation on the associations of insomnia symptoms with multidimensional school performance is highly necessary. This study assessed 4 aspects of school performance, including attention and concentration, interest and motivation, academic achievement, and school relationship.<sup>10–12</sup>

In China, particular attention and special expectations are placed on children's academic performance. It has become a common practice for Chinese adolescents to spend more and more time on academic works even at the cost of sacrificing sleep to prepare for the forthcoming high school/college entrance examination. We speculate that this academic pressure may make Chinese adolescents experience high levels of stress and anxiety, which would lead to symptoms of insomnia. A previous study confirmed our hypothesis that the pressure of maintaining academic scores could cause stress and anxiety, which were associated with insomnia symptoms.<sup>13</sup> Therefore, compared to their peers in other countries, Chinese adolescents could be more susceptible to insomnia.<sup>14–16</sup>

This study comprehensively examines the associations of insomnia symptoms with school performance, including attention and concentration, interest and motivation, academic achievement, and school relationships among adolescents in Shanghai, China.

## Methods

### Subjects and procedures

A cross-sectional study was conducted during November 2009 in Shanghai, China. There are 17 districts in Shanghai, 9 located in the urban area and 8 in the suburbs. From these districts, 4 urban schools and 2 suburban schools were randomly sampled, and for every district, 2 junior high schools and 2 senior high schools were randomly sampled. Study subjects were recruited from these schools. Among 5159 students who were invited to take part in this study, 4966 (response rate: 96.25%) returned qualified questionnaires. More detailed information of the study design was described elsewhere.<sup>17</sup>

The questionnaire survey was performed during a regular health education class. In the class, questionnaires were disseminated to the students and their responsible teachers. Researchers explained the study purpose and the questionnaire guidelines and, particularly, emphasized that participation was voluntary. Students were requested to fill out the questionnaire with help from their parents. All students who did not attend the class were excluded from the survey.

### Measures

#### Insomnia symptoms

The Chinese version of the adolescent sleep disturbance questionnaire (ASDQ), a 6-subscale instrument, was used to examine sleep problems in this study. The ASDQ is a self-administrated questionnaire, which was developed based on literature review, a pilot study, and a reliability assessment.<sup>18–21</sup> Our previous study has proved that the ASDQ is a qualified instrument for assessing sleep problems among Chinese adolescents,<sup>22</sup> and the psychometric properties have been proven to be acceptable (Cronbach  $\alpha$  coefficients for internal consistency were 0.71 for the overall questionnaire and 0.61–0.73 for subscales, and intraclass correlation coefficients for the 2-week interval test-retest reliability were 0.85 for the overall questionnaire and 0.64–0.82 for subscales).<sup>23</sup>

Among the 6 subscales of the ASDQ, 3 were specifically designed to evaluate insomnia symptoms, covering 3 core characteristics of insomnia: difficulties in falling asleep (5 items), difficulties in maintaining sleep (7 items), and difficulties in reinitiating sleep (5 items).<sup>23</sup> The internal consistency (Cronbach  $\alpha$ ) and intraclass correlation coefficients for the test-retest reliability of the 3 subscales were 0.72 and 0.80 for the subscale of difficulties in falling asleep, 0.66 and 0.72 for subscale of difficulties in maintaining sleep, and 0.69 and 0.71 for the subscale of difficulties in reinitiating sleep.

For each item of ASDQ, the response was assessed on a 5-point Likert scale (4 = always/6–7 nights per week, 3 = quite often/3–5 nights per week, 2 = sometimes/1–2 nights per week, 1 = occasionally/<1 night per week, and 0 = never). An *individual sleep problem* was defined as the sleep behavior occurring sometimes or more often. Based on the scoring system, the prevalence of each subscale problem was calculated. For the purpose of the present study, insomnia symptoms were defined as having at least 1 individual insomnia problem within a respective subscale. The definition and cutoff were established with reference to clinical relevance and previous literature.<sup>14,24</sup> Comparatively, this is a mild and low cutoff for insomnia symptoms, which is helpful to explore the impact of insomnia on school performance.

#### School performance

The teacher school achievement form (TSAF) was used to evaluate adolescents' school performance by their responsible teachers.<sup>11,12</sup> In Shanghai, class size is no more than 30 students per class in junior high school and no more than 40 students per class in senior high school. Therefore, each responsible teacher assessed approximately 30 or 40 students.

The TSAF had proven to be good for assessing school performance among Chinese children and adolescents in our previous study.<sup>10</sup> The questionnaire was conceptually grouped into 4 subscales: (1) attention and concentration (2 items), (2) interest and motivation (4 items), (3) academic achievement (5 items), and (4) school relationship (2 items). Each response was scored as 1 for "excellent," 2 for "good," 3 for "medium," 4 for "somewhat poor," and 5 for "poor." In this scoring system, the higher the scores are, the lower the school performance.

- 1 Subscale of attention and concentration: to assess the degree of concentration on class listening or doing exercises.
- 2 Subscale of interest and motivation: Four items were used to evaluate children's interest and motivation toward study. For example, can he/she do his/her homework on his/her own? Can he/she prepare lessons before class? Does he/she have learning strategy to gain his/her learning achievement? And can he/she take the initiative to overcome the obstacle during learning?
- 3 Subscale of academic achievement: This part included items with regard to achievement in listening and speaking, reading, writing, mathematical calculating, and logical analysis.
- 4 Subscale of school relationship: Social relationship in school was investigated by 2 items: Can he/she do good job in teamwork? Can he/she get along well with peers and teachers?

The psychometric properties of the TSAF were also acceptable (Cronbach  $\alpha$  coefficients for the internal consistency were 0.96 for the overall questionnaire, 0.93 for subscale of attention and concentration, 0.94 for subscale of interest and motivation, 0.92 for subscale of academic achievement, and 0.93 for subscale of school relationship). Intraclass correlation coefficients for the test-retest reliability were 0.85 for the overall questionnaire and 0.64–0.88 for subscales.

#### Confounding factors

The possible confounding factors were grouped into 4 domains:

- 1 Demographic characteristics included age, sex, and class type (senior high school class/junior high school class).

- 2 Family structure and socioeconomic characteristics included family income (<1000, 1000–3000, and  $\geq$ 3000 renminbi [yuan] per person per month), family structure (single parent family, nuclear family, and large family [a family with grandparents, parents, and child]), and educational levels of parents (middle school or below, high school, and college or above).
- 3 Adolescent biological chronic health problems and routine behaviors included overweight and obesity status (yes/no), chronic respiratory condition (yes/no, defined as being ever diagnosed with allergic rhinitis and bronchitis, asthma, or tonsil/adenoidal hypertrophy by pediatricians), chronic pain (yes/no), history of attention-deficit/hyperactivity disorder diagnosis (yes/no), active or passive smoking (yes/no), drinking (yes/no), television viewing per day during weekdays and at weekends ( $\geq$ 2 h/d vs <2 h/d), computer use (usually/no), and physical activity during weekdays and at weekends (<1 h/d vs  $\geq$ 1 h/d).
- 4 Family history of sleep disorders included history of sleep disorders of parents (yes/no) and history of sleep disorders of grandparents (yes/no).
- 5 Study burden and school schedules included homework time during weekdays and weekends ( $\geq$ 2 h/d vs <2 h/d), review time during weekdays and weekends ( $\geq$ 2 h/d vs <2 h/d), regular study time (yes/no), reading time during weekdays and weekends ( $\geq$ 2 h/d vs <2 h/d), school start/end time (before 7:00 AM vs after 7:00 AM/after 4:30 PM vs before 4:30 PM).

The details of each factor were shown in Supplemental Materials, Supplementary Table S1.

#### Statistical analysis

Statistical descriptions were made using the mean and standard deviation for continuous variables, and percentage for categorical variables. To identify the relationship between insomnia symptoms and school performance in our sampled adolescents, logistic regression analyses were performed. Unadjusted odds ratio (OR) and 95% confidence intervals (CIs) were calculated by univariate logistic regression. Adjustments were further made by multivariable regression models following a 3-step procedure. Each model included additional variables to assess the relationship between insomnia symptoms and school performance. In the first step, a simple model (model I) was established, adjusting only for demographic and socioeconomic

characteristics. Secondly, variables including biological chronic health problems and routine behaviors and activities were further included (model II). Finally, a full model (model III) was established by simultaneously adjusting for demographic and socioeconomic characteristics, biological chronic health problems, routine behaviors and activities, and study burden and school schedules.

All analyses were performed using the Statistical Package for Social Sciences for Windows, version 15.0 (SPSS Inc, Chicago, IL). Statistical significance was set at the level of  $P < .05$  (2-tailed).

#### Ethics statement

The ethical application and consent procedure of this study were approved by the Ethics Committee of Shanghai Jiao Tong University School of Medicine.

#### Results

##### The description of the sample characteristics

For the purpose of the present study, among 4966 students who returned qualified questionnaires, 256 children were excluded from the final analyses because of missing data on the ASDQ ( $n = 219$ ) and/or TSAF ( $n = 39$ ). A total of 4710 adolescents (49.3% boys vs 50.7% girls) were ultimately included in the analyses. The mean age was 15.59 years (SD = 2.04; range 11.44–20.85 years). Figures 1 and 2 show the prevalence of insomnia symptoms by age and sex. There was a trend for a lower prevalence of insomnia symptoms with increasing age ( $\chi^2 = 33.497$ ,  $P = .001$ ). Compared to girls, boys had a higher prevalence of insomnia symptoms (boys 68.9% vs girls 65.5%;  $\chi^2 = 6.416$ ,  $P = .011$ ), especially for maintaining sleep difficulty (boys 42.7% vs girls 39.7%;  $\chi^2 = 4.727$ ,  $P = .030$ ). The more detailed description of sample characteristics was summarized in Supplementary Table S1.

##### The associations between insomnia symptoms and school performance

As shown in Table 1, there were significant associations of insomnia symptoms with school performance—including attention and concentration; interest and motivation; academic achievement; and, in some cases, school relationship—in univariate regression models. After controlling for demographic and socioeconomic characteristics (model I), aside from school relationship, other

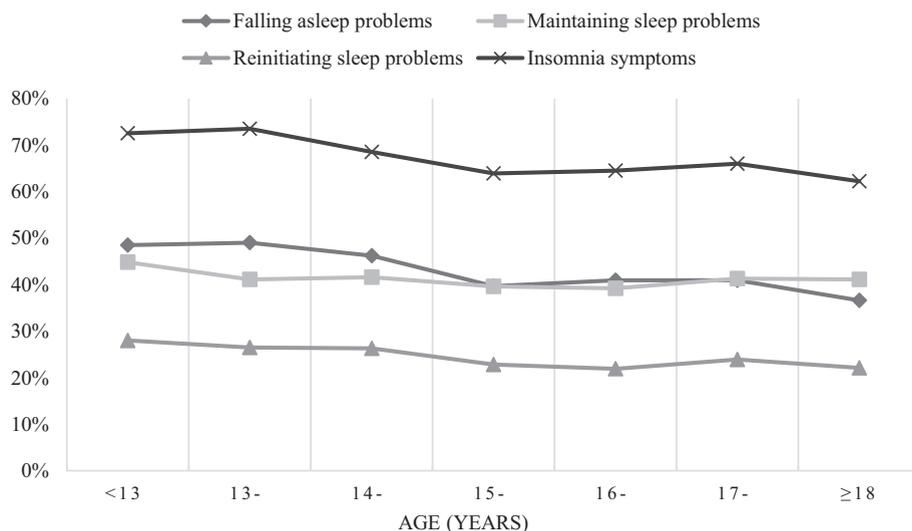


Fig. 1. The prevalence of insomnia symptoms by age.

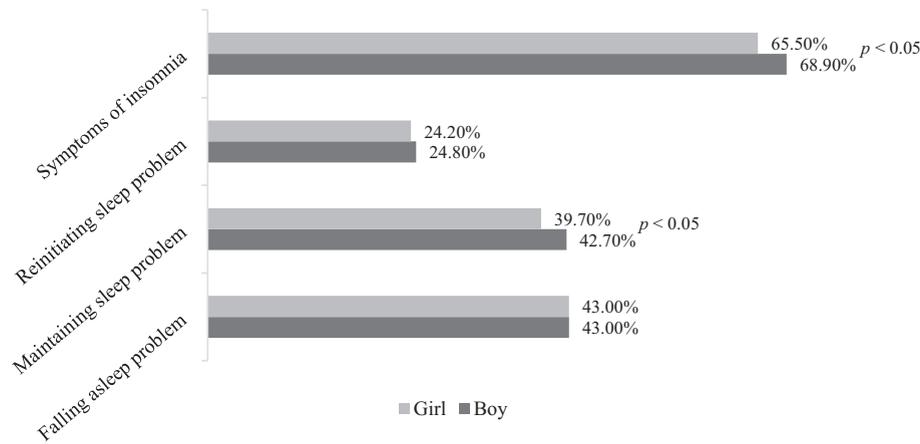


Fig. 2. The prevalence of insomnia symptoms by sex.

associations stayed significant. When further controlling for chronic health problems and routine behaviors and activities (model II), the results remained stable. Finally, after simultaneously controlling for school schedules and study burden in model III, significant associations still existed in attention and concentration, interest and motivation, and academic achievement. Among the 3 dimensions of insomnia symptoms, problem in falling asleep seemed to have the greatest impact on school performance, especially for attention and concentration (OR = 1.30, 95% CI: 1.11-1.52, P = .001).

It should be emphasized that, in this study, to some extent, there was a dose-response relationship between insomnia symptoms and school performance (Fig. 3). After controlling for all possible confounders, the coexistence of insomnia symptoms was related to poorer school performance. Detailed information is shown in Table 2. In addition, we observed that the more frequent the insomnia symptoms, especially problems falling asleep, the poorer the school performance in most cases (Supplementary Table S2-S4).

**Discussion**

This study examined the associations of insomnia symptoms with school performance among adolescents in Shanghai, China. In this study, we collected data on insomnia symptoms from 3 dimensions, covering the core characteristics of insomnia. Meanwhile, we evaluated 4 aspects of school performance. Such a careful and multidimensional evaluation enabled us to better understand the associations between insomnia symptoms and school performance. We found that insomnia symptoms, especially difficulty in falling asleep, were related to poor school performance, shown in decreased attention and concentration, interest and motivation, and academic achievement. It is an interesting finding that more frequent insomnia symptoms were related to the poorer school performance. Although it is not an obvious dose-dependent association, the finding is still noteworthy and should be studied further. These findings could enrich our understanding of the relationships between sleep and school

**Table 1**  
Associations of insomnia symptoms with school performance by univariate and multivariate logistical regression (N = 4966)

Insomnia symptoms	School performance							
	Attention Highest quartile vs other		Motivation Highest quartile vs other		Achievements Highest quartile vs other		Relationship Highest quartile vs other	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR(95% CI)	P value
<b>Crude model</b>								
Falling asleep problem vs none	1.30 (1.14-1.47)	<.001	1.18 (1.04-1.34)	.012	1.31 (1.16-1.49)	<.001	1.24 (1.09-1.41)	.001
Maintaining sleep problem vs none	1.36 (1.20-1.54)	<.001	1.32 (1.16-1.50)	<.001	1.26 (1.11-1.43)	.001	1.10 (0.97-1.25)	.134
Reinitiating sleep problem vs none	1.17 (1.01-1.34)	.034	1.23 (1.06-1.42)	.006	1.25 (1.08-1.44)	.002	1.08 (0.94-1.25)	.294
Insomnia symptoms vs none	1.35 (1.18-1.55)	<.001	1.31 (1.15-1.50)	<.001	1.34 (1.17-1.54)	<.001	1.22 (1.06-1.40)	.005
<b>Adjusted model</b>								
<b>Model I</b>								
Falling asleep problem vs none	1.34 (1.17-1.54)	<.001	1.23 (1.06-1.42)	.005	1.33 (1.16-1.52)	<.001	1.29 (1.12-1.48)	<.001
Maintaining sleep problem vs none	1.36 (1.19-1.57)	<.001	1.35 (1.17-1.56)	<.001	1.26 (1.10-1.45)	.001	1.09 (0.95-1.25)	.238
Reinitiating sleep problem vs none	1.13 (0.97-1.33)	.127	1.24 (1.06-1.46)	.009	1.25 (1.07-1.46)	.005	1.07 (0.92-1.26)	.376
Insomnia symptoms vs none	1.30 (1.09-1.56)	.004	1.29 (1.08-1.54)	.005	1.31 (1.10-1.56)	.002	1.14 (0.96-1.36)	.114
<b>Model II</b>								
Falling asleep problem vs none	1.34 (1.16-1.54)	<.001	1.23(1.06-1.42)	.006	1.32(1.14-1.52)	<.001	1.30(1.12-1.50)	<.001
Maintaining sleep problem vs none	1.36 (1.17-1.57)	<.001	1.34 (1.15-1.55)	<.001	1.27(1.10-1.47)	.001	1.10 (0.95-1.27)	.199
Reinitiating sleep problem vs none	1.15 (0.98-1.36)	.090	1.26(1.07-1.49)	.006	1.24 (1.05-1.45)	.010	1.09 (0.92-1.28)	.316
Insomnia symptoms vs none	1.28 (1.06-1.53)	.009	1.29 (1.07-1.55)	.007	1.33 (1.11-1.60)	.002	1.15 (0.96-1.38)	.138
<b>Model III</b>								
Falling asleep problem vs none	1.30 (1.11-1.52)	.001	1.16 (0.99-1.37)	.067	1.24 (1.06-1.45)	.007	1.26 (1.08-1.48)	.003
Maintaining sleep problem vs none	1.25 (1.06-1.46)	.007	1.22 (1.04-1.44)	.017	1.14 (0.97-1.34)	.110	1.04 (0.89-1.22)	.627
Reinitiating sleep problem vs none	1.07 (0.90-1.29)	.439	1.20 (1.00-1.45)	.048	1.15 (0.97-1.38)	.118	1.09 (0.91-1.31)	.333
Insomnia symptoms vs none	1.22 (1.03-1.44)	.021	1.20 (1.02-1.42)	.028	1.25 (1.06-1.47)	.008	1.08 (1.00-1.39)	.054

Model I: adjusted for demographic characteristics and socioeconomic characteristics.  
 Model II: model I adjustments plus biological chronic health problems and routine behaviors and activities.  
 Model III: model II adjustments plus school schedules and study burden.

performance and are of significance in the promotion of adolescent sleep hygiene and school health.

*Insomnia symptoms in adolescents*

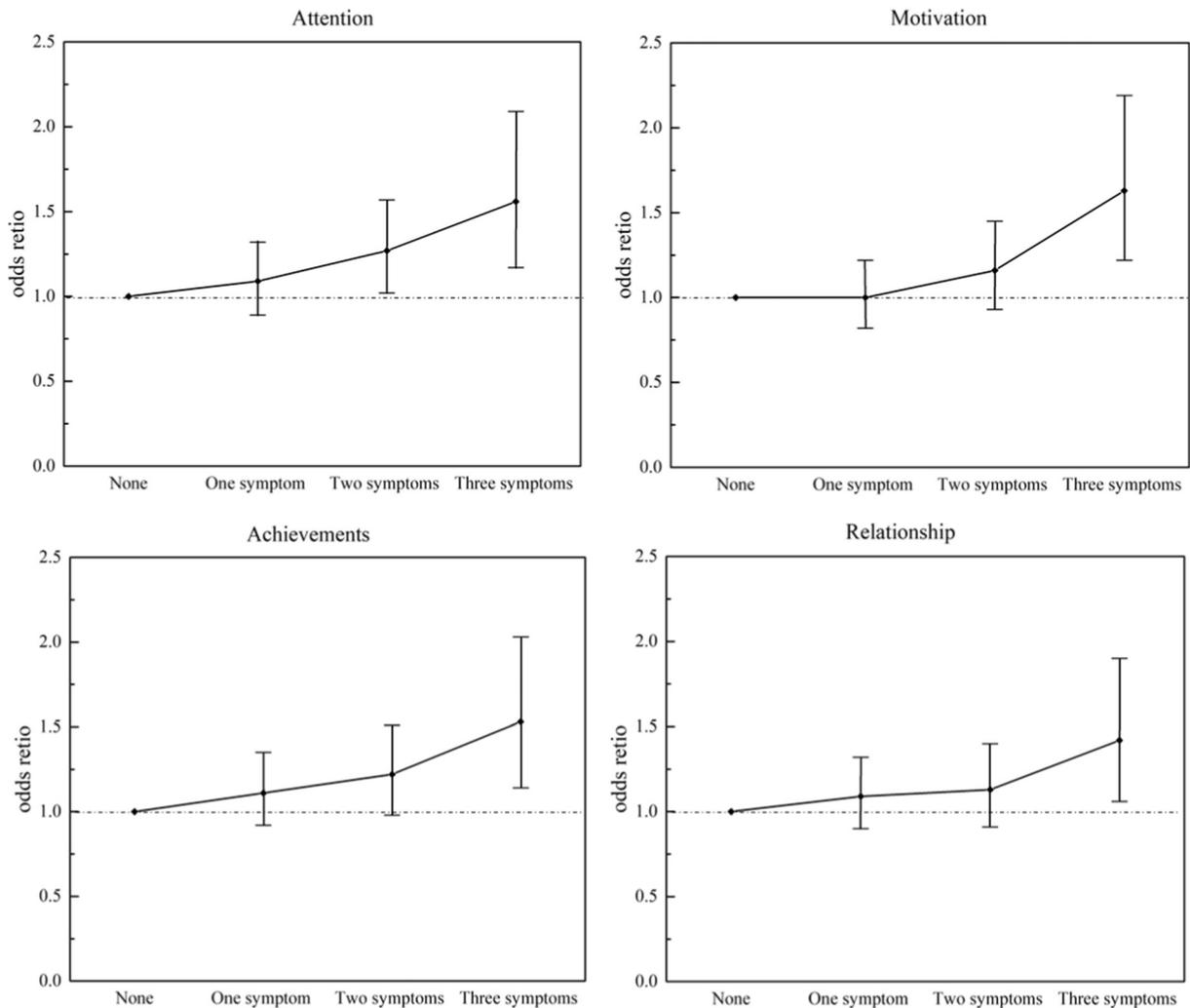
The present study demonstrated that more than three-fifths of sampled adolescents suffered from symptoms of insomnia with a frequency of at least 1 night per week. Based on strict criteria of insomnia, 2 previous studies reported a remarkably high prevalence of insomnia, approximately 16.0%, in Chinese adolescents.<sup>20,25</sup> Studies in other countries similarly demonstrated that insomnia symptoms were prevalent among adolescents.<sup>2,5</sup> For example, a study in Portugal found that nearly a quarter of adolescents suffered from insomnia symptoms at least 3 nights per week.<sup>2,5</sup> Taken together, adolescents could be a susceptible population for insomnia and should be given special attention when evaluating the impacts of insomnia symptoms.

Previous studies revealed that the prevalence of insomnia was associated with age and sex.<sup>2-5,25-27</sup> This study found that there was a slight tendency toward a lower prevalence of insomnia symptoms with increasing age. A study among Finnish adolescents similarly demonstrated that the prevalence of insomnia symptoms decreases with increasing age. Adolescence is the transition period between childhood and adulthood. Because of the complex interaction of

multiple biological and psychological changes, adolescence represents a susceptible period for mental health problems. With increasing age, adolescents would gradually adapt to complex changes with the development and the maturation in biological and psychological functioning, which may explain the gradual descending pattern of insomnia symptoms with age. With regard to the sex difference, the results are still inconsistent.<sup>2,3,5</sup> Our results indicated that the prevalence of insomnia symptoms was a little higher in boys than in girls. The difference between boys and girls was small (about 3%), which was observed only in subscale of difficulty in maintaining sleep. Other studies reported different findings.<sup>2,3,5</sup> Except for different evaluation scales of insomnia symptoms that were adopted in these studies,<sup>2,3,5</sup> other possible explanations for the inconsistency included the difference of sample characteristics, such as age range, culture background, and the possible ethnic differences.

*Insomnia symptoms and school performance*

It has been widely recognized that sleep is critically important for cognitive development during childhood and adolescence.<sup>28,29</sup> Our previous study found that the most marked reduction in sleep duration occurred in adolescents,<sup>17</sup> which indicated that Chinese adolescents represent a susceptible population for sleep deprivation. The present study specifically examined the associations between



**Fig. 3.** Dose-effect relationship between insomnia symptoms and school performance, adjusting for demographic characteristics, socioeconomic characteristics, biological chronic health problems, routine behaviors and activities, school schedules, and study burden.

**Table 2**  
Dose-effect relationship between numbers of insomnia symptoms and school performance (N = 4966)

Insomnia symptoms	School performance							
	Attention Highest quartile vs other		Motivation Highest quartile vs other		Achievements Highest quartile vs other		Relationship Highest quartile vs other	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
<b>Crude model</b>								
None	1.00		1.00		1.00		1.00	
1 Symptom	1.20 (1.03-1.41)	.021	1.10 (0.94-1.29)	.245	1.17 (0.99-1.37)	.059	1.13 (0.97-1.32)	.130
2 Symptoms	1.43 (1.20-1.71)	<.001	1.34 (1.12-1.60)	.001	1.46 (1.22-1.74)	<.001	1.28 (1.08-1.53)	.005
3 Symptoms	1.67 (1.33-2.10)	<.001	1.58 (1.26-2.00)	<.001	1.65 (1.31-2.08)	<.001	1.30 (1.03-1.65)	.028
<b>Adjusted model</b>								
<b>Model I</b>								
None	1.00		1.00		1.00		1.00	
1 Symptom	1.20 (1.01-1.43)	.042	1.11 (0.93-1.33)	.254	1.14 (0.96-1.36)	.140	1.13 (0.95-1.34)	.376
2 Symptoms	1.38 (1.14-1.68)	.001	1.29 (1.06-1.57)	.011	1.38 (1.14-1.67)	.001	1.21 (0.99-1.46)	.238
3 Symptoms	1.79 (1.39-2.31)	<.001	1.85 (1.43-2.38)	<.001	1.82 (1.42-2.33)	<.001	1.42 (1.10-1.83)	<.001
<b>Model II</b>								
None	1.00		1.00		1.00		1.00	
1 Symptom	1.14 (0.95-1.37)	.152	1.08 (0.90-1.30)	.429	1.14 (0.95-1.37)	.157	1.12 (0.94-1.34)	.211
2 Symptoms	1.39 (1.14-1.70)	.001	1.32 (1.08-1.61)	.008	1.41 (1.16-1.72)	.001	1.20 (0.98-1.46)	.079
3 Symptoms	1.77 (1.36-2.29)	<.001	1.80 (1.38-2.34)	<.001	1.74 (1.34-2.25)	<.001	1.47 (1.13-1.92)	.004
<b>Model III</b>								
None	1.00		1.00		1.00		1.00	
1 Symptom	1.09 (0.89-1.32)	.409	1.00 (0.82-1.22)	.993	1.11 (0.92-1.35)	.283	1.09 (0.90-1.32)	.385
2 Symptoms	1.27 (1.02-1.57)	.033	1.16 (0.93-1.45)	.195	1.22 (0.98-1.51)	.072	1.13 (0.91-1.40)	.278
3 Symptoms	1.56 (1.17-2.09)	.003	1.63 (1.22-2.19)	.001	1.53 (1.14-2.03)	.004	1.42 (1.06-1.90)	.018

insomnia symptoms and school performance among adolescents in China. In this study, a multidimensional evaluation, covering attention and concentration, interest and motivation, academic achievement, and school relationship, was performed on school performance. Moreover, a teacher-reported scale, not the usual self-reported form, was adopted, which made the evaluation much more objective. The design was valuable for the comprehensive and objective understanding of the associations between insomnia symptoms and school performance.

Accumulating studies have suggested that sleep plays a particularly important role in the maintenance of attention in both children and adult.<sup>30–32</sup> Our study found that insomnia symptoms, mainly problem in falling asleep and maintaining sleep, were related to poor attention and concentration among adolescents. The potential mechanism may lie in the connection between sleep and neurocognitive functioning, where it was proposed that selective and goal-directed attention was characterized by an involvement of the prefrontal cortex, which is especially sensitive to sleep and vulnerable to disrupted sleep.<sup>33,34</sup> A recent study provided an alternative explanation for this correlation: common thalamic circuits regulate sensory processing across sleep and attention, and their disruption may lead to a correlated dysfunction.<sup>35,36</sup>

Previous studies have confirmed that insomnia symptoms have adverse impacts on academic achievements among adolescents.<sup>3,4,9</sup> In agreement with these studies, our results demonstrated that insomnia symptoms, especially falling asleep problem, were related to poor academic achievement in Chinese adolescents. The evidence on associations of sleep with learning interest and motivation is extremely limited. To the best of our knowledge, only 2 studies explored the topic, where it was shown that late bedtimes contributed to a poor learning motivation in adolescents,<sup>6,10</sup> especially in girls.<sup>6</sup> The present study found that insomnia symptoms were related to decreased learning interest and motivation, which provided new evidence with regard to the relationships between sleep and school performance. Our results demonstrated that problem in falling asleep was involved in poor school relationship among Chinese adolescents. A lot of studies have found that sleep problems are associated with problematic behavior, poor executive functioning, and/or negative mood.<sup>8,28,37,38</sup> Therefore, it is plausible

that sleep problems may cause poor school relationship. Our previous study suggested that all 3 dimensions of insomnia symptoms were associated with an increased likelihood of psychological problems among Chinese adolescents.<sup>22</sup> It has been confirmed that stress, anxiety, and depression could lead to lower academic performance.<sup>13</sup> Conversely, academic pressure could make adolescents more susceptible to insomnia symptoms. Therefore, psychological problems may be an important mechanism linking insomnia symptoms and school performance.

Finally, our results, for the first time, reported a dose-response relationship between insomnia symptoms and school performance. This finding demonstrates the importance of sleep hygiene intervention and promotion in school health and school performance.

#### Limitations

Several limitations should be acknowledged in interpreting the findings of our study. First, we collected information on sleep through self-reported questionnaires but not objective measures. Objective measurement is a more rigorous method which, however, is usually not feasible for large samples. Second, although the responsible teachers could provide comparatively comprehensive evaluation of school performance, it is inevitable that responsible teachers may not know everyone in her/his class equally. It would be helpful to collect data on grades or standardized test scores to assess academic achievement. Third, other factors, such as IQ, would be potential confounders in the association between sleep and school performance. In addition, it is well known that insomnia can lead to short sleep duration. Therefore, there is strong correlation between insomnia symptoms and sleep duration. In the present study, we did not control for sleep duration when examining the associations between insomnia symptoms and school performance. Finally, based on our cross-sectional study, it is difficult to establish a causal relationship between insomnia symptoms and school performance.

#### Conclusions

Insomnia symptoms were associated with poor school performance among adolescents in China, and the associations seemed to

be dose dependent. This is the first to report the possible accumulative impact of insomnia on cognitive functioning in adolescents. As adolescence is a susceptible period for sleep problems, the findings of this study may have significant implications for public health and clinical intervention.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sleh.2018.12.008>.

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