Prevalence of sleep disturbances in Chinese adolescents: A systematic review and meta-analysis

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Abstract

Objectives
To review cross-sectional studies on the prevalence of sleep disturbance in Chinese adolescents and use a meta-analysis to explore the factors that may explain the heterogeneity between estimates of the prevalence.

Methods
We followed the Preferred Reporting Items for Systematic Review and Meta-analysis and searched the PubMed, Embase, Cochrane Library, PsycINFO, Scopus, Web of Science, SinoMed, Chinese National Knowledge Infrastructure (CNKI), WanFang, and VIP Database for Chinese Technical Periodicals databases from their inception through June 30, 2020. Analysis of the abstract, full-text, and data were conducted independently with uniform standards. Sub-group analyses and meta-regression analyses were performed to explore the associations between prevalence and gender, sex ratio, mean age, area, studying stage, sample size, survey time, response rate, assessment tools, PSQI cut-off, and quality score of the study.

Results
A total of 63 studies (64 groups of outcomes) were included in our analysis, covering 430,422 adolescents across China, of which 104,802 adolescents had sleep disturbances. The overall pooled prevalence was 26% (95% CI: 24–27%). Adolescents in senior high school (28%, 95% CI: 24–31%, p<0.001) had a higher prevalence of sleep disturbances than those in junior high school (20%, 95% CI: 15–24%, p<0.001). Studies with effective sample size of more than 1,000 and less than 3,000 had the highest prevalence of 30% (95% CI: 24–35%, p<0.001). The prevalence of sleep disturbances was not affected by other factors.
Conclusion
This systematic review and meta-analysis revealed that sleep disturbances are common in Chinese adolescents, and effective psychological and behavior intervention may be needed to help adolescents solve their sleep problems.

Introduction
In recent years, sleep disturbances have become increasingly more common worldwide. According to the China Sleep Quality Survey Report in 2018, among the 100,000 respondents, 83.81% suffered from some type of sleep disturbance [1]. Sleep disturbances like insufficient sleep time, irregular sleep patterns, poor sleep quality, and daytime sleepiness are common in Chinese adolescents, due to the competitiveness of top-level educational resources and intense social pressure [2, 3]. Furthermore, the early start time for school, heavy coursework loads, evening and night social activities, and online game addiction accelerates the sleep debt of Chinese adolescents. However, poor sleep quality would lead to mood disorders, such as negative affect, anxiety, and depression, poor academic performance, cognitive impairment, obesity, and high blood pressure [4–8].

Several studies have assessed the prevalence of sleep disturbances in Chinese adolescents. However, the prevalence estimates have varied substantially, reflecting the differences in the characteristics of adolescents and assessment instruments. Thus, a systematic review and meta-analysis should be done to better understand the prevalence of sleep disturbances in Chinese adolescents to develop effective psychological and behavior intervention that may be needed to help adolescents solve their sleep problems.

Therefore, our aim was to estimate the prevalence of sleep disturbances in Chinese adolescents and explore the heterogeneity between studies using subgroup analyses and meta-regression analyses, in terms of characteristics, assessment tools, and study quality.

Methods
This study is approved by the Ethics Committee of Medicine School of Jiujiang University with approval number JJU202006026.

Search strategy
This systematic review and meta-analysis were performed according to the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) [9]. We searched the PubMed, Embase, Cochrane Library, PsycINFO, Scopus, Web of Science, SinoMed, Chinese National Knowledge Infrastructure (CNKI), WanFang, and VIP Database for Chinese Technical Periodicals databases from its inception to June 30, 2020, without language restrictions. The search strategy was approved by experts in sleep problems from the Department of Clinical Psychology and the Department of Neurology in hospital. Full search terms are provided in the Appendix in S1 File, including prevalence, epidemiology, cross-sectional study, rate in conjunction with sleep disturbances, insomnia, sleep disorders, sleep symptoms, sleep quality, and sleep problems in Chinese adolescents. The references of selected papers were screened in NoteExpress (Version 3.2.0) [10].
Study selection
Studies were included in the analysis if they met the following criteria: (1) subjects aged from 13 to 19 years old in China; (2) cross-sectional epidemiology survey reported the prevalence of sleep disturbances with standardized assessment tools (Pittsburgh Sleep Quality Index/Athens Insomnia Scale/ICSD-2); (3) sample size ≥300; (4) full text written in Chinese or English. Studies were excluded for the following reasons: (1) only research articles were considered (conference abstracts, protocols, reviews, meta-analyses, citations, comments, and news release were excluded); (2) missing sampling method, sample size, or response rate; (3) based on experiments of clinical treatment or intervention; (4) focused on special population, such as patients with mental problems, students with post-traumatic stress disorder, and teenagers with medical conditions. Any disagreement in the screening procedure was discussed and resolved by a third reviewer.

Data extraction and study quality
Two reviewers independently screened the titles, abstracts, and full text. A duplicate extraction form was used to record information, which was tabulated using Microsoft Excel. The information included survey year, geographic location (area), effective sample size, response rate, sampling methods, male proportion, age, studying stage, assessment instruments, the cut-off for sleep disturbance, prevalence of sleep disturbance, the timeframe of sleep disturbance, and the quality score of study evaluation, which is provided in the Appendix in S1 File.

The quality of the included articles was assessed using the 11-item methodological checklist recommended by the Agency for Healthcare Research and Quality (AHRQ) [11] for cross-sectional studies (https://www.ncbi.nlm.nih.gov/books/NBK35156/). An item would be scored “1” only if it was answered as “Yes”; the item would be scored “0” when it was answered “No” or “Unclear”. The quality of the study was assessed as (1) “low” when the score was 0–3; (2) “moderate” when the score was 4–7; and (3) “high” when the score was 8–11. Studies classified as “low” quality were excluded from further meta-analysis. Any discrepancy in assessment was also resolved by the third reviewer when necessary.

Data analysis
We used STATA version 14.0 (Stata Corporation, College Station, TX, USA) and the fixed/random-effects models to calculate pooled estimates for sleep disturbance prevalence and corresponding 95% confidence intervals (CIs). Between-study heterogeneity was tested with $I^2$ statistic and Cochrane Q statistics, while random-effects models were used when $I^2 > 50\%$ and $p < 0.10$ indicated significant heterogeneity and $I^2 > 75\%$ indicated high heterogeneity [12, 13]. Subgroup analyses were performed to compare the differences in gender, area, assessment tools, effective sample size, and study stage with the chi-square test. Furthermore, the meta-regression analysis, using the Knapp-Hartung modification method, was performed to explore the influence of moderators on heterogeneity. Publication bias was conducted using Begg and Egger tests and funnel plots [14, 15]. Sensitivity analyses were conducted to test the consistency and quality of pooled results by removing each study individually. All tests were two-tailed with a statistically significant threshold of $P < 0.05$.

Results
Studies retrieved and description
Our search strategy identified 4,891 potentially eligible records. We screened the total abstracts of 3,421 records after removing duplicates, reviews, animal experiments, and articles published
before 2010, of which 431 full-texts were read, and 61 met the inclusion criteria. Hand search-
ing contributed an additional two articles, resulting in a total of 63 articles (64 groups of out-
comes) for the analyses (Fig 1).

A total of 430,422 subjects (males: 50.08%) were assessed, covering 28 mainland cities and
14 administrative provinces/municipalities, including Beijing, Shanghai, Hong Kong, Macau,
and Taiwan. A total of 53 studies reported their prevalence of sleep disturbances using the
Pittsburgh Sleep Quality Index (PSQI) [16], while five studies used the Insomnia Severity
Index (ISI) [17], and three studies used three subtypes of insomnia [difficulty initiating sleep
(DIS), difficulty maintaining sleep (DMS), and early morning awakening (EMA)], based on
the International Classification of Sleep Disorders Diagnoses, Second Edition (ICSD-2) [18]
from the American Academy of Sleep Medicine (2005). One study defined sleep disturbance using the Insomnia Self-Assessment Inventory (ISAI) from Social Development Trend Survey [19, 20] in three scales: difficulty in initiating sleep (DIS), difficulty in maintaining sleep (DMS), and nonrestorative sleep (NRS). The participants from 11 survey studies were from junior high school, while 24 studies focused on students from senior high school. The other studies had students from both schools, see details in Table 1.

Methodological quality of studies

The quality of the included studies, as assessed by AHRQ, is shown in Table 2. The median study quality score was 5 (range 4–7). A total of 22 studies (34.92%) failed to indicate the exact time of the survey. Thirteen studies (20.63%) were scored 4, nine studies (14.29%) were scored 7, and the remaining were scored 5 and 6. None of the studies were scored less than 4 with low quality.

Prevalence of sleep disturbances

In total, the 63 eligible studies included 64 groups of outcomes (one study had two groups). For the meta-analysis, the prevalence of sleep disturbances in adolescence ranged from 8% in Gaomi to 54.7% in Taiwan, while the pooled prevalence was 26% (95% CI: 24–27%). Substantial heterogeneity existed between the studies, $I^2 = 99.14\%$, chi-square = 1871.42, $p < 0.001$, $\tau^2 = 0.02$ (Fig 2). There were no significant changes in the results after removing each study sequentially.

Subgroup analyses

The estimates of sleep disturbance prevalence from the subgroup analysis, determined for gender, area, sample size, studying stage, survey time, instruments, PSQI cut-off, and quality score of study, are shown in Table 3. Compared to other sample sizes, effective samples of more than 1,000 and less than 3,000, indicated the highest pooled prevalence of 30% (95% CI: 24–35%, $p < 0.001$). The prevalence of sleep disturbance in senior high school students (28%, 95% CI: 24–31%, $p < 0.001$) was higher than junior high school students (20%, 95% CI: 15–24%, $p < 0.001$). The subgroup of the sample size and studying stage indicated statistically significant heterogeneity with $Q_{11.99} = 20.83\%$, $Q_{7.77} = 9.78\%$, Q11.99 ($p = 0.01$) and Q7.77 ($p = 0.01$). There were no statistically significant differences in heterogeneity between the other groups.

Meta-regression analyses

The meta-regression was performed using the Knapp-Hartung modification method. Further details are presented in Table 4. The sample size between 1,000 and 3,000 ($\tau^2 = 0.006994$, $p = 0.004 < 0.05$) and studying stage ($\tau^2 = 0.005651$, $p = 0.009 < 0.05$) were statistically significant, which accounted for 9.78% and 20.83% of between-study heterogeneity, respectively. There were no statistically significant contributions to heterogeneity in mean age, sample size, survey time, the quality score of study (all $p$-values $>0.05$). No model was created that included all factors to explain the heterogeneity of this meta-analysis.

Publication bias

Publication bias was found using visual inspection of the funnel plot and Egger’s test ($t = 2.04$, $p = 0.046$), as shown in Fig 3. The trim-and-fill method was used to eliminate bias by trimming nine studies, including Liu 2019, Chan et al. 2020, Liu et al. 2012, Fan et al. 2018, Luo et al.
Table 1. Quality assessment of cross-sectional studies with AHRQ methodological checklist.

| Author            | 1 | 2 | 3 | 4 | 5       | 6 | 7 | 8 | 9 | 10 | 11 | Total Score |
|-------------------|---|---|---|---|---------|---|---|---|---|----|----|-------------|
| Ge and Li 2010    | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Liu 2010          | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | No | Yes | No | 6           |
| Ye 2010           | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | No | Yes | No | 6           |
| Liu 2010          | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Liu, et al 2010   | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Mak, et al 2010   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 7           |
| Liu, et al 2011   | Yes | Yes | No | No | Not Clear | No | Yes | No | Yes | No | Yes | 6           |
| Liu, et al 2011   | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | No | Yes | 6           |
| Liu, et al 2011   | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Zeng 2011         | Yes | Yes | No | No | Not Clear | No | Yes | No | No | Yes | No | 4           |
| Cheung and Wong 2011 | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Zhang, et al 2012 | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Luo, et al 2012   | Yes | Yes | No | No | Not Clear | No | Yes | No | Yes | No | Yes | 5           |
| Liu, et al 2012   | Yes | Yes | Yes | No | Not Clear | No | No | No | Yes | Yes | No | 6           |
| Han 2012          | Yes | Yes | Yes | No | Not Clear | No | No | No | Yes | No | Yes | 4           |
| Zhou, et al 2012  | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Cheng, et al 2012 | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Pan, et al 2012   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Xu, et al 2012    | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Wang 2013         | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Ren, et al 2013   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Du, et al 2013    | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Yan, et al 2013   | Yes | Yes | Yes | No | Not Clear | No | Yes | No | No | Yes | No | 5           |
| Peng, et al 2013  | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Chen, et al 2013  | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Zhang, et al 2013 | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Wang, et al 2014  | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 4           |
| Ning, et al 2014  | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 4           |
| Xu, et al 2014    | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 4           |
| Cui 2014          | Yes | Yes | No | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 5           |
| Yang, et al 2014  | Yes | Yes | No | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 5           |
| Chen, et al 2014  | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Guo, et al 2014   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Zhu, et al 2015   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 7           |
| Zhou & Yao 2015   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 7           |
| Jing, et al 2015  | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 5           |
| Hou, et al 2015   | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 5           |
| Huang, et al 2015 | Yes | Yes | Yes | No | Not Clear | No | Yes | No | Yes | Yes | No | 5           |
| Bao, et al 2016   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | Yes | No | 5           |
| Tan, et al 2016   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 6           |
| Zhang, et al 2016 | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 6           |
| Zhang, et al 2016 | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 6           |
| Tao 2016          | Yes | Yes | Yes | No | Not Clear | Yes | Yes | No | Yes | No | Yes | 6           |
| Li, et al 2017    | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 6           |
| Yang, et al 2017  | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 6           |
| Du, et al 2017    | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 6           |
| Luo, et al 2017   | Yes | Yes | Yes | No | Not Clear | Yes | Yes | Yes | No | Yes | No | 6           |

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2012, Guo et al. 2014, Tan et al. 2016, Luo 2020, and Cheng et al. 2012 [32, 33, 36, 52, 59, 71, 73, 76, 77]. When this was done, the estimated prevalence was reduced to 23.6%.

Discussion

This meta-analysis, which pooled 430,422 adolescents in junior/senior high schools, proved the existence of sleep disturbances with an average prevalence of 26% (95% CI: 24–27%). This rate is higher than the pooled prevalence of university students at 25.7% (95% CI: 22.5–28.9%) and adults (<43.7 years old) at 20.4% (95% CI: 14.2–28.2%) [78, 79]. In addition, this was even higher than the pooled prevalence of insomnia in the general Chinese population at 15% (95% CI: 12.1–18.5%) [79]. It is possible that a trend may exist, in which the prevalence of sleep disturbance is lower during junior high school (20%, 95% CI: 15–24%), followed by an increase in senior high school (28%, 95% CI: 24–31%), a reduction in adulthood [79], followed by an increase to the highest pooled prevalence level of 35.9% in older Chinese adults (95% CI: 30.6–41.2%) [80]. The pooled prevalence of sleep disturbances reached the first peak in older adolescents.

Age is commonly associated with the degree of disturbance in Chinese adolescents [35, 38, 81]; however, our findings show that the prevalence increases with the studying stage, rather
### Table 2. Characteristics of studies included in this meta-analysis.

| Study | Survey Time | Area | Sampling Method | Effective Sample | Response Rate (%) | Proportion of Males (%) | Age (Mean ± SD) | Studying Stage | Assessment Instrument | Cut-off | Prevalence of Sleep disturbance (%) | Time Frame | Quality Score |
|-------|-------------|------|----------------|------------------|-------------------|------------------------|------------------|----------------|----------------------|---------|-----------------------------|------------|---------------|
| Ge and Li 2010 [21] | 2010 | Hangzhou-S | C | 341 | 96.88 | 60.80 | 12–18 | J | PSQI | ≥ 8 | 21.99 | LM | 5 |
| Liu 2010 [22] | 2010 | Fuzhou-S | R | 757 | 86.20 | 47.56 | 15.26 ± 2.27 | J, S | PSQI | ≥ 8 | 15.85 | LM | 6 |
| Ye 2010 [23] | 2009 | Macau-S | R, C | 501 | 93.64 | 51.50 | 15.38 ± 1.32 | J | PSQI | ≥ 8 | 25.20 | LM | 6 |
| Liu 2010 [5] | 2010 | Taiyuan-N | R | 439 | 97.50 | 47.20 | 13–16 | J | PSQI | ≥ 8 | 27.40 | LM | 7 |
| Liu, et al 2010 [24] | 2010 | Fuzhou-S | S | 381 | 84.70 | 51.44 | 15.38 ± 1.32 | S | PSQI | ≥ 8 | 31.50 | LM | 5 |
| Mak, et al 2010 [25] | 2010 | Hong Kong-S | S, R | 28839 | 84.80 | 49.70 | 15.38 ± 1.32 | S | DIS/DMS/EMA ICSD-2 | ≥ 3 times/week | 35.10 | LM | 7 |
| Liu, et al 2011 [26] | 2010 | Fuzhou-S | S, R | 566 | 94.30 | 44.88 | NR | J, S | PSQI | ≥ 8 | 17.10 | LM | 4 |
| Liu, et al 2011 [27] | 2009 | Nanchang-S | S, C | 950 | 95.00 | 49.70 | 14.9±0.76 | J | PSQI | ≥ 8 | 17.68 | LM | 6 |
| Liu, et al 2011 [28] | 2010 | Fuzhou-S | S, R | 609 | 93.69 | 47.13 | 12–19 | J, S | PSQI | ≥ 8 | 15.90 | LM | 5 |
| Zeng 2011 [29] | NR | Zhejiang Province-S | S, R | 354 | 97.00 | 49.20 | 16.5±1.2 | S | PSQI | ≥ 8 | 32.80 | LM | 4 |
| Cheung & Wong 2011 [30] | 2010 | Hong Kong-S | R | 719 | 100.00 | 60.40 | 10–14 | J, S | PSQI | ≥ 5/6 | 30.70 | LM | 5 |
| Zhang, et al 2012 [31] | 2010 | Xuzhou-S | S, C | 1385 | 99.00 | 54.00 | NR | J, S | PSQI | ≥ 8 | 36.60 | LM | 5 |
| Luo, et al 2012 [32] | 2009 | Guangdong Province-S | C, R | 4800 | 96.00 | 48.10 | 14.9±1.36 | J, S | ISI | ≥ 8 | 38.20 | LTW | 5 |
| Liu, et al 2012 [33] | 2009 | Guangdong Province-S | C | 344 | 100.00 | 45.10 | 14–20 | S | PSQI | ≥ 8 | 37.80 | LM | 4 |
| Han 2012 [34] | 2010 | Beijing-N | S, C | 352 | 95.00 | 52.50 | NR | E, J, S | PSQI | ≥ 8 | 12.86 | LM | 4 |
| Zhou, et al 2012 [35] | 2008 | Shanghai-S | R | 1221 | 99.00 | 46.60 | 12–18 | J, S | PSQI | ≥ 8 | 34.32 | LM | 7 |
| Cheng, et al 2012 [36] | 2008 | Taiwan-S | R | 2360 | 83.30 | 66.00 | NR | NR | PSQI | ≥ 6 | 54.70 | LM | 5 |
| Pan, et al 2012 [37] | 2009 | Heshan-S | J, R | 861 | 95.70 | 47.60 | 15.3±1.8 | S | DIS/DMS/EMA ICSD-2 | ≥ 3 times/week | 22.90 | LM | 6 |
| 2009 | Macau-S | J, R | 618 | 95.10 | 41.90 | 15.6±1.8 | S | DIS/DMS/EMA ICSD-2 | ≥ 3 times/week | 16.50 | LM | 6 |
| Xu, et al 2012 [38] | NR | Hefei-S | R | 5226 | 97.90 | 55.70 | 17.36±2.93 | J, S, U | PSQI | ≥ 8 | 20.00 | LM | 6 |
| Wang 2013 [39] | NR | Hefei-S | C | 542 | 90.00 | 0.90 | 18.69±1.69 | S | PSQI | ≥ 8 | 26.80 | LM | 6 |
| Ren, et al 2013 [40] | NR | Weifang-N | C, R | 852 | 100.00 | 49.06 | 13.65±1.01 | J | PSQI | ≥ 7 | 10.10 | LM | 5 |
| Du, et al 2013 [41] | 2011 | Gaomi-N | R, C | 1063 | 97.40 | 48.60 | 15.21±0.73 | J | PSQI | ≥ 8 | 8.00 | LM | 5 |

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| Study                | Survey Time | Area                        | Sampling Method | Effective Sample | Response Rate (%) | Proportion of Males (%) | Age (Mean ± SD) | Studying Stage | Assessment Instrument | Cut-off Prevalence of Sleep disturbance (%) | Time Frame | Quality Score |
|----------------------|-------------|-----------------------------|-----------------|------------------|-------------------|-------------------------|----------------|----------------|------------------------|--------------------------------------------|-------------|---------------|
| Yan, et al[42]       | 2011        | Changsha-S                  | S, R            | 2216             | 96.94             | 51.80                   | 14.6±1.56       | J, S           | PSQI                   | ≥ 8                                        | 13.40       | LM 5          |
| Peng, et al[43]      | 2012        | Urumqi-N                    | C               | 1096             | 99.27             | 49.73                   | 16.2±0.74       | S              | PSQI                   | ≥ 8                                        | 21.10       | LM 7          |
| Chen, et al[44]      | 2001        | Taiwan-S                    | S               | 2113             | 100.00            | 52.86                   | 15–17           | S              | DIS/DMS/ NRS-ISAI     | ≥3 times/week                             | 20.90       | LM 6          |
| Zhang, et al[45]     | NR          | Xuzhou-S                    | R               | 1052             | 87.70             | 52.76                   | NR              | J              | PSQI                   | ≥ 8                                        | 20.20       | LM 5          |
| Wang, et al[46]      | NR          | Shandong Province-N         | R, C            | 1227             | 81.80             | 44.40                   | NR              | S              | PSQI                   | ≥ 8                                        | 27.20       | LM 4          |
| Ning, et al[47]      | 2012–2013   | Xuzhou-S                    | C, R            | 4279             | 100.00            | 52.46                   | NR              | J              | PSQI                   | ≥ 8                                        | 26.40       | LM 5          |
| Xu, et al[48]        | 2009        | Shanghai-S                  | C               | 301              | 99.30             | 40.33                   | 16–17           | S              | PSQI                   | ≥ 8                                        | 11.63       | LM 5          |
| Cui[49]              | NR          | He’nan Province-N           | S, R            | 1406             | 100.00            | 43.17                   | NR              | J              | PSQI                   | ≥ 8                                        | 29.20       | LM 5          |
| Yang, et al[50]      | NR          | Chengdu-S                   | C               | 1180             | 90.77             | 52.20                   | 16.58±0.37      | S              | PSQI                   | ≥ 8                                        | 28.47       | LM 4          |
| Chen, et al[51]      | 2011        | Shenyang/Xinxiang/ Chongqing/ Guangzhou-NS | C | 13817 | 99.00 | 48.10 | 14.8±1.8 | J, S | PSQI | ≥ 8 | 26.50 | LM 7 |
| Guo, et al[52]       | NR          | Guangdong Province-S        | S, R, C         | 3186             | 95.20             | 53.40                   | 15.6±1.6        | J, S           | PSQI                   | ≥ 8                                        | 39.60       | LM 5          |
| Zhu, et al[53]       | NR          | Liu’an-S                    | C               | 543              | 90.00             | 56.70                   | 18.62           | S              | PSQI                   | ≥ 8                                        | 28.00       | LM 4          |
| Zhou & Yao[54]       | 2012        | Shanghai-S                  | R               | 1173             | 91.36             | 50.13                   | 12.11–17.71     | J, S           | PSQI                   | ≥ 8                                        | 18.84       | LM 7          |
| Jing, et al[55]      | 2015        | Ningbo-S                    | J, C            | 3932             | 99.70             | 51.60                   | 15.08±1.54      | J, S           | ISI                    | ≥ 8                                        | 25.30       | LTW 5         |
| Hou, et al[56]       | 2014        | Shen Zhen-N                 | S, R, C         | 1175             | 100.00            | 52.51                   | NR              | S              | PSQI                   | ≥ 8                                        | 34.40       | LM 5          |
| Huang, et al[57]     | NR          | Nanchang-N                  | S, C            | 608              | 95.30             | 51.81                   | 14–18           | S              | PSQI                   | ≥ 8                                        | 20.20       | LM 4          |
| Bao, et al[58]       | NR          | Guangdong Province-S        | R, C            | 1053             | 100.00            | 45.20                   | 14.95±1.66      | S              | PSQI                   | ≥ 8                                        | 15.60       | LM 4          |
| Tan, et al[59]       | 2012        | Shantou-S                   | R               | 1661             | 96.20             | 51.80                   | 14.53           | S              | PSQI                   | ≥ 5                                        | 40.00       | LM 6          |
| Zhang, et al[60]     | 2011–2012   | Hong Kong-S                 | R               | 7507             | 55.20             | 51.50                   | 8–17            | E, J           | DIS/DMS/ EMA ICSD-2   | ≥3 times/week                             | 25.79       | LM 6          |
| Zhang, et al[61]     | NR          | Yinchuan-N                  | S, C            | 3360             | 98.82             | 50.90                   | 17.62±1.03      | S              | PSQI                   | ≥ 8                                        | 27.53       | LM 5          |
| Tao[62]              | NR          | Guangyuan-S                 | R               | 386              | 96.50             | 52.07                   | 18.5±1.6        | S              | PSQI                   | ≥ 8                                        | 23.32       | LM 4          |
| Li, et al[63]        | 2014–2015   | Guangdong/Liaoning/ Shandong/Hu’nan/ Shanxi/ Guizhou-NS | S, C | 123459 | 95.93 | 52.20 | 15.04 | J, S | PSQI | ≥ 8 | 22.41 | LM 7 |

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| Study | Survey Time | Area | Sampling Method | Effective Sample | Response Rate (%) | Proportion of Males (%) | Age (Mean ± SD) | Studying Stage | Assessment Instrument | Cut-off | Prevalence of Sleep disturbance (%) | Time Frame | Quality Score |
|-------|-------------|------|-----------------|------------------|-------------------|------------------------|----------------|---------------|---------------------|---------|---------------------------|------------|---------------|
| Yang, et al 2017 | NR | Zhongshan-S | C | 1323 | 98.66 | 60.24 | NR | J | PSQI | ≥ 8 | 27.51 | LM | 4 |
| Du, et al 2017 | NR | He‘nan/Hu‘nan Province-NS | C | 305 | 97.00 | 40.00 | 11–17 | J, S | PSQI | ≥ 8 | 19.34 | LM | 4 |
| Luo, et al 2017 | 2014 | Guangzhou-S | R | 3342 | 70.61 | 80.00 | 17.67 ± 1.73 | S | ISI | > 8 | 29.83 | LTW | 6 |
| Li, et al 2017 | 2015 | Shenzhen-S | C | 860 | 95.56 | 50.35 | 14.34 ± 1.27 | J, S | PSQI | ≥ 8 | 18.30 | LM | 7 |
| Zhang, et al 2017 | 2015–2016 | Shenzhen-S | S, C | 3168 | 98.54 | 52.90 | 15.01 ± 1.76 | J, S | PSQI | ≥ 8 | 22.00 | LM | 5 |
| Yao, et al 2017 | 2016 | Shenyang-N | C | 775 | 95.10 | 53.16 | 15.58 ± 1.65 | J, S | PSQI | ≥ 8 | 18.30 | LM | 7 |
| Zhou, et al 2017 | 2016 | Xuzhou-S | R | 600 | 100.00 | 51.67 | NR | NR | ISI | > 8 | 32.00 | LTW | 5 |
| Chen, et al 2017 | 2006–2007 | Nanyang-N | S, C | 360 | 97.63 | 50.56 | 16.30 | S | PSQI | ≥ 8 | 33.61 | LM | 5 |
| Shen 2017 | NR | Ganzhou-S | S, R | 3081 | 97.01 | 50.80 | NR | J | PSQI | ≥ 8 | 10.30 | LM | 6 |
| Huang 2018 | 2014 | Nanchang-S | S, C, R | 608 | 95.30 | 51.81 | 16.27 ± 0.87 | S | PSQI | ≥ 8 | 20.20 | LM | 6 |
| Huang, et al 2018 | 2016 | Guangzhou-S | S, C | 5781 | 91.76 | 44.56 | 12–20 | J, S | PSQI | ≥ 8 | 33.10 | LM | 6 |
| Wu 2018 | 2016 | Urmqi-N | R | 8242 | 93.73 | 48.80 | 14.54 ± 1.79 | J, S | PSQI | ≥ 8 | 26.44 | LM | 6 |
| Fan, et al 2018 | 2016 | Yinchuan-N | C | 2116 | 83.93 | 42.16 | 17.17 ± 0.94 | S | PSQI | ≥ 8 | 38.04 | LM | 6 |
| Li 2019 | NR | Yancheng-N | J | 625 | 95.00 | 57.40 | NR | J | PSQI | ≥ 8 | 33.00 | LM | 5 |
| Liu 2018 | 2017–2018 | Shanghai-S | S, C, R | 1986 | 85.00 | 51.30 | 14.71 ± 2.01 | J, S | ISI | > 8 | 37.00 | LTW | 7 |
| Wu, et al 2019 | 2014–2015 | Shanxi Province-N | S, C | 9560 | 100.00 | 44.80 | 15.3 ± 1.8 | J, S | PSQI | ≥ 8 | 23.60 | LM | 6 |
| Xiao, et al 2019 | 2015 | Guangdong/Liaoning/Shandong/Hunan/Shanshi/Chongqing/Guizhou-NR | S, C, R | 153547 | 96.18 | 48.00 | 15 ± 1.8 | J, S | PSQI | ≥ 8 | 21.60 | LM | 6 |
| Chan, et al 2020 | 2017-2019 | Hong Kong-S | R | 1667 | 61.10 | 56.50 | 14.8 ± 1.6 | J, S | DIS/DMS/EMA ICSD-2 | ≥ 3 times/week | 37.00 | LM | 5 |
| Luo 2020 | NR | Huizhou-S | C | 1016 | 98.00 | 45.00 | 15–16 | S | PSQI | ≥ 8 | 47.00 | LM | 4 |

Area: S-Southern China, N-Northern China. Sampling Method: C-Cluster sampling; R-Random sampling; S-Stratified sampling; J-Judgmental sampling. Studying Stage: E-Elementary School, J-Junior High School, S-Senior High School. Timeframe: LM-Last Month, LTW-Last Two Weeks. PSQI: Pittsburgh Sleep Quality Index; ISA: Insomnia Severity Index; ICSD-2: International Classification of Sleep Disorders diagnoses, Second Edition; ISAI: Insomnia Self-Assessment Inventory.

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Fig 2. Forest plot of pooled estimates for prevalence.

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### Table 3. Subgroup analyses of studies included in this meta-analysis.

| Subgroup Analysis | Events | Sample Size | Prevalence (%) | 95% CI (%) | Weight (%) | I² | p | Q(p) | Heterogeneity between-group | Begg’s test z (p) | Egger’s test t (p) |
|-------------------|--------|-------------|----------------|------------|------------|----|---|------|----------------------------|-----------------|-----------------|
| **Gender (22)**   |        |             |                |            |            |    |   |      |                             |                 |                 |
| Male (22)         | 10825  | 38189       | 28             | 24–33      | 49.96      | 98.97 | p<0.001 | 0.12 (0.72) | 0.652 (0.419) 0.16 (0.872) |
| Female (22)       | 10123  | 35923       | 27             | 24–31      | 50.04      | 98.16 | p<0.001 | 0.89 (0.34) | 0.05 (0.964) -0.04 (0.967) |
| **Area (59)**     |        |             |                |            |            |    |   |      |                             |                 |                 |
| North China (16)  | 8664   | 33456       | 24             | 21–28      | 26.69      | 98.56 | p<0.001 | 11.99 (0.01*) | 2.15 (0.032) 4.10 (0.003) |
| South China (43)  | 31585  | 105883      | 27             | 24–30      | 73.31      | 99.1  | p<0.001 | 0.612 (0.653) -0.30 (0.770) |
| **Sample Size (63)** | |            |                |            |            |    |   |      |                             |                 |                 |
| <500 (10)         | 992    | 3712        | 26             | 21–31      | 14.49      | 92.19 | p<0.001 | 11.99 (0.01*) | 2.15 (0.032) 4.10 (0.003) |
| 500–1000 (16)     | 2384   | 11645       | 21             | 18–24      | 26.23      | 94.8  | p<0.001 | 0.612 (0.653) -0.30 (0.770) |
| 1000–3000 (20)    | 9040   | 29489       | 30             | 24–35      | 31.65      | 99.61 | p<0.001 | 0.612 (0.653) -0.30 (0.770) |
| >3000 (17)        | 92387  | 385576      | 27             | 24–29      | 27.63      | 99.14 | p<0.001 | 0.612 (0.653) -0.30 (0.770) |
| **Studying Stage (34)** | |            |                |            |            |    |   |      |                             |                 |                 |
| Junior High School Students (11) | 1902 | 11087 | 20 | 15–24 | 31.53 | 97.81 | p<0.001 | 7.77 (0.01*) | 1.87 (0.062) 4.07 (0.003) |
| Senior High School Students (23) | 7645 | 26651 | 28 | 24–31 | 68.47 | 97.15 | p<0.001 | 0.60 (0.552) 0.12 (0.904) |
| **Survey Time (41)** | |            |                |            |            |    |   |      |                             |                 |                 |
| 2010–2015 (28)    | 24153  | 81319       | 25             | 22–29      | 68.3      | 99.11 | p<0.001 | 0.83 (0.36) | 0.39 (0.694) -1.68 (0.104) |
| 2015–2019 (13)    | 71672  | 315693      | 27             | 25–29      | 31.7      | 98.94 | p<0.001 | 0.43 (0.669) 2.98 (0.013) |
| **Instruments (63)** | |            |                |            |            |    |   |      |                             |                 |                 |
| PSQI (53)         | 86634  | 374157      | 25             | 24–27      | 82.49      | 98.87 | p<0.001 | 3.41 (0.06) | 0.49 (0.623) 1.81 (0.076) |
| Others (10)       | 18169  | 56265       | 29             | 25–33      | 17.51      | 98.74 | p<0.001 | 0.31 (0.755) -1.42 (0.190) |
| **PSQI Cut-Off (53)** | |            |                |            |            |    |   |      |                             |                 |                 |
| ≥8 (48)           | 83953  | 367344      | 24             | 23–26      | 90.45      | 98.51 | p<0.001 | 1.27 (0.26) | 0.48 (0.631) 1.36 (0.182) |
| Others (5)        | 2681   | 6813        | 34             | 17–51      | 9.55       | 99.59 | p<0.001 | 0.73 (0.462) -0.03 (0.978) |
| **Quality Score (63)** | |            |                |            |            |    |   |      |                             |                 |                 |
| 4 (13)            | 2514   | 9457        | 26             | 21–31      | 19.71      | 97.22 | p<0.001 | 2.50 (0.47) | 1.16 (0.246) 0.89 (0.392) |
| 5 (23)            | 11961  | 40287       | 28             | 23–32      | 35.88      | 99.18 | p<0.001 | 0.26 (0.792) 0.38 (0.705) |
| 6 (18)            | 47009  | 207873      | 24             | 21–26      | 30.16      | 98.92 | p<0.001 | 0.07 (0.944) 1.04 (0.314) |
| 7 (9)             | 43319  | 172805      | 27             | 22–32      | 14.26      | 99.60 | p<0.001 | 0.10 (0.917) 0.88 (0.406) |

*p<0.05

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### Table 4. Meta-regression analysis.

| Categories | Exp (B) | Standard Error | Z-value | P-value | [95% CI] | Tau² | Adjusted R² (%) |
|------------|---------|----------------|---------|---------|----------|------|-----------------|
| Mean Age   | 0.009947| 0.122517       | 0.81    | 0.422   | 0.9852099| 1.035407| 0.007496 0      |
| Sex Ratio  | 1.000031| 0.00091        | 0.03    | 0.973   | 0.9982132| 1.001851| 0.007877 0      |
| Response Rate | 0.997623| 0.0013064     | -1.82   | 0.074   | 0.9950149| 1.000238| 0.007435 4.09   |
| Sample Size | 1.092256| 0.0325041      | 2.97    | 0.004*  | 1.029135| 1.159248| 0.006994 9.78   |
| Studying Stage | 0.0842858| 0.0304005    | 2.77    | 0.009*  | 0.0224354| 0.1461361| 0.005651 20.83% |
| Survey Time | 1.002648| 0.0044096      | 0.6     | 0.551   | 0.9937753| 1.0116 | 0.008077 0      |
| Quality Score | 0.995359| 0.0122886      | -0.38   | 0.708   | 0.9710951| 1.020229| 0.007868 0      |

*p<0.05

https://doi.org/10.1371/journal.pone.0247333.t004
than the mean age. Senior high school students had a higher pooled prevalence of sleep disturbance compared to junior high school students (28%, 95% CI: 24–31% vs. 20%, 95% CI: 15–24%) in China, which may be attributed to academic pressure, insufficient sport duration, and increased anxiety/depression levels [33, 34, 56]. The difference in the studying stage accounted for 20.83% of the variation for between-study heterogeneity ($\tau^2 = 0.005651$, $p = 0.009$).

Gender did not affect the pooled prevalence in our results, which is inconsistent with other studies [31, 36, 52, 55, 66]. There were also no differences in the sex ratio, geographical location, survey time, or quality evaluation of the studies. In total, 84.13% of studies used PSQI and 79.19% used PSQI, with a cut-off $\geq 8$, and there were no significant differences between PSQI and other instruments and between PSQI cut-off $\geq 8$ and others through the sub-group analyses. This was likely due to representation issues.

Statistically significant differences were also found in the sample size (<500 (26%, 95% CI [24–29%]) vs. 500–100 (21%, 95% CI [18–24%]) vs. 1,000–3,000 (30%, 95% CI [24–35%]) vs. >3000 (27%, 95% CI [24–29%])). Furthermore, the sample size of 1,000–3,000 contributed to 9.78% ($\tau^2 = 0.006994$, $p = 0.004^*$) of the heterogeneity.
All of the included studies with “moderate” quality pooled 104,802 adolescents with sleep disturbances, covering 14 administrative provinces and 28 cities across China, and showed a good representation of Chinese adolescents. Approximately 79.37% of the included studies response rates were more than 90%. In this meta-analysis, we used sub-group analyses and meta-regression analyses to explore the sources of heterogeneity, but we could not find an overall explanation of the heterogeneity sources. Thus, several limitations should be addressed. First, some of the studies did not report the exact survey time, which is important for students. Sleep quality is different between school days and non-school days, and between exam periods and non-exam periods [82]. Second, most studies failed to report issues of study quality control that could affect the reliability and validity of the study results. Third, some detailed characteristics of the subjects were not presented. The meta-analysis was based on published data, which could lead to difficulties in further sub-group analyses and meta-regression analyses. In addition, we believe that sub-group analyses of different types of sleep disturbances in Chinese adolescents by severity degree should be taken into consideration in future research, which will be useful to get to the point. Fourth, we could not eliminate the high level of heterogeneity in the prevalence estimate due to many different epidemiological survey studies.

In conclusion, the pooled prevalence of sleep disturbances in Chinese adolescents was 26% (95% CI, 24–27%), higher than the pooled prevalence in the general population (15%, 95% CI: 12.1–18.5%) in China. The sub-group analyses and meta-regression analyses indicated that higher prevalence was associated with studying stage and effective sample size, especially for adolescents in senior high school (28%, 95% CI: 24–31%) and sample sizes between 1,000 and 3,000 (30%, 95% CI: 24–35%). Further research is needed to better understand the sleep disturbances of adolescents to develop effective psychological and behavioral interventions.

**Supporting information**

S1 File. Appendix. Search strategies & quality assessment & PRISMA 2009 checklist.
(PDF)

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