The Prevalence of Attention Deficit/Hyperactivity Disorder among Chinese Children and Adolescents

Anni Liu1, Yunwen Xu2, Qiong Yan1 & Lian Tong1

Updating the worldwide prevalence estimates of attention-deficit hyperactivity disorder (ADHD) has significant applications for the further study of ADHD. However, previous reviews included few samples of Chinese children and adolescents. To conduct a systematic review of ADHD prevalence in Mainland China, Hong Kong, and Taiwan to determine the possible causes of the varied estimates in Chinese samples and to offer a reference for computing the worldwide pooled prevalence. We searched for PubMed, Embase, PsycINFO, Web of Science, China National Knowledge Infrastructure, VIP, WANFANG DATA, and China Science Periodical Database databases with time and language restrictions. A total of 67 studies covering 642,266 Chinese children and adolescents were included. The prevalence estimates of ADHD in Mainland China, Hong Kong, and Taiwan were 6.5%, 6.4%, and 4.2%, respectively, with a pooled estimate of 6.3%. Multivariate meta-regression analyses indicated that the year of data collection, age, and family socioeconomic status of the participants were significantly associated with the prevalence estimates. Our findings suggest that geographic location plays a limited role in the large variability of ADHD prevalence estimates. Instead, the variability may be explained primarily by the years of data collection, and children's socioeconomic backgrounds, and methodological characteristics of studies.

Attention-deficit/hyperactivity disorder (ADHD) is one of the most common childhood psychiatric disorders, with symptoms including inattention, impulsivity, and hyperactivity1–3. As a major public health problem4, ADHD has been associated with a wide variety of adverse health outcomes for affected individuals5,6 and severe financial burdens for families and societies7. Concerns have been raised regarding the true prevalence of ADHD among children, the knowledge of which is critical for further service planning, resource allocation, training, and research priorities8. In the last few decades, a host of investigators have made substantial efforts to determine the prevalence of ADHD. Several reviews reported a broad range of prevalence rates, from as low as nearly 1% to as high as nearly 20% among children and adolescents throughout the world9–14. A comprehensive review including 102 studies worldwide reported a pooled prevalence estimate of 5.3% in children11. Another review covering 86 studies found that the prevalence estimates only employing the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) as the diagnostic criteria varied from 5.9% to 7.1% in children and adolescents14. However, previous systematic reviews seldom selected a sufficient proportion of studies conducted among Asian children and adolescents, and were especially lacking of Chinese samples, despite the fact that China has the largest number of children and adolescents in the world.

To our knowledge, the first investigation of Minor Brain Dysfunction (an alternative name of ADHD) prevalence among children was conducted in Mainland China in 198115. With the introduction of the Diagnostic and Statistical Manual of Mental Disorders, Third Edition (DSM-III) into China in the 1980s, multifold epidemiological surveys have been carried out on children and adolescents in Mainland China, Hong Kong, and Taiwan, and yielded the prevalence estimates ranging from as low as 0.7% to as high as 14.1%16,17. Our previous systematic review published in Chinese included 33 studies conducted in Mainland China from 1983 to 2011 and reported a pooled ADHD prevalence of 5.7% in Chinese children and adolescents18.

Geographical, demographic and cultural factors have been suggested as important variables that contribute to the heterogeneity of ADHD prevalence across studies16,19. Given that the scope of this systematic review falls on

1School of Public Health, Fudan University/Key Laboratory Public Health Safety, Chinese Ministry of Education, Shanghai, China. 2Department of Epidemiology, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland, United States. Correspondence and requests for materials should be addressed to L.T. (email: ltong@fudan.edu.cn)
the Chinese children and adolescents in Mainland China, Hong Kong and Taiwan, it is noteworthy to mention the features of social-cultural contexts in those three regions. For instance, compared with Hong Kong and Taiwan, the children in Mainland China have experienced more intensely unbalanced development, due to historical reasons and social transformations. Furthermore, the significant gaps in the economic situations among different urban and rural areas within the Mainland China may fuel the diverse epidemiological aspects of ADHD. More importantly, the long-term one-child policy has notably affected the children's living surroundings in Mainland China, and thus may increase the chances of suffering the psychological and behavioral problems for the only children due to the lack of playmates, compared to the children with siblings. It is also worth mentioning that the highly competitive educational system with the increasing academic pressures in China may expose Chinese children to chronic stress, thus increasing susceptibility to mental health problems, including ADHD. Methodological characteristics, such as screening and diagnostic methods, may be associated with the heterogeneity in prevalence results as well.

It is clear that an estimated ADHD prevalence from one location fails to represent the overall prevalence among Chinese children, while a systematic understanding of the ADHD prevalence estimates in Chinese children and adolescents may provide a better insight into the overall and subgroup distribution and etiology of ADHD under different social and cultural backgrounds. Furthermore, a meta-analysis that computes the prevalence estimates of ADHD in the three regions will offer the supportive data for the accurate prediction of the worldwide pooled prevalence. Therefore, the purposes of this study are: (1) to estimate the overall and subgroup prevalence estimates of ADHD among children and adolescents in Mainland China, Hong Kong, and Taiwan from 1980 to 2016; (2) to analyze the trends of ADHD prevalence in the three locations in a period spanning the past 3 decades to aid in predicting future trends; and (3) to explore the possible causes of the varied prevalence estimates.

Results
Systematic review. We screened 4704 abstracts, reviewed 125 full-text articles, and selected 67 studies for the final systematic review. Of these, 13 were published in English and 54 were published in Chinese. Figure 1 presents the flowchart of study selection. Table 1 displays the characteristics of the articles included in this systematic review. A total of 70 ADHD prevalence rates were reported in the English studies. Specifically, 60 prevalence rates were from Mainland China, 2 from Hong Kong, and 8 from Taiwan (Table 1). A total of 642266 children and adolescents were included in our systematic review, 227943 of them being from Mainland China, 3610 from Hong Kong, and 410713 from Taiwan. The first epidemiological investigation of Chinese children with ADHD was conducted in Mainland China in 1981. Only 6 studies (9.0%) were conducted in the first 10 years (1980–1990), and the number of studies remarkably increased from 1991–2000 (10 studies) to 2001–2010 (33 studies). In recent years (2011–2016), 18 studies were carried out. In terms of regions, 49 prevalence rates were determined from samples collected in urban areas, 20 were based on mixed samples from both Urban & rural areas, and only 1 focused solely on children in rural areas. The time frame of data collection varied across studies, indicating different study designs. The majority of the prevalence rates were from cross-sectional studies, 59 of which collected the data within 1 year. Five cohort studies in Taiwan implemented the data collection for over 2 years. Only 7 studies chose preschoolers as the study population, while over 60% of studies consisted of school-aged children and adolescents. Among the 67 studies, the Conners’ Parent Rating Scale and Conners’ Teacher Rating Scale were the most commonly used screening methods. Over half of the studies employed the diagnostic criteria of the DSM-III/III-R/IV.

Although all estimates from 67 studies were at moderate or low risk of bias, only 1 estimate met all 10 criteria, and 65% were at low risk of bias. The majority of estimates rated poorly for the representativeness of the national population (93%), and the strict measurement of the reliability and validity of the study instrument (85%). Besides, most estimates did not collect ADHD diagnostic information directly from children or adolescents (93%). Summary statistics for risk of bias for estimates are provided in Table 1.

Prevalence of ADHD. The overall and subgroup prevalence estimates of ADHD are shown in Table 2. The pooled prevalence of ADHD was 6.3% (95% confidence interval [CI], 5.7–6.9). The estimated rates in Mainland China, Hong Kong, and Taiwan were 6.5% (95% CI, 5.7–7.3), 6.4% (95% CI, 1.5–11.3), and 4.2% (95% CI, 3.2–5.2), respectively. ADHD was more common in boys (8.9%, 95% CI, 7.6–10.2) than in girls (4.0%, 95% CI, 3.4–5.2). The pooled prevalence rates were 5.5% (95% CI, 4.2–6.8) between 1980 and 1990, 6.9% (95% CI, 4.2–9.6) between 1991 and 2000, 6.0% (95% CI, 5.2–6.7) between 2001 and 2010, and 6.7% (95% CI, 5.2–8.2) between 2011 and 2016. The pooled prevalence rate was 5.5% (95% CI, 3.3–7.7) for preschoolers, and 6.5% (95% CI, 5.5–7.4) for school-aged children and adolescents, while the overall prevalence of combining two age groups was 6.1% (95% CI, 5.1–7.2). The forest plot of the subgroup estimates is presented in Fig. 2.

Sources of variability in prevalence estimates. Substantial heterogeneity across studies was detected ($I^2 = 99%$; $Q = 9121.98, df = 69, P < 0.001$), thus, the meta-regression analyses were used to explore the potential causes. In univariate meta-regression analyses (Table 3), there was a significant increase in prevalence estimates in all three periods of 1991–2000 ($\beta = 0.39, P < 0.001$), 2001–2010 ($\beta = 0.36, P < 0.001$), and 2011–2016 ($\beta = 0.38, P < 0.001$) compared with the period of 1980–1990. The studies with combined samples from both urban & rural areas yielded significantly higher ADHD prevalence estimates than those with urban samples ($\beta = 0.35, P < 0.001$). Both school-aged children and adolescents ($\beta = 0.37, P < 0.001$) and preschoolers combined with school-aged children and adolescents ($\beta = 0.37, P < 0.001$) had significantly higher prevalence estimates than preschoolers. The larger sample sizes of 2000–5000 ($\beta = 0.39, P < 0.001$) or over 5,000 ($\beta = 0.32, P < 0.001$) generated significantly higher prevalence estimates than the sample sizes of less than 2000. There was a significant increase in prevalence estimates when the informants were parents ($\beta = 0.37, P < 0.001$) as well as...
both teachers and parents ($\beta = 0.39, P < 0.001$) compared with only teachers. The studies that underwent diagnostic procedure ($\beta = 0.33, P < 0.001$) or both screening and diagnostic procedures ($\beta = 0.37, P < 0.001$) displayed significantly higher prevalence estimates than those only with screening procedure. The studies employing Conners-based screening criteria yielded significantly lower estimates than those with other screening criteria, e.g., DSM-III/-III-R ($\beta = 0.37, P = 0.019$), DSM-IV/DISC-IV ($\beta = 0.37, P < 0.001$), Conners combined with DSM criteria ($\beta = 0.44, P < 0.001$). Compared to the studies conducted with the diagnostic criteria of DSM-III/-III-R, the studies using DSM-IV/DISC-IV ($\beta = 0.37, P < 0.001$), CCMD-II/II-R/III ($\beta = 0.36, P = 0.001$), DSM-IV combined with Conners ($\beta = 0.42, P < 0.001$) or ICD-9-CM ($\beta = 0.25, P = 0.02$) as the diagnostic criteria had significantly higher prevalence estimates.

Table 4 shows the results of multivariate regression analyses. The following factors remained significant: years of data collection, region, and age of participants. Specifically, consistent with univariate regression results, ADHD prevalence was lowest in the first 10 years (1980–1990) and significantly increased in a spanning period of next 3 decades, and school-aged children and adolescents ($\beta = 0.19, P < 0.001$) and preschoolers combined with school-aged children and adolescents ($\beta = 0.16, P = 0.003$) yielded significantly higher prevalence estimates than preschoolers. In addition, the rural areas showed significantly higher prevalence estimates than urban areas ($\beta = 0.34, P = 0.009$).

Discussion
We identified 67 original studies conducted in Mainland China, Hong Kong, and Taiwan from 1980 to 2016, covering 642,266 children and adolescents. Our prevalence estimate (6.3%) was lower than the 7.2% reported in a worldwide systematic review that included 175 studies from 1977 to 2013. This discrepancy can be associated with the fact that a handful of Chinese studies (15 studies) were selected by Thomas et al. Meanwhile, our prevalence estimate was pronouncedly higher than the 3.4% reported in another systematic review study that included 48 studies from 1985 to 2012, with only one Chinese study. Those worldwide ADHD systematic reviews were mainly based on original investigations conducted in Western countries and published in English. Therefore, they neglected a substantial proportion of Chinese investigations and publications, further bringing about both selection bias and publication bias. On the contrary, our pooled ADHD prevalence was highly representative of
| Author, y | City/ Location | Time Frame | Region | Sample's Age | Proportion of Boys | Sample Size | Source of Information | Screening and/or Diagnosis | Screening Criteria | Diagnostic Criteria | Original Prevalence | Risk of Bias Score |
|-----------|----------------|------------|--------|---------------|-------------------|-------------|----------------------|-------------------------|-------------------|-------------------|------------------|------------------|
| Wang RC et al. 1983 | Basoding | ≤ 1 year | Urban | School age | 0.51 | 1,588 | T | Screening, & diagnosis | Others | DSM-III | 0.03 | 5 |
| Wang L et al. 1987 | Tianjin | ≤ 1 year | Urban | School age | — | 9,971 | T and P | Screening, & diagnosis | Others | DSM-III | 0.04 | 6 |
| Zhang ML et al. 1991 | Baotou | ≤ 1 year | Urban, & rural | School age | 0.53 | 14,739 | T and P | Screening, & diagnosis | Conners, & Others | DSM-III, & Others | 0.14 | 7 |
| Wang LM et al. 1993 | Hefei | ≤ 1 year | Urban | School age | 0.51 | 1,377 | T and P | Screening, & diagnosis | Conners, & DSM-III | DSM-III | 0.07 | 7 |
| Wang Z et al. 1993 | Changsha | ≤ 1 year | Urban | Preschool, & school age | — | 1,173 | T and P | Screening, & diagnosis | Others | CCMD-II | 0.04 | 5 |
| Lin YL et al. 1996 | Putian | ≤ 1 year | Urban, & rural | School age | 0.51 | 12,638 | T and P | Screening, & diagnosis | Conners, & Others | CCMD-III-R | 0.03 | 7 |
| Zhang QF et al. 1999 | Hefei | ≤ 1 year | Urban, & rural | School age | 0.49 | 1,021 | P | Screening | Others | — | 0.11 | 6 |
| Jiang H et al. 2000 | Shanghai | ≤ 1 year | Urban, & rural | School age | 0.49 | 1,310 | T | Screening | Conners, & Others | — | 0.04 | 5 |
| Jiang L et al. 2002 | Zhenjiang | ≤ 1 year | Urban | School age | 0.49 | 3,698 | P | Screening | DSM-IV | — | 0.07 | 8 |
| Wang XL et al. 2002 | Xiamen | 1 - 2 years | Urban | School age | 0.50 | 3,989 | T and P | Screening, & diagnosis | Conners | DSM-IV, & Others | 0.06 | 7 |
| Sun XY et al. 2003 | Zibo | ≤ 1 year | Urban, & rural | Preschool, & school age | 0.53 | 3,987 | T and P | Screening, & diagnosis | Conners | DSM-III | 0.04 | 7 |
| Chen SZ et al. 2004 | Guilin | ≤ 1 year | Urban | Preschool, & school age | 0.49 | 9,162 | T and P | Screening, & diagnosis | Conners, & DSM-IV | DSM-IV | 0.04 | 5 |
| Ying WG et al. 2004 | Heze | ≤ 1 year | Urban | School age | 0.52 | 912 | T and P | Diagnosis | — | CCMD-III | 0.08 | 5 |
| Kulibahan et al. 2005 | 2006 | Kuitun | ≤ 1 year | Urban | 0.57 | 1,244 | T and P | Screening, & diagnosis | Conners | DSM-IV | 0.12 | 7 |
| Huangsha ZM et al. 2006 | Foshan | ≤ 1 year | Urban | School age | 0.50 | 2,982 | P | Screening | DSM-IV | — | 0.02 | 7 |
| Liu L et al. 2006 | Ningxia | ≤ 1 year | Urban | School age | 0.51 | 2,664 | T | Screening | Conners | — | 0.13 | 7 |
| Zhang W et al. 2007 | Six cities in Mainland China | ≤ 1 year | Urban, & rural | School age | 0.49 | 1,051 | P | Screening | DSM-IV | — | 0.05 | 6 |
| Yang BF et al. 2007 | Jining | ≤ 1 year | Urban, & rural | School age | 0.51 | 1,158 | P | Screening | Conners | — | 0.07 | 7 |
| Ba JF et al. 2008 | Huaihai | ≤ 1 year | Urban | School age | 0.55 | 2,141 | T | Screening | Conners | — | 0.08 | 7 |
| Sun D et al. 2008 | Mudanjiang | ≤ 1 year | Urban | School age | 0.56 | 6,994 | P | Screening, & diagnosis | Conners | CCMD-III | 0.09 | 7 |
| Sun DF et al. 2008 | Shandong | ≤ 1 year | Urban | Preschool, & school age | 0.51 | 8,235 | P | Screening, & diagnosis | DSM-IV | Others | 0.06 | 7 |
| Jiang H et al. 2008 | Weihai | ≤ 1 year | Urban | School age | 0.53 | 4,268 | P | Screening | DSM-IV | — | 0.06 | 7 |
| Chang XL et al. 2009 | Zhenjiang | ≤ 1 year | Urban, & rural | Preschool age | 0.51 | 724 | P | Screening | Conners | — | 0.03 | 7 |
| Han LT et al. 2010 | Liuyang | ≤ 1 year | Urban | School age | 0.50 | 5,000 | T and P | Screening, & diagnosis | Conners, DSM-IV, & Others | DSM-IV | 0.12 | 6 |
| Zhang BC et al. 2011 | Guiyang | ≤ 1 year | urban | School age | 0.47 | 3,016 | P | Screening, & diagnosis | Conners | DSM-IV | 0.01 | 7 |
| Wang HM et al. 1997 | Taiyuan | ≤ 1 year | Urban | School age | 0.50 | 2,114 | T and P | Screening | DSM-III-R | — | 0.04 | 7 |
| Zhao PF et al. 2005 | Shaodong | ≤ 1 year | Urban, & rural | School age | 0.51 | 1,069 | — | Screening | Conners | — | 0.09 | 7 |
| Xu L et al. 2005 | Fuan | ≤ 1 year | Urban | Preschool, & school age | 0.51 | 3,738 | P | Screening | DSM-III | — | 0.04 | 5 |
| Liang D et al. 2006 | Changchun | ≤ 1 year | Urban | School age | 0.49 | 7,117 | T | Screening | Conners | — | 0.02 | 7 |
| Liang D et al. 2006 | Changchun | ≤ 1 year | Urban | School age | 0.49 | 7,117 | P | Screening | Conners | — | 0.01 | 7 |
| Author, y | City/ Location | Time Frame | Region | Sample's Age | Proportion of Boys | Sample Size | Source of Information | Screening and/or Diagnosis | Screening Criteria | Diagnostic Criteria | Original Prevalence | Risk of Bias Score |
|----------|----------------|------------|--------|---------------|-------------------|------------|---------------------|--------------------------|-------------------|------------------|------------------|------------------|
| Tang SW et al., 2008 | Urumuqi | ≤ 1 year | Urban | Preschool age | 0.49 | 1,967 | T | Screening | Conners | — | 0.08 | 7 |
| Shi ST et al., 2002 | Yunnan | 1-2 years | Urban, & rural | School age | 0.50 | 5,650 | T and P | Screening | Conners, & DSM-IV | — | 0.07 | 5 |
| Guo M et al., 2008 | Nanchang | ≤ 1 year | Urban | School age | 0.54 | 633 | T and P | Screening, & diagnosis | Conners | CCMD-III | 0.06 | 5 |
| Guan BQ et al., 2005 | Six cities in Mainland China | ≤ 1 year | Urban, & rural | School age | 0.54 | 9,495 | T and P | Screening, & diagnosis | DSM-IV | DSM-IV, & Others* | 0.06 | 8 |
| Guo HL et al., 2011 | Binzhou | ≤ 1 year | Urban | School age | 0.43 | 4,275 | P | Screening | DSM-IV, & Others* | — | 0.06 | 6 |
| Wang SY et al., 2014 | Lanzhou | ≤ 1 year | Urban | School age | 0.51 | 3,604 | T, & P | Screening, & diagnosis | Conners | DSM-IV | 0.11 | 7 |
| Xu GQ et al., 2012 | Cixi | 1-2 years | Urban | Preschool, & school age | — | 1,245 | — | Screening | DSM-IV | — | 0.08 | 5 |
| Liu F et al., 2012 | Lanzhou | 1-2 years | Urban, & rural | School age | 0.50 | 1,021 | P | Screening, & diagnosis | DSM-IV | DSM-IV | 0.04 | 6 |
| Yu L et al., 2013 | Huizhou | ≤ 1 year | Urban | School age | 0.47 | 6,856 | P | Screening, & diagnosis | DSM-IV | DSM-IV | 0.07 | 5 |
| Wang LZ et al., 2010 | Wuxi | ≤ 1 year | Urban | Preschool age | 0.56 | 604 | P | Screening, & diagnosis | Conners | DSM-IV | 0.05 | 6 |
| Zhang HY et al., 2010 | Lanzhou | ≤ 1 year | Urban | Preschool, & school age | 0.55 | 1,001 | P | Screening, & diagnosis | Conners | DSM-IV | 0.09 | 5 |
| Li Y et al., 2015 | Tianjin | ≤ 1 year | Urban | Preschool, & school age | 0.59 | 2,046 | P | Screening, & diagnosis | DSM-IV | DSM-IV, & Conners | 0.14 | 7 |
| Jiang HJ et al., 2013 | Dongyang | ≤ 1 year | Urban | Preschool, & school age | 0.53 | 3,882 | P | Screening | Conners | — | 0.05 | 6 |
| Shi LJ et al., 2012 | Leshan | ≤ 1 year | Urban | Preschool, & school age | 0.52 | 1,400 | P | Screening | DSM-IV | — | 0.04 | 7 |
| Zhang CJ et al., 2014 | Guiyang | ≤ 1 year | Urban | Preschool age | 0.54 | 4,489 | T and P | Screening, & diagnosis | DSM-IV | Others* | 0.01 | 7 |
| Wang AP et al., 2011 | Yiwu | ≤ 1 year | Urban | Preschool, & school age | — | 1,376 | — | Screening | DSM-IV | — | 0.09 | 7 |
| Meng LP et al., 1999 | Jiaozuo | ≤ 1 year | Urban | Preschool, & school age | 0.54 | 904 | P | Screening | DSM-III-R | — | 0.10 | 7 |
| Shen P., 2012 | Wuxi | ≤ 1 year | Urban | School age | 0.54 | 2,397 | S | Screening | CCMD-III | — | 0.10 | 8 |
| Wang C et al., 1982 | Hengyang | ≤ 1 year | Urban | School age | 0.50 | 3,804 | T and P | Diagnosis | — | DSM-III | 0.07 | 5 |
| Li XL et al., 2012 | Walmaoqi | ≤ 1 year | Urban | School age | 0.53 | 2,066 | T and P | Screening, & diagnosis | Conners | DSM-IV, & Conners | 0.05 | 7 |
| Luo Z et al., 2013 | Taizhou | ≤ 1 year | Rural | Preschool age | — | 1,699 | P | Screening | Conners | — | 0.12 | 6 |
| He M et al., 2012 | Guangzhou | ≤ 1 year | Urban | Preschool age | 0.55 | 1,326 | T and P | Screening, & diagnosis | Conners | DSM-IV | 0.05 | 6 |
| Jin WL et al., 2009 | Shanghai | ≤ 1 year | Urban | Preschool, & school age | 0.50 | 5,648 | T and P | Screening, & diagnosis | DSM-IV | DSM-IV | 0.05 | 6 |
| Leung PW et al., 2008 | Hong Kong | ≤ 1 year | Urban | School age | 0.48 | 541 | P and S | Screening | DISC-IV, & Others* | — | 0.04 | 10 |
| GauSS et al., 1995 | Taiwan | ≤ 1 year | Urban, & rural | School age | 0.50 | 1,070 | T | Screening, & diagnosis | Others* | DSM-IV | 0.08 | 7 |
| GauSS et al., 1996 | Taiwan | ≤ 1 year | Urban, & rural | School age | 0.50 | 1,051 | T | Screening, & diagnosis | Others* | DSM-IV | 0.06 | 7 |
| GauSS et al., 1997 | Taiwan | ≤ 1 year | Urban, & rural | School age | 0.50 | 1,035 | T | Screening, & diagnosis | Others* | DSM-IV | 0.03 | 7 |
| Leung PW et al., 1996 | Hong Kong | ≤ 1 year | Urban | School age | 1.00 | 3,069 | T and P | Screening, & diagnosis | Others* | DSM-III-R | 0.09 | 7 |
| Lu L et al., 2003 | Wuhan | ≤ 1 year | Urban | Preschool, & school age | 0.49 | 2,128 | T and P | Screening, & diagnosis | Conners, & DSM-IV | Others* | 0.14 | 7 |
| Lam JT et al., 2005 | Nanning | ≤ 1 year | Urban | School age | 0.47 | 1,429 | S | Diagnosis | DSM-IV, & Conners | — | 0.08 | 8 |

Continued
Chinese children and adolescents, an apparent advantage to generate better population-based benchmarks for Chinese professionals and the public, and to be beneficial for the accurate estimation of the worldwide ADHD prevalence.

Our study revealed that ADHD prevalence in Chinese children and adolescents arose over time, with slight fluctuations. Even though recent worldwide systematic reviews with meta-analyses showed no evidence of the ascent in the number of children who met the standard diagnostic criteria over the past three decades, a roster of previous studies that employed the data collected in the USA, UK, and Canada from the 1990s to 2000s exhibited a time trend of mounting ADHD diagnoses and prescriptions of medications for ADHD treatment. Similarly, the present study showed the investigations implemented from the next 3 decades reported a higher ADHD prevalence rate than those from 1980–1990. The ascending academic pressure emanate from the fierce Chinese educational competition may be associated with the increase in the number of Chinese school-aged children and adolescents with ADHD symptoms.

We also found that the rates reported by both parents and teachers were higher than those reported by either parents or teachers, corresponding to the stereotype that Chinese children should obey their both parents and teachers, and very active children are generally considered to be either badly behaved or hyperactive, especially in the context of the rising recognition of ADHD in recent years. Additionally, the result from the present study that school-aged children and adolescents with ADHD symptoms.

Table 1. Description of studies included in the systematic review. Conners, Conners’ Parent Rating Scale and/or Conners’ Teacher Rating Scale; DSM-III, Diagnostic and Statistical Manual of Mental Disorders, Third Edition; DSM-III-R, Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; CCMD-II, Chinese Classification and Diagnosis of Mental Diseases, Second Edition; CCMD-II-R, Chinese Classification and Diagnosis of Mental Diseases, Revised Second Edition; CCMD-III, Chinese Classification and Diagnosis of Mental Diseases, Third Edition; ICD-9-CM, The International Classification of Diseases, Ninth Revision, Clinical Modification; DISC-IV, Diagnostic Interview Schedule for Children- Version 4; —, no available data or not applicable; T, teacher; P, parent; S, student. *Others appearing in both screening criteria and diagnostic criteria columns means the authors employed other types of screening criteria or diagnostic criteria, such as clinical checks, interviews, and standard questionnaires (e.g., Eysenck Personality Questionnaire, Achenbach’s child behavioral checklist, Rutter’s Teacher (B2) Questionnaire and Parent (A3) Questionnaire, Standardized Chinese Version of the Child Behavior Checklist, etc.) in their prevalence studies.
| Study characteristics                        | Number of estimates | Prevalence estimates (%) | 95% CI of estimates |
|---------------------------------------------|---------------------|--------------------------|---------------------|
| **Year of data collection**                 |                     |                          |                     |
| 1980–1990                                   | 6                   | 5.5                      | 4.2–6.8             |
| 1991–2000                                   | 12                  | 6.9                      | 4.2–9.6             |
| 2001–2010                                   | 34                  | 6.0                      | 5.0–6.7             |
| 2011–2016                                   | 18                  | 6.7                      | 5.2–8.2             |
| **Geographical location**                   |                     |                          |                     |
| Mainland China                              | 60                  | 6.5                      | 5.7–7.3             |
| Hong Kong                                   | 2                   | 6.4                      | 1.5–11.3            |
| Taiwan                                      | 8                   | 4.2                      | 3.2–5.2             |
| **Time frame**                              |                     |                          |                     |
| ≤1 year                                     | 60                  | 6.4                      | 5.6–7.2             |
| 1–2 years                                   | 5                   | 6.3                      | 5.2–7.3             |
| >2 years                                    | 5                   | 4.7                      | 3.3–6.1             |
| **Region**                                  |                     |                          |                     |
| Urban areas                                 | 50                  | 6.4                      | 5.6–7.2             |
| Rural areas                                 | 1                   | 11.9                      | 10.4–13.4           |
| Urban, & rural areas                        | 19                  | 5.7                      | 4.4–6.9             |
| **Age of participants**                     |                     |                          |                     |
| Preschoolers                                | 7                   | 5.5                      | 3.3–7.7             |
| School–aged children and adolescents        | 46                  | 6.4                      | 5.5–7.4             |
| Preschoolers, & school–aged children and adolescents | 17              | 6.1                      | 5.1–7.2             |
| **Sample size**                             |                     |                          |                     |
| ≤2,000                                      | 30                  | 6.7                      | 5.8–7.5             |
| 2,000–5,000                                 | 20                  | 7.1                      | 5.4–8.7             |
| >5,000                                      | 20                  | 4.9                      | 3.9–5.9             |
| **Source of information**                   |                     |                          |                     |
| Teacher                                     | 10                  | 6.0                      | 4.0–8.0             |
| Parent                                      | 23                  | 6.3                      | 5.0–7.7             |
| Teacher, & parent                           | 24                  | 6.8                      | 5.5–8.1             |
| Others (Student/student, & parent/student, teacher, & parent/not reported) | 7 | 4.6 | 3.3–5.9 |
| **Procedure of screening and/or diagnosis** |                     |                          |                     |
| Screening                                   | 27                  | 6.5                      | 5.3–7.7             |
| Diagnosis                                   | 8                   | 4.9                      | 3.8–6.1             |
| Screening, & diagnosis                      | 35                  | 6.4                      | 5.3–7.5             |
| **Screening criteria**                      |                     |                          |                     |
| Conners                                     | 24                  | 6.7                      | 5.2–8.3             |
| DSM-III–III–R                              | 3                   | 6.0                      | 3.7–8.3             |
| DSM-IV/DISC-IV                              | 16                  | 6.1                      | 4.8–7.4             |
| Conners, & DSM–III/-IV                      | 5                   | 8.6                      | 5.4–11.9            |
| Others (CCMD-III/questionnaires/interviews/clinical checks, etc.) | 14 | 5.6 | 4.1–7.2 |
| **Diagnostic criteria**                     |                     |                          |                     |
| DSM-III–III–R                              | 9                   | 6.7                      | 4.0–9.4             |
| DSM-IV/DISC-IV                              | 16                  | 6.4                      | 4.8–8.0             |
| CCMD-II–II–R/–III                           | 5                   | 6.0                      | 3.0–8.9             |
| DSM-IV, & Conners                           | 4                   | 7.9                      | 4.9–11.0            |
| ICD-9–CM                                    | 4                   | 2.9                      | 1.8–4.1             |
| Others (questionnaires/interviews/clinical checks, etc.) | 5 | 5.5 | 2.9–8.2 |
| **Total**                                   | 70                  | 6.3                      | 5.7–6.9             |

Table 2. General characteristics of included prevalence rates. CI: Confidence Interval; Conners, Conners’ Parent Rating Scale and/or Conners’ Teacher Rating Scale; DSM-III, Diagnostic and Statistical Manual of Mental Disorders, Third Edition; DSM-III-R, Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; CCMD-II, Chinese Classification and Diagnosis of Mental Diseases, Second Edition; CCMD-III, Chinese Classification and Diagnosis of Mental Diseases, Revised Second Edition; CCMD-III, Chinese Classification and Diagnosis of Mental Diseases, Third Edition; ICD-9–CM, The International Classification of Diseases, Ninth Revision, Clinical Modification; DISC-IV, Diagnostic Interview Schedule for Children-Version 4. *Some articles didn't report the source of information. †Only articles that reported the diagnostic criteria were counted.
from high-SES backgrounds, children in rural areas showed a significantly higher ADHD prevalence than their counterparts in urban areas in our study. Nevertheless, caution should be taken in drawing conclusions in that only one selected study consisted of the sample solely from rural areas.

While our systematic review included studies specifically conducted in Mainland China, Hong Kong, and Taiwan, no difference was detected in the ADHD prevalence estimates among the three regions after controlling for other factors of the heterogeneity across studies. This finding corroborated the limited function of geographic location in the large variability of ADHD prevalence estimates which was found in the previous review with worldwide samples. Nonetheless, it may not be neglected that remarkable differences in the socioeconomic development among the three regions during the last three decades may greatly impact the ADHD prevalence estimates. The previous worldwide systematic review also suggested that the heterogeneity of methodological characteristics may have caused the differences in ADHD prevalence in different locations. Our review indicated the similar findings that variations of the sample size, study design and screening/diagnostic criteria among the three regions explained the regional differences in prevalence estimates. For instance, although most included studies were conducted in Mainland China, studies in Taiwan had the largest number of participants, and they were more weighted in our meta-analyses. Whereas most studies in Mainland China and Hong Kong were cross-sectional, most studies in Taiwan were longitudinal. In general, compared to studies from Mainland, which wide range of screening/diagnostic criteria were used, most investigators from Hong Kong and Taiwan selected DSM and ICD-based criteria to define the ADHD.

**Limitations.** First, the literature published in the local languages of Hong Kong and Taiwan was not included in our review. Second, the high heterogeneity across studies and publication bias may weaken our ability to precisely estimate the ADHD prevalence among Chinese children and adolescents. Specifically, the pronounced variations in the procedures of screening and/or diagnosis and associated criteria across the studies raised the incomparability across the original ADHD prevalence rates, and thus caused the uncertainty to our pooled prevalence estimates. Third, the ADHD prevalence estimates found in our subgroup meta-analyses cannot adequately discern the differences in economic situations among different Urban and rural areas, and the subgroup estimates cannot be generalized to the only rural areas.
Conclusions
This is one of the few comprehensive systematic reviews of ADHD prevalence estimates among Chinese children and adolescents in Mainland China, Hong Kong, and Taiwan over the past three decades. The prevalence estimates of ADHD among children in Mainland China and Hong Kong are similar and consistent with the reported rate in previous reviews. However, Taiwan has significantly lower prevalence than other regions. Even though our results should be interpreted with caution because of the large variability found in the analyses. Moreover, our findings suggest that the geographic location plays a limited role in the heterogeneity of ADHD prevalence estimates in Chinese children. Instead, the variability may be primarily explained by the methodological characteristics of studies, years of data collection, and participants’ socioeconomic backgrounds. Our analyses also indicate that high-quality studies, such as cohort studies or repeated cross-sectional studies, are required to assess the true trend of ADHD prevalence.

### Table 3.

| Characteristics of studies                                      | β     | 95% CI       | F    | F²-res (%) |
|-----------------------------------------------------------------|-------|--------------|------|------------|
| Years of data collection (1980–1990 as index)                   |       |              |      |            |
| 1991–2000                                                       | 0.39* | 0.30–0.47    | 130.58*| 99.15      |
| 2001–2010                                                       | 0.36* | 0.31–0.41    |      |            |
| 2011–2016                                                       | 0.38* | 0.31–0.45    |      |            |
| Geographical location (Mainland China as index)                 |       |              |      |            |
| Hong Kong                                                       | 0.38  | −0.14–0.90   |      |            |
| Taiwan                                                          | 0.31* | 0.05–0.57    |      |            |
| Time frame (<1 year as index)                                   |       |              |      |            |
| 1–2 years                                                       | 0.38* | 0.05–0.71    | 4.56*| 99.78      |
| >2 years                                                        | 0.31  | −0.01–0.64   |      |            |
| Region (urban areas as index)                                   |       |              |      |            |
| Rural areas                                                     | 0.53  | −0.14–1.20   |      |            |
| Urban, & rural areas                                            | 0.35* | 0.20–0.50    |      |            |
| Age of participants (preschoolers as index)                     |       |              |      |            |
| School-aged children and adolescents                            | 0.37* | 0.33–0.42    | 189.18*| 98.92      |
| Preschoolers, & school-aged children and adolescents            | 0.37* | 0.29–0.44    | 33.34*| 99.42      |
| Sample size(<2,000 as index)                                    |       |              |      |            |
| 2,000–5,000                                                     | 0.39* | 0.27–0.51    |      |            |
| >5,000                                                          | 0.32* | 0.20–0.44    |      |            |
| Source of information (teacher as index)                        |       |              | 75.62*| 98.98      |
| Parent                                                          | 0.37* | 0.30–0.45    |      |            |
| Teacher, & parent                                              | 0.39* | 0.31–0.46    |      |            |
| Others (Student/student, & parent/student, teacher, & parent/not reported) | 0.31* | 0.17–0.45    |      |            |
| Procedure of screening and/or diagnosis (screening as index)    |       |              | 41.85*| 99.43      |
| Diagnosis                                                       | 0.33* | 0.15–0.51    |      |            |
| Screening, & diagnosis                                         | 0.37* | 0.28–0.46    |      |            |
| Screening criteria (Conners as index)                           |       |              | 18.78*| 99.61      |
| DSM-III/-III-R                                                 | 0.37* | 0.06–0.68    |      |            |
| DSM-IV/DISC-IV                                                 | 0.37* | 0.24–0.50    |      |            |
| Conners, & DSM-III/-IV                                         | 0.44* | 0.20–0.68    |      |            |
| Others (CCMD-II/questionnaires/interviews клинических проверок, тд.) | 0.35* | 0.21–0.49    |      |            |
| Diagnostic criteria (DSM–III–III–R as index)                   |       |              | 18.89*| 99.62      |
| DSM-IV/DISC-IV                                                 | 0.57* | 0.27–0.68    |      |            |
| CCMD-II/-II-R                                                  | 0.36* | 0.17–0.56    |      |            |
| DSM-IV, & Conners                                              | 0.42* | 0.20–0.64    |      |            |
| ICD–9-CM                                                        | 0.25* | 0.03–0.47    |      |            |
| Others (questionnaires/interviews клинических проверок, тд.)    | 0.33* | 0.13–0.52    |      |            |

| β     | 95% CI       | F    | F²-res (%) |
|-------|--------------|------|------------|
| 0.30–0.47 |      | 130.58*| 99.15      |
| 0.31–0.41 |      |      |            |
| 0.31–0.45 |      |      |            |
| 0.05–0.57 |      |      |            |
| 0.05–0.71 |      | 4.56*| 99.78      |
| −0.01–0.64 |      |      |            |
| −0.14–1.20 |      |      |            |
| 0.20–0.50 |      |      |            |
| 0.27–0.51 |      |      |            |
| 0.20–0.44 |      |      |            |
| 0.30–0.45 |      |      |            |
| 0.31–0.46 |      |      |            |
| 0.17–0.45 |      |      |            |
| 0.15–0.51 |      |      |            |
| 0.28–0.46 |      |      |            |
| 0.06–0.68 |      |      |            |
| 0.24–0.50 |      |      |            |
| 0.20–0.68 |      |      |            |
| 0.21–0.49 |      |      |            |
| 0.27–0.68 |      |      |            |
| 0.17–0.56 |      |      |            |
| 0.20–0.64 |      |      |            |
| 0.03–0.47 |      |      |            |
| 0.13–0.52 |      |      |            |

**Table 3.** The associations between study characteristics and the ADHD prevalence estimates. CI, Confidence Interval; Conners, Conners’ Parent Rating Scale and/or Conners’ Teacher Rating Scale; DSM-III, Diagnostic and Statistical Manual of Mental Disorders, Third Edition; DSM-III-R, Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; CCMD-II, Chinese Classification and Diagnosis of Mental Diseases, Second Edition; CCMD-II-R, Chinese Classification and Diagnosis of Mental Diseases, Revised Second Edition; CCMD-III, Chinese Classification and Diagnosis of Mental Diseases, Third Edition; ICD-9-CM, The International Classification of Diseases, Ninth Revision, Clinical Modification; DISC-IV, Diagnostic Interview Schedule for Children-Version 4; F²-res (%), the percentage of the residual variation that is attributable to between-study heterogeneity.
### Study Inclusion and Exclusion Criteria.

Inclusion criteria were: (1) original prevalence studies were conducted in the Mainland of China, Hong Kong, or Taiwan; (2) participants aged 18 years old or younger; (3) participants were screened for and/or diagnosed with ADHD; (4) any of the following assessment tools for ADHD were applied: Conners' Parent Rating Scale (Conners), Conners’ Teacher Rating Scale (Conners), DSM-III, Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition (DSM-III-R), DSM-IV, International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), International Classification of Diseases, Tenth Edition (ICD-10), Chinese Classification and Diagnosis of Mental Diseases, Second Edition (CCMD-II), Chinese Classification and Diagnosis of Mental Diseases, Revised Second Edition (CCMD-II-R), Chinese Classification and Diagnosis of Mental Diseases, Third Edition (CCMD-III), Diagnostic Interview Schedule for Children (DSM-IV), and others (e.g., standard questionnaires/interviews/clinical checks).

Exclusion criteria were: (1) participants were over 18 years old; (2) participants were migrant children or adolescents younger than 18 years old who were native Chinese/Hong Kongese/Taiwanese; (3) none of the following standardized tools was employed: Conners, DSM-III, DSM-III-R, DSM-IV, ICD-9-CM, ICD-10, CCMD-II-II-R/III, DISC-IV or others (e.g., standard questionnaires/interviews/clinical checks); (4) the study was based in the clinic or patient based; (5) the sample size was less than 500, considering potential lower power due to small sample size.

### Table 4. The associations between study characteristics and the ADHD prevalence rate. $I^2$-res (%), the percentage of the residual variation that is attributable to between-study heterogeneity. The overall $I^2$-res (%) is 98.22. *$P < 0.05$.

| Study characteristics | $\beta$  | 95% CI |
|-----------------------|---------|--------|
| **Years of data collection (1980–1990 as index)** |         |        |
| 1991–2000             | 0.21*   | 0.09–0.32 |
| 2001–2010             | 0.20*   | 0.12–0.28 |
| 2011–2016             | 0.19*   | 0.11–0.28 |
| **Geographical location (Mainland China as index)** |         |        |
| Hong Kong             | −0.05   | −0.23–0.13 |
| Taiwan                | −0.07   | −0.18–0.04 |
| **Region (urban areas as index)** |         |        |
| Rural areas           | 0.34*   | 0.09–0.59 |
| Urban, & rural areas  | −0.02   | −0.09–0.06 |
| **Age of participants (preschoolers as index)** |         |        |
| School-aged children and adolescents | 0.19* | 0.10–0.27 |
| Preschoolers, & school-aged children and adolescents | 0.16* | 0.06–0.26 |
| **Sample size (≤2,000 as index)** |         |        |
| 2,000–5,000           | 0.03    | −0.05–0.10 |
| >5,000                | −0.07   | −0.14–0.01 |
| **Procedure of screening and/or diagnosis (screening as index)** |         |        |
| Diagnosis             | 0.09    | −0.02–0.20 |
| Screening, & diagnosis| 0.06    | −0.004–0.12 |

**Methods and Materials**

**Literature Search.** A search of the literature published in English was performed using PubMed, Embase, PsycINFO, and Web of Science databases. The literature published in Chinese was searched using the China National Knowledge Infrastructure, VIP, WANFANG DATA, and China Science Periodical Database databases. These four Chinese databases include most of the articles published in Chinese among Mainland China, Hong Kong, and Taiwan. The year of publication was confined between 1978 and 2016, because the World Health Organization enacted the International Classification of Diseases, Ninth Edition (ICD-9) in which hyperkinetic disorder was defined (an alternative name for ADHD) in 1978. The search strategy was composed of search fragments of population (i.e. children and adolescent), disease condition (i.e. attention deficit disorder with hyperactivity), outcome (i.e. prevalence) and geographic location (i.e. China). Four investigators (L.A.N., X.Y.W., Y.Q., and T.L.) used the same search strategies for all databases when conducting the literature search (Appendix 1).

**Study Inclusion and Exclusion Criteria.** Three authors (L.A.N., X.Y.W., and T.L.) worked on the selection, inclusion, and exclusion criteria. Each author independently conducted a literature search, reviewed abstracts for further full-text reviews, and selected eligible studies according to the preset criteria. Studies with incomplete data or disagreements could not be included in the final analyses unless the three authors reached a consensus.

The selection criteria were: (1) original prevalence studies were conducted in the Mainland of China, Hong Kong, or Taiwan; (2) participants aged 18 years old or younger; (3) participants were screened for and/or diagnosed with ADHD; (4) any of the following assessment tools for ADHD was applied: Conners’ Parent Rating Scale (Conners), Conners’ Teacher Rating Scale (Conners), DSM-III, Diagnostic and Statistical Manual of Mental Disorders, Revised Third Edition (DSM-III-R), DSM-IV, International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), International Classification of Diseases, Tenth Edition (ICD-10), Chinese Classification and Diagnosis of Mental Diseases, Second Edition (CCMD-II), Chinese Classification and Diagnosis of Mental Diseases, Revised Second Edition (CCMD-II-R), Chinese Classification and Diagnosis of Mental Diseases, Third Edition (CCMD-III), Diagnostic Interview Schedule for Children-Version 4 (DISC-IV), and others (e.g., standard questionnaires/interviews/clinical checks).

Exclusion criteria were: (1) participants were over 18 years old; (2) participants were migrant children or adolescents younger than 18 years old who were native Chinese/Hong Kongese/Taiwanese; (3) none of the following standardized tools was employed: Conners, DSM-III, DSM-III-R, DSM-IV, ICD-9-CM, ICD-10, CCMD-II-II-R/III, DISC-IV or others (e.g., standard questionnaires/interviews/clinical checks); (4) the study was clinic based or patient based; (5) the sample size was less than 500, considering potential lower power due to small sample size.
Data extraction. The following key variables were extracted: 1) title of article; 2) years of data collection (the publication year was used as a proxy for studies without this information); 3) geographical locations (Mainland China, Hong Kong, and Taiwan); 4) time frame (referring to the period of data collection); 5) regions (rural area, urban area, or combination of rural and urban areas); 6) age of participants; 7) sample size; 8) procedure of screening and/or diagnosis; 9) screening criteria; 10) source of screening information; 11) diagnostic criteria; 12) overall ADHD prevalence rate; 13) gender-specific ADHD prevalence rates; 14) number of participants with ADHD; 15) gender-specific numbers of participants with ADHD. All the variables were collected and double checked by 2 reviewers (L.A.N., and X.Y.W.), with a third reviewer (T.L.) acting as arbitrator. The description of included studies is shown in the Table 1.

Risk of Bias Assessment. Two reviewers (L.A.N. and T. L.) assessed the risk of bias for each included study using a reliable Risk of Bias Tool for prevalence studies developed by Hoy et al. Each included study was judged by 10 items that assess measurement bias, selection bias, and bias related to the analysis (all rated as either high or low risk) and an overall assessment of risk of bias rated as low, moderate, or high risk. The more criteria were met, the lower the risk of bias. If the text was unclear, a high risk of bias was then recorded. A study was considered to have a high overall risk of bias if 3 criteria or less were met, moderate risk of bias if 4 to 6 criteria were met, and low risk of bias if 7 to 10 criteria were met.

Data Analysis. To minimize the effects of extreme prevalence rates on the overall estimates, we stabilized the variance of the study-specific prevalence with the Freeman-Tukey double arcsine transformation in both univariate and multivariate models. We applied Begg’s Test and Egger’s test to test publication bias. Inferred from the funnel and bias plots (Fig. 3), we performed the trim and fill method. The results indicated that no additional prevalence study was needed to adjust for the publication bias. Funnel plot asymmetry does not necessarily indicate publication bias (PB) in proportion studies. The quantity $I^2$ was used to detect the heterogeneity of this meta-analysis. Next, we fitted a random-effect model to estimate the overall and subgroup pooled prevalence of ADHD using untransformed prevalence rates. To further explore the potential sources of heterogeneity, we conducted the random-effect meta-regression analyses using transformed prevalence rates. Dummy variables were used in our univariate and multivariate meta-regression analyses. All data analyses were performed using Stata 14.0 (Stata Corp, College Station, TX). A two-tailed $P$ value of less than 0.05 was considered statistically significant.

Both univariate and multivariate meta-regression analysis were carried out. In each model, for categorical variable, one group was set as the reference group according to the purpose of analysis. In the final multivariate
meta-regression model, the variable time frame was excluded due to the insufficient supportive literature regarding
the role of time frame for data collection in the heterogeneity of ADHD prevalence findings. Additionally, the variable
procedure of screening and/or diagnosis was included in the final model instead of screening criteria or
diagnostic criteria because placing the latter variables in the multivariate regression model would greatly reduce
the number of samples and decrease the precision. Additionally, 6 studies did not report their sources of screening
information, thus the variable source of information was dropped as well. In summary, the following covariates
were finally examined in the multivariate model using the restricted maximum likelihood estimator: years of
data collection, geographic location, region, age of participants, sample size, and procedure of screening and/or
diagnosis. Stepwise was used to select the significant variables to the model.

Data availability. The datasets generated and analyzed during the current study are available from the cor-
responding author on reasonable request.

References
1. Thapar, A. & Cooper, M. Attention deficit hyperactivity disorder. Lancet 387, 1240–1250, https://doi.org/10.1016/s0140-
6736(15)00238-x (2016).
2. American Psychiatric Association. Diagnostic and statistical manual of mental diseases (DSM-IV), 4th ed. (American Psychiatric
Publishing, 1994).
3. World Health Organization (WHO). The ICD-10 classification of mental and behavioral disorders: diagnostic criteria for research.
(WHO, 1993)
4. Centers for Disease Control and Prevention (CDC). Attention deficit/hyperactivity disorder: a public health research agenda, https://
www.cdc.gov/nchdddc/adhd/research.html (2017)
5. Dulcan, M. Practice parameters for the assessment and treatment of children, adolescents, and adults with attention-deficit/
hyperactivity disorder. American Academy of Child and Adolescent Psychiatry. Journal of the American Academy of Child and
Adolescent Psychiatry 36, 851–812 (1997).
6. Swanson, J. M. et al. Attention-deficit/hyperactivity disorder and hyperkinetic disorder. Lancet 351, 429–433 (1998).
7. National Institutes of Health Consensus Development Conference Statement: diagnosis and treatment of attention-deficit/
hyperactivity disorder (ADHD). Journal of the American Academy of Child and Adolescent Psychiatry 39, 182–193 (2000).
8. Singh, I. Beyond polemics: science and ethics of ADHD. Nature reviews. Neuroscience 9, 957–964, https://doi.org/10.1038/nrn2514
(2008).
9. Polanczyk, G. V., Salum, G. A., Sugaya, L. S., Caye, A. & Rohde, L. A. Annual research review: A meta-analysis of the worldwide
prevalence of ADHD: is it an American condition? World epidemiology and cross-cultural validity of ADHD, in attention deficit hyperactivity
disorder: state of the science: best practices. (Civic Research Institute, 2002).
10. Polanczyk, G. V., de Lima, M. S., Horta, B. L., Biederman, J. & Rohde, L. A. The worldwide prevalence of ADHD: a systematic review
and metaregression analysis. The American journal of psychiatry 164, 942–948, https://doi.org/10.1176/appi.ajp.2007.164.6.942
(2007).
11. H. R., B. The diagnostic classification, epidemiology and cross-cultural validity of ADHD, in attention deficit hyperactivity disorder:
state of the science: best practices. (Civic Research Institute, 2002).
12. Wilcutt, E. G. The prevalence of DSM-IV attention-deficit/hyperactivity disorder: a meta-analytic review. Neurotherapeutics: the
journal of the American Society for Experimental NeuroTherapeutics 9, 490–499, https://doi.org/10.1007/s13311-012-0135-8
(2012).
13. Provincial Psychiatric Hospital. An investigation report on minor brain dysfunction in five primary schools in Guiyang city.
Guizhou Medical Journal 6, 47–49 (1981).
14. Zhang, B. C. et al. Survey of ADHD among primary and middle school students in urban area of Guiyang city. Maternal and Child
Health Care of China 26, 4892–4894 (2011).
15. Zhang, M. L., Bai, G. L., Yang, Q. L., Cao, G. H. & Qiao, Y. R. A survey of ADHD among children in Urban, & rural areas of Baotou.
Inner Mongolia Medical Journal 15, 114–115 (1995).
16. Tong, L., Shi, H. & Zang, J. Prevalence of ADHD in children of China: a systematic review and meta-analysis. Chinese Journal of
Public Health 29, 1279–1283 (2013).
17. Rapley, M. D. Clinical practice. Attention deficit-hyperactivity disorder. The New England journal of medicine 352, 165–173,
https://doi.org/10.1056/NEJMcop032387 (2005).
18. Duan, C., Lv, L., Wang, Z. & Guo, J. The survival and development status of floating of children in China: an analysis of the sixth
population census data. South China Population 4(44–55), 80 (2013).
19. Liu, X. et al. Behavioral and emotional problems in Chinese adolescents: parent and teacher reports. Journal of the American
Academy of Child and Adolescent Psychiatry 49, 428–436, https://doi.org/10.1097/00004583-200107000-00018 (2001).
20. Xiao, Y. et al. Prevalence of psychiatric disorders among children and adolescents in northeast China. PloS one 9, e111223,
https://doi.org/10.1371/journal.pone.0111223 (2014).
21. Peng, C., Ye, C. & Xie, K. Analysis of relation between middle school student study stress and their parents. Guide of Science&Education
23, 45–46 (2011).
22. Liu, Y. & Lu, Z. Chinese high school students’ academic stress and depressive symptoms: gender and school climate as moderators.
Stress and health: journal of the International Society for the Investigation of Stress 28, 340–346, https://doi.org/10.1002/smi.2418
(2012).
23. Thomas, R., Sanders, S., Doust, J., Beller, E. & Glasziou, P. Prevalence of attention-deficit/hyperactivity disorder: a systematic
review and meta-analysis. Pediatrics 135, e994–1001, https://doi.org/10.1542/peds.2014-3482 (2015).
24. Polanczyk, G. V., Willcutt, E. G., Salum, G. A., Kieling, C. & Rohde, L. A. ADHD prevalence estimates across three decades: an
updated systematic review and meta-regression analysis. International journal of epidemiology 43, 434–442, https://doi.
org/10.1093/ije/dyt261 (2014).
25. Wender, A. G. et al. Utilization of pharmacologic treatment in youths with attention deficit/hyperactivity disorder in Medicaid
database. The Annals of pharmacotherapy 42, 24–31, https://doi.org/10.1345/aph.1K143 (2008).
26. Robison, L. M., Skaar, T. L., Sclar, D. A. & Galin, R. S. Is attention deficit hyperactivity disorder increasing among girls in the US?
Trends in diagnosis and the prescribing of stimulants. CNS drugs 16, 129–137 (2002).
27. Robison, L. M., Sclar, D. A., Skaar, T. L. & Galin, R. S. National trends in the prevalence of attention-deficit/hyperactivity disorder
and the prescribing of methylphenidate among school-age children: 1990-1995. Clinical pediatrics 38, 209–217, https.
doi.org/10.1177/000992289903800402 (1999).
28. Garfield, C. F. et al. Trends in attention deficit hyperactivity disorder ambulatory diagnosis and medical treatment in the United
States, 2000-2010. Academic pediatrics 12, 110–116, https://doi.org/10.1016/j.acap.2012.01.003 (2012).
31. McCarthy, S. et al. The epidemiology of pharmacologically treated attention deficit hyperactivity disorder (ADHD) in children, adolescents and adults in UK primary care. BMC pediatrics 12, 78, https://doi.org/10.1186/1471-2431-12-78 (2012).
32. Brault, M. C. & Lacourse, E. Prevalence of prescribed attention-deficit hyperactivity disorder medications and diagnosis among Canadian preschoolers and school-age children: 1994-2007. Canadian journal of psychiatry. Revue canadienne de psychiatrie 57, 93–101, https://doi.org/10.1177/0008471205700206 (2012).
33. Russell, G., Ford, T., Rosenberg, R. & Kelly, S. The association of attention deficit hyperactivity disorder with socioeconomic disadvantage: alternative explanations and evidence. Journal of child psychology and psychiatry, and allied disciplines 55, 436–445, https://doi.org/10.1111/jcpp.12170 (2014).
34. Russell, A. E., Ford, T., Williams, R. & Russell, G. The Association Between Socioeconomic Disadvantage and Attention Deficit/Hyperactivity Disorder (ADHD): A Systematic Review. Child psychiatry and human development 47, 440–458, https://doi.org/10.1007/s10578-015-0578-3 (2016).
35. Hoy, D. et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. Journal of clinical epidemiology 65, 934–939, https://doi.org/10.1016/j.jclinepi.2011.11.014 (2012).
36. Freeman, M. F. & Tukey, J. W. Transformations related to the angular and the square root. The Annals of Mathematical Statistics 21, 607–611 (1950).
37. Hayashino, Y., Noguchi, Y. & Fukui, T. Systematic evaluation and comparison of statistical tests for publication bias. Journal of epidemiology 15, 235–243 (2005).
38. Duval, S. & Tweedie, R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. Biometrics 56, 455–463 (2000).
39. Hunter, J. P. et al. In meta-analyses of proportion studies, funnel plots were found to be an inaccurate method of assessing publication bias. Journal of Clinical Epidemiology 67(4), 897–903 (2014).
40. Higgins, J. P., Thompson, S. G., Deeks, J. J. & Altman, D. G. Measuring inconsistency in meta-analyses. BMJ (Clinical research ed.) 327, 557–560, https://doi.org/10.1136/bmj.327.7414.557 (2003).
41. Wang, R. C. et al. A survey of children with hyperkinetic syndrome in Baoding city. Hebei Medical Journal 9, 122 (1987).
42. Tang, W. B. et al. Prevalence study of ADHD among children in Hexi district, Tianjin city. Chinese Journal of Public Health 9, 90 (1993).
43. Wang, L. M. et al. An epidemiological survey on childhood hyperkinetic syndrome among aged 7–10 in Dongli district of Harbin, Harbin city. Chinese Journal of Behavioral Medical Science 6, 284–286 (1997).
44. Tang, J. P., Tu, J., Cao, H. G., Yang, L. C. & Que, X. H. Investigation and analysis of children's attention deficit disorder in part of preschools, primary schools and secondary schools in Changsha city. Hunan Medical Journal 15, 185–186 (1998).
45. Lin, Y. L., Zhaung, H. C. & Zheng, Y. T. Investigation and analysis of ADHD among school age children in Putian county. Fujian Medical Journal 21, 105–107 (1999).
46. Zhang, J. P. & Yu, A. P. Investigation on prevalence of ADHD among children aged 6-11 in Hefei city. Literature and information on preventive medicine 6, 309–310 (2000).
47. Jiang, H. et al. Investigation and analysis of ADHD among pupils in Pudong New Area. Chinese Journal of School Health 21, 189–190 (2000).
48. Jiang, L., Chang, W. J., Su, Y., Liu, W. H. & Cao, G. W. Epidemiological survey of attention-deficit hyperactivity disorder in pupils of urban districts in Zhenjiang. Academic Journal of Second Military Medical University 25, 1238–1240 (2004).
49. Wang, X. L. et al. Epidemiological investigation and analysis of information with ADHD of school age children in Xianmen. Chinese Journal of Child Health 15(479-480), 483 (2007).
50. Sun, X. Y. et al. Investigation on the incidence of ADHD among children in Zibo City. Chinese Mental Health Journal 17, 453 (2003).
51. Chen, S. Z. et al. Incidence and related factors of ADHD in children of Guilin city. Chinese Journal of Clinical Psychology 12(370), 386–387 (2004).
52. Ying, W. G. & Zhu, X. Y. Prevalence study of ADHD among children in a primary school, Mudan district, Heze city. Preventive Medicine Tribune 12, 762 (2006).
53. Kulibahan, Li, D. M., Yeerken, R. M. & Pangegepii Investigation of attention deficit hyperactivity disorder among the ethnic Han and Kazakh students from Kuntun city of Xinjiang. Chinese Journal of Contemporary Pediatrics 7, 366–368 (2005).
54. Huangfu, Z. M. Study on epidemic and family factors of children with attention deficit hyperactivity disorder in Foshan city. China Journal of Modern Medicine 16(149–150), 153 (2006).
55. Liu, L., Wen, J., Du, Y., Hai, J. J. & Ma, X. R. A cross-sectional study of ADHD among children in part regions of Ningxia. Journal of Ningxia Medical College 28, 415–417 (2006).
56. Zhang, W., Liu, X. P., Gu, Q., Jiao, R. & Ran, L. W. An epidemiological investigation of ADHD in six cities. Chinese Journal of Clinical Psychology 15, 23–25 (2007).
57. Yang, B. F., Song, H. M., Liu, X. H., Lin, R. & Wang, B. B. Prevalence of ADHD and its influencing factors in Jining city. Journal of Public Health and Preventive Medicine 19, 34–37 (2008).
58. Ba, J. F., Huo, B. Y. & Hu, B. T. An Epidemiological Survey Of Attention Deficit Hyperactivity Disorder Among School-age Children In Huaibei. Henan Journal of Preventive Medicine 19, 252–253 (2008).
59. Sun, D., Yang, Y., Song, Y. & Yu, S. C. An epidemiological survey of ADHD among pupils in Mudanjian city. Sichuan Mental Health 21, 164–166 (2008).
60. Sun, D. F., Yi, M. J., Li, M. & Li, Y. L. An investigation of ADHD and family environment in 8235 school children aged 4-16 years old in Northern Shandong. Chinese Journal of Nervous and Mental Diseases 35, 650–654 (2009).
61. Jiang, H. et al. An epidemiological survey on ADHD in school age children of Weihai. Journal of Psychiatry 23, 116–118 (2010).
62. Chang, X. L., Zhang, Y. & Wang, H. Y. An epidemiological survey of attention deficit hyperactivity disorder among preschool children in Zhenjiang. China Journal of Health Psychology 19, 1350–1352 (2011).
63. Han, L. T., Han, J. Y., Huang, G. Y. & Li, J. W. An epidemiological investigation of children with attention deficit hyperactivity disorder and related factors in Laoxing county, Laoxing province. Medical Journal of Chinese People's Health 23, 883–887 (2011).
64. Wang, H. M., Zhang, H. Q., Liang, Y. Y. & Zhang, P. Y. An epidemiological investigation of ADHD among children in Taiyuan city. Chinese Mental Health Journal 11(47), 54 (1997).
65. Zhao, P. F. & Xie, H. An epidemiological investigation of children's attention deficit hyperactivity disorder in Shaodong county. Practical Preventive Medicine 12, 368 (2005).
66. Xu, M. An investigation of children's attention deficit hyperactivity disorder in Fuan city. Chinese Journal of School Doctor 19, 587–588 (2005).
67. Liang, D., Wang, Y. & Li, C. H. An epidemiological survey of attention deficit hyperactivity disorder among students aged 6-18 years old in Central Districts, Changchun city. Maternal and Child Health Care of China 24, 522–524 (2009).
68. Tang, S. W. & Shao, H. A survey of attention deficit hyperactivity disorder among preschool children in Urumqi. Chinese Journal of Misdiagnoses 8, 3517–3518 (2008).
69. Shi, S. T. et al. An epidemiological survey of attention deficit hyperactivity disorder in four ethnic groups in Yunnan. Chinese Journal of Child Health Care 16, 204–206 (2008).
70. Guo, M. et al. Study and logistic analysis on attention deficit hyperactivity disorder among 633 pupils. Modern Preventive Medicine 36, 3651–3653 (2009).
71. Guan, B. Q. et al. Prevalence of psychiatric disorders in primary and middle school students in Hunan Province. *Chinese Journal of Contemporary Pediatrics* **12**, 123–127 (2010).

72. Guo, H. L. & Chen, G. An investigation on related factors of attention deficit hyperactivity disorder among children aged 6–16 years in Binzhou area. *Shandong Medical Journal* **51**, 77–78 (2011).

73. Wang, S. Y. et al. Prevalence of attention deficit hyperactivity disorder and its related factors among 6–13-year-old school children in Lanzhou city. *Practical Clinical Medicine* **16**, 90–95, 101 (2015).

74. Xu, G. Q. Investigation and Analysis on related factors of children’s attention deficit hyperactivity disorder in Cixi city. *Modern Practical Medicine* **26**, 68–69 (2014).

75. Liu, F., Liao, L. H. & Jiang, Z. S. Analysis of related factors of attention deficit hyperactivity disorder among children between 6 and 12 years old in Liuzhou. *Contemporary Medicine Forum* **12**, 179–181 (2014).

76. Yu, L., He, C., Zhou, Y. & Luo, H. Y. Epidemiological investigation and model study of correction and interference on children’s attention deficit hyperactivity disorder in Huizhou city’s primary school students. *Chinese Journal of Practical Nervous Diseases* **16**, 19–21 (2013).

77. Wang, L. Z., Liu, J. & Wei, Y. R. Relationship between attention deficit hyperactivity disorder in preschool children and child neglect. *Chinese Journal of Woman and Child Health Research* **24**, 144–146 (2013).

78. Zhang, H. Y. & Lu, G. L. Preliminary exploration of children attention deficit hyperactivity disorder and sleep disorders. *China Practical Medical* **8**, 43–45 (2012).

79. Li, Y., Huang, M. X., Yu, Q. & Zhao, B. Investigation of children and adolescents with attention deficit hyperactivity disorder combined with conduct disorder. *Journal of International Psychiatry* **42**, 32–35 (2013).

80. Jiang, H. J. & Lu, H. Y. Analysis of influencing factors of children’s attention deficit hyperactivity disorder in Dongyang city. *Chinese Journal of Public Health Management* **31**, 594–595, 600 (2015).

81. Li, L. & Wang, F. Epidemiological survey of attention deficit hyperactivity disorder among children aged 4–9 years old in Leshan city, Sichuan Province. *Maternal and Child Health Care of China* **29**, 1734–1735 (2014).

82. Zhang, C. J., Ai, R. & Deng, B. ADHD among preschool students in Guiyang kindergartens. *Chinese Journal of School Health* **35**, 60–61 (2014).

83. Wang, A. P., Wang, D., Luo, X. P. & He, X. Z. An investigation of influencing factors of children’s attention deficit and hyperactivity disorder in Yiwa city. *Maternal and Child Health Care of China* **28**, 996–998 (2013).

84. Meng, L. P., Zhao, Z. H., Zheng, F. L., Jiang, Y. R. & Huo, K. M. Epidemiological study of attention deficit hyperactivity disorder of the children in Jiaozuo. *Henan Medical Research* **8**, 364–365 (1999).

85. Shen, P. Survey report on 2397 students’ attention deficit hyperactivity disorder. *Jiangsu Education Research* **4**, 35–38 (2013).

86. Wang, C. R., Min, P. C. & Lin, X. W. Investigation and treatment report of mild brain dysfunction in 3804 pupils in Hengyang city. *Journal of Hengyang Medical College* **15**, 314–315 (1987).

87. Li, X. L. & Mahenefauliati, K. Epidemiology of attention deficit hyperactivity disorder among Urumqi children aged 6 to 14. *Chinese Journal of School Health* **35**(1204-1205), 1208 (2014).

88. Luo, Z. & Xu, F. Z. The analysis of risk factors of preschool children with ADHD in industrially developed rural areas. *Chinese Journal of General Practice* **11**, 1756–1757 (2013).

89. He, M., Su, Z., Peng, R. C. & Fan, Y. Q. Prevalence survey analysis of preschoolers obstructive sleep apnea syndrome and attention deficit hyperactivity disorder in liwan district of Guangzhou city. *Chinese Community Doctors* **30**, 136–138 (2014).

90. Jin, W., Du, Y., Zhong, X. & David, C. Prevalence and contributing factors to attention deficit hyperactivity disorder: a study of five- to fifteen-year-old children in Zhabei District, Shanghai. *Asia-Pacific psychiatry: official journal of the Pacific Rim College of Psychiatrists* **6**, 397–404, https://doi.org/10.1111/appy.12114 (2014).

91. Leung, P. W. et al. Prevalence of DSM-IV disorders in Chinese adolescents and the effects of an impairment criterion: a pilot community study in Hong Kong. *European child & adolescent psychiatry* **17**, 452–461, https://doi.org/10.1007/s00787-008-0687-7 (2008).

92. Gau, S. S., Chong, M. Y., Chen, T. H. & Cheng, A. T. A 3-year panel study of mental disorders among adolescents in Taiwan. *The American journal of psychiatry* **162**, 1344–1350, https://doi.org/10.1176/appi.ajp.162.7.1344 (2005).

93. Leung, P. W. et al. The diagnosis and prevalence of hyperactivity in Chinese schoolboys. *The British journal of psychiatry: the journal of mental science* **168**, 486–496 (1996).

94. Lu, L., Shi, Q. I., Zhong, Y. F., Wang, Z. M. & Chen, Z. Y. Attention deficit hyperactivity disorder and the related factors in children in Wuhan city: an analysis of 2199 questionnaires coming from 12 grades. *Chinese Journal of Clinical Rehabilitation* **9**, 116–118 (2005).

95. Lam, I. T., Yang, L., Zheng, Y., Ruan, C. & Lei, Z. Attention deficit and hyperactivity disorder tendency and unintentional injury among adolescents in China. *Accident; analysis and prevention* **38**, 1176–1182, https://doi.org/10.1016/j.aap.2006.05.004 (2006).

96. Chien, I. C., Lin, C. H., Chou, Y. J. & Chou, P. Prevalence, incidence, and stimulant use of attention-deficit hyperactivity disorder in Taiwan, 1996–2005: a national population-based study. *Social psychiatry and psychiatric epidemiology* **47**, 1885–1890, https://doi.org/10.1007/s00127-012-0501-1 (2012).

97. Shen, Y. C., Wang, Y. F. & Yang, X. L. An epidemiological investigation of minimal brain dysfunction in six elementary schools in Beijing. *Journal of child psychology and psychiatry, and allied disciplines* **26**, 777–787 (1985).

98. Tseng, W. L., Kawabata, Y., Gau, S. S. & Crick, N. R. Symptoms of attention-deficit/hyperactivity disorder and peer functioning: a nationwide population-based prospective cohort study. *Journal of child psychology and psychiatry, and allied disciplines* **54**, 1208–1214, https://doi.org/10.1111/jcpp.12087 (2013).

99. Chen, M. H. et al. Association between psychiatric disorders and iron deficiency anaemia among children and adolescents: a nationwide population-based study. *BMC psychiatry* **13**, 161, https://doi.org/10.1186/s12888-013-0161-3 (2013).

**Acknowledgements**

All phases of this study were funded by the Award from Shanghai Municipal Health Bureau (Grant No. 15GWZK0402), the National Natural Science Foundation of China (Grant No. 81402693), and Shanghai Pujiang Program (Grant No.14PJ(C)012). The authors thank Dr. Jelena Kolic from The University of British Columbia for her contribution to the manuscript revision.
Author Contributions
T.L. conceptualized and designed the study. L.A.N., X.Y.W., Y.Q. and T.L. collected data. L.A.N and X.Y.W. carried out the initial analyses. L.A.N. rafted the initial manuscript. L.A.N., X.Y.W. and T.L. reviewed and edited the manuscript.

Additional Information
Supplementary information accompanies this paper at https://doi.org/10.1038/s41598-018-29488-2.

Competing Interests: The authors declare no competing interests.

Publisher's note: Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2018