Postprint of a Meta-Analysis on the Prevalence and Influencing Factors of Myopia in Chinese Children and Adolescents

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Abstract

Background Myopia is a type of refractive error. In recent years, the prevalence of myopia among children and adolescents has remained high and shown a trend toward younger onset, posing a significant threat to their physical and mental health. Currently, there are few systematic studies on myopia and its risk factors in children and adolescents.

Objective To investigate the prevalence and influencing factors of myopia among children and adolescents in China using meta-analysis.

Methods A combination of Mesh subject terms and free-text terms was used to search the Web of Science, PubMed, Cochrane Library, CNKI, Wanfang Data, VIP, and SinoMed databases for studies on the prevalence and influencing factors of myopia, with the search period up to November 2024. Two researchers independently screened the studies and reached consensus on inclusion. Study quality was assessed using the Agency for Healthcare Research and Quality (AHRQ) evaluation criteria. Meta-analysis was performed using Stata 18.0 software.

Results A total of 33 studies were included, involving 768,813 myopic children and adolescents. Meta-analysis results showed that the prevalence of myopia among Chinese children and adolescents was 58% (95%CI=54%-62%). The following were risk factors for myopia (P<0.05): female gender (OR=1.41, 95%CI=1.21-1.64), high school (OR=3.59, 95%CI=1.17-10.97), grade level (OR=1.53, 95%CI=1.33-1.77), urban residence (OR=2.12, 95%CI=1.29-3.48), maternal myopia (OR=1.49, 95%CI=1.18-1.88), paternal myopia (OR=1.57, 95%CI=1.22-2.02), one myopic parent (OR=1.88, 95%CI=1.78-1.99), both parents myopic (OR=2.45, 95%CI=1.97-3.06), overweight or obesity (OR=1.74,

95%CI=1.63-1.85), incorrect reading/writing posture (OR=1.35, 95%CI=1.14-1.60), reading or using electronic screens while lying or prone (OR=1.17, 95%CI=1.03-1.33), daily screen time >2 h (OR=1.29, 95%CI=1.15-1.44), daily outdoor activity time <2 h (OR=1.41, 95%CI=1.10-1.80), average daily sleep time $ $8 h (OR=1.71, 95%CI=1.28-2.30), and attending academic tutoring $ $2 h in the past week (OR=1.27, 95%CI=1.12-1.42). Performing eye exercises (OR=0.79, 95%CI=0.64-0.98), preference for vegetables and fruits (OR=0.84, 95%CI=0.76-0.92), and outdoor activity areas during breaks (OR=0.75, 95%CI=0.74-0.77) were protective factors (P<0.05).

Conclusion The prevalence of myopia among Chinese children and adolescents is high. Gender, education level, residence, family history of myopia, obesity, visual habits, sleep time, and insufficient outdoor activity are major risk factors for myopia in this population. Greater attention should be paid to myopia in children and adolescents, with early identification and intervention to reduce the prevalence of myopia and improve quality of life for affected children.

Full Text

Meta-Analysis of the Prevalence and Risk Factors of Myopia in Chinese Children and Adolescents

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Abstract

Background: Myopia is a refractive error, and in recent years, the prevalence of myopia among children and adolescents has remained high and has shown a tendency toward earlier onset, posing a great threat to the physical and mental health of this population. Currently, there are few systematic studies on myopia and its risk factors in children and adolescents.

Objective: To explore the prevalence and influencing factors of myopia among children and adolescents in China using meta-analysis.

Methods: A combination of MeSH subject terms and free terms was used to search for studies on myopia prevalence and influencing factors in Web of Science, PubMed, Cochrane Library, China National Knowledge Infrastructure (CNKI), Wanfang Data, VIP Chinese Journal Full-Text Database, and China Biology Medicine (SinoMed) databases up to November 2024. Two researchers

independently screened studies and reached consensus on final inclusion. Study quality was assessed using the Agency for Healthcare Research and Quality (AHRQ) evaluation criteria, and meta-analysis was performed using Stata 18.0 software.

Results: A total of 33 studies were included, comprising 768,813 myopic children and adolescents. Meta-analysis showed that the prevalence of myopia among Chinese children and adolescents was 58% (95%CI=54%-62%). Risk factors included female gender (OR=1.41, 95%CI=1.21-1.64), high school level (OR=3.59, 95%CI=1.17-10.97), grade level (OR=1.53, 95%CI=1.33-1.77), urban residence (OR=2.12, 95%CI=1.29-3.48), maternal myopia (OR=1.49, 95%CI=1.18-1.88), paternal myopia (OR=1.57, 95%CI=1.22-2.02), one myopic parent (OR=1.88, 95%CI=1.78-1.99), both parents myopic (OR=2.45, 95%CI=1.97-3.06), overweight or obesity (OR=1.74, 95%CI=1.63-1.85), incorrect reading/writing posture (OR=1.35, 95%CI=1.14-1.60), reading or viewing screens while lying down (OR=1.17, 95%CI=1.03-1.33), daily screen time >2 hours (OR=1.29, 95%CI=1.15-1.44), daily outdoor activity <2 hours (OR=1.41, 95%CI=1.10-1.80), average daily sleep $ $8 hours (OR=1.71, 95%CI=1.28-2.30), and attending academic tutoring $ $2 hours/week in the past week (OR=1.27, 95%CI=1.12-1.42) (P<0.05). Protective factors included performing eye exercises (OR=0.79, 95%CI=0.64-0.98), preference for vegetables and fruits (OR=0.84, 95%CI=0.76-0.92), and outdoor activities during recess (OR=0.75, 95%CI=0.74-0.77) (P<0.05).

Conclusion: The prevalence of myopia among Chinese children and adolescents is high. Gender, school level, residence, family history of myopia, obesity, ocular habits, sleep duration, and insufficient outdoor activity are the main risk factors. Greater attention should be paid to myopia in this population, with early identification and intervention to reduce prevalence and improve quality of life.

Keywords: myopia; child; adolescent; prevalence; risk factor; meta-analysis

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Myopia is a type of refractive error in which light rays entering the eye parallel to the optical axis are focused in front of the retina when the eye is in a relaxed state [1]. Myopia has become a global public health problem, particularly pronounced among young populations in East and Southeast Asia [2]. According to a 2020 report by the National Health Commission, the overall myopia rate among children and adolescents in China was 52.7%, with a continuing trend toward onset at younger ages [3]. The prevalence of myopia among Chinese children and adolescents remains high, and this trend is intensifying with increasing academic pressure and the advent of the digital age. The threat posed by myopia to the physical and mental health of children and adolescents cannot be ignored. At the physiological level, myopia impairs visual function, affecting perception and judgment of the surrounding environment, and can lead to a series of ocular complications such as retinal detachment and glaucoma, potentially resulting

in vision loss in severe cases. At the psychological level, myopia may trigger issues such as inferiority complex and anxiety among children and adolescents [4]. Furthermore, myopia imposes a heavy economic burden on families and society, including costs for myopia treatment and vision correction products, as well as academic and employment difficulties resulting from myopia.

To reduce the prevalence of myopia among children and adolescents, relevant authorities have issued multiple myopia prevention and control guidelines, explicitly calling for comprehensive efforts to advance myopia prevention and control work [5]. In-depth analysis of the prevalence and influencing factors of myopia among children and adolescents in China is of great significance for relevant departments to formulate effective prevention and control strategies and reduce myopia rates. However, although numerous studies have examined the prevalence or influencing factors of myopia among Chinese children and adolescents, systematic evaluation and comprehensive analysis are lacking. This situation may be attributable to differences in study design, sample selection, diagnostic criteria, and other aspects. Based on this, the present study aims to comprehensively search domestic and international databases to collect literature on the prevalence and influencing factors of myopia among Chinese children and adolescents, employ systematic review and meta-analysis methods to assess the quality of included literature and extract data, and objectively and accurately reflect the epidemiological status and influencing factors of myopia among Chinese children and adolescents. It is hoped that this will provide more accurate and reliable scientific evidence and references for relevant departments to formulate myopia prevention and control policies, and offer robust data support and theoretical foundations for schools, families, and communities to carry out myopia prevention work.

1 Materials and Methods

This study was registered with the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42024600293.

1.1 Inclusion and Exclusion Criteria

Inclusion criteria: (1) Study subjects must be Chinese children and adolescents aged 5-18 years. Studies including participants older than 18 were required to provide age stratification, allowing extraction of data for the 5-18 age group; (2) Sample size for myopia studies must be $ $2,000; (3) Study period limited to within 5 years (January 2020 to November 2024); (4) Study results must report myopia prevalence or influencing factors.

Exclusion criteria: (1) Conference abstracts, reviews, or commentaries; (2) Duplicate publications; (3) Incomplete or missing data preventing extraction of relevant indicators; (4) Non-Chinese or non-English articles; (5) Failure to clearly distinguish between normal vision and myopia groups; (6) Studies of isolated populations (e.g., schools for deaf-mute or blind students). Studies

with sample sizes <2,000 were excluded because their age-defined subgroups were too small to reliably assess myopia prevalence and risk factors.

1.2 Literature Search Strategy

Chinese search terms included children, adolescents, myopia, refractive error, prevalence, epidemiological survey, and risk factors. English search terms included youth, adolescent, teenager, child, myopia, shortsightedness, refractive error, prevalence, incidence, epidemiology, influence, risk factors, and determinants. A combination of MeSH subject terms and free terms was used to search for studies on myopia prevalence and risk factors in CNKI, Wanfang Data, VIP, SinoMed, Web of Science, PubMed, and Cochrane Library databases up to November 2024. The search strategy for PubMed is shown in .

1.3 Literature Screening and Data Extraction

Literature was imported into EndNote 21, and two researchers independently screened studies according to inclusion and exclusion criteria. After screening, results were cross-checked, and any disagreements were resolved through group discussion or by a third researcher. Data extracted from included studies included first author, survey year, region, age, sample size, prevalence rate, diagnostic criteria, and risk factors.

1.4 Literature Quality Assessment

This study used the Agency for Healthcare Research and Quality (AHRQ) evaluation criteria to assess literature quality. The AHRQ scale contains 11 items. After full-text review, included studies were scored: 0-3 points indicated low quality, 4-7 points indicated moderate quality, and 8-11 points indicated high quality. Two researchers independently assessed the quality of included literature, with disagreements resolved through consultation with a third researcher.

1.5 Statistical Methods

This study used Stata 18.0 for meta-analysis, statistically analyzing myopia prevalence rates and OR values with 95% confidence intervals for various risk factors. Heterogeneity was assessed using Q tests and I^2 statistics. A random-effects model was adopted if $I^2 \geq 50\%$, while a fixed-effects model was used if $I^2 < 50\%$. Publication bias was examined using funnel plots, Begg' s test, and Egger's test. If publication bias was detected, the trim-and-fill method was used to test the robustness of results. Heterogeneity sources were explored through sensitivity analysis and subgroup analysis. $P<0.05$ was considered statistically significant.

2 Results

2.1 Literature Screening Process and Results

A total of 3,134 relevant articles were retrieved. After removing duplicates, 1,968 articles remained. After reading 138 full-text articles, 105 were excluded, and 33 articles [6-38] were finally included, comprising 3 English articles [36-38] and 30 Chinese articles [6-35]. The literature screening flowchart is shown in [Figure 1: see original paper] [39-40].

2.2 Basic Characteristics and Quality Assessment of Included Studies

The 33 included studies comprised 1,542,628 children and adolescents, including 768,813 myopic cases. According to AHRQ quality assessment criteria, 8 studies were rated as high quality [7,9,17-18,25,36-38] and 25 as moderate quality [6,8,10-16,19-24,26-35]. The studies covered 17 provinces/municipalities/autonomous regions. Detailed quality assessment and basic characteristics of included studies are shown in .

2.3 Myopia Prevalence

2.3.1 Meta-Analysis Results Thirty-three studies [6-38] investigated myopia prevalence in children and adolescents. Significant heterogeneity existed among studies (I^2=99.95%), so a random-effects model was used. Results showed that the prevalence of myopia among Chinese children and adolescents was 58% (95%CI=54%-62%), as shown in [Figure 2: see original paper].

2.3.2 Subgroup Analysis Subgroup analysis was conducted based on gender, school level, residence, ethnicity, and diagnostic criteria. Results showed that myopia prevalence was higher among females, middle/high school students, urban residents, Han ethnicity, and those diagnosed using criterion A ($P<0.05$), as shown in .

2.3.3 Sensitivity Analysis Sensitivity analysis for myopia prevalence was performed using the leave-one-out method. Results showed that randomly removing any included study did not affect the overall findings, indicating that the random-effects model produced robust results, as shown in [Figure 3: see original paper].

2.4 Influencing Factors

2.4.1 Meta-Analysis Results This study combined analyses of identical influencing factors reported in $ $2 studies. Results showed that middle school level, picky eating, reading/screens in sunlight, viewing electronic screens in the dark after sunset, reading/screens while walking or riding, reading or using electronic products in dim light, resting for 1 hour after $ $1 hour of near work, adjusting desk/chair height once per academic year, rural residence, and

regular seat changes were not influencing factors for myopia in children and adolescents (P>0.05). Risk factors included female gender, high school level, grade level, urban residence, maternal myopia, paternal myopia, one myopic parent, both parents myopic, overweight/obesity, incorrect reading/writing posture, reading/screens while lying down, daily screen time >2 hours, daily outdoor activity <2 hours, average daily sleep $ $8 hours, and attending academic tutoring $ $2 hours/week in the past week (P<0.05). Protective factors included performing eye exercises, preference for vegetables and fruits, and outdoor activities during recess (P<0.05), as shown in .

2.4.2 Sensitivity Analysis Sensitivity analysis was performed for influencing factors reported in $ $2 studies, using both fixed-effects and random-effects models to calculate OR values and 95%CIs. Results showed minimal differences between models except for high school level and urban residence, indicating high stability of the meta-analysis results for influencing factors, as shown in .

2.5 Publication Bias Analysis

The funnel plot for myopia prevalence among Chinese children and adolescents showed an asymmetric distribution of scatter points, as shown in [Figure 4: see original paper]. Begg' s test yielded P=0.200>0.05, suggesting low probability of publication bias. However, Egger' s test showed P=0.009<0.05, indicating possible publication bias. After adding 17 virtual studies using the trim-and-fill method, results remained unchanged, indicating that publication bias did not affect the stability of findings, as shown in [Figure 5: see original paper].

3 Discussion

3.1 Prevalence of Myopia Among Chinese Children and Adolescents

This study included 33 articles, and meta-analysis showed a myopia prevalence of 58% (95%CI=54%-62%) among Chinese children and adolescents. This is higher than the 52.7% rate reported by the National Health Commission in 2020 [3], possibly due to increased use of smartphones, tablets, and computers over the past five years, longer screen time, increased academic pressure with higher grade levels, longer reading time and greater visual intensity, and reduced outdoor activity time.

Subgroup analysis revealed significant differences in myopia prevalence by gender, school level, residence, ethnicity, and diagnostic criteria, with higher rates among females, middle/high school students, urban residents, Han ethnicity, and those using diagnostic criterion A (P<0.05).

(1) Gender: Results showed that females were more likely to be myopic than males, consistent with previous studies [41-42]. Compared with males, females tend to be more introverted, prefer quiet activities, engage in longer indoor activities such as reading, studying, or using electronic devices, and participate

less in outdoor physical activities. Prolonged near work increases ocular burden. Additionally, females experience earlier physiological development, with estrogen receptors widely distributed in retinal and scleral tissues. Elevated estrogen levels in adolescent females regulate matrix metalloproteinase (MMPs) activity, participating in scleral extracellular matrix (ECM) remodeling and accelerating myopia progression [43-45].

(2) School level: As grade level increases, children and adolescents face mounting pressure from entrance examinations, with increased academic workload, longer high-intensity near work time, reduced outdoor activity time, and insufficient sleep. High-intensity near work causes persistent accommodative lag, positioning the retinal image plane behind the photoreceptor layer and creating hyperopic defocus that promotes scleral remodeling and axial elongation [46-48].

(3) Residence: Urban children are more susceptible to myopia than suburban/rural children, likely due to multiple environmental and lifestyle factors. Urban children face greater educational pressure, while suburban children have more opportunities for outdoor activity and natural light exposure. Outdoor natural light stimulates retinal cells to release dopamine, activating receptors that inhibit excessive axial elongation [49], helping slow myopia progression. Additionally, inadequate lighting in urban school environments represents another disadvantageous factor for myopia development [50].

(4) Ethnicity: Han children and adolescents (60%) had higher myopia prevalence than non-Han (56%), possibly because Han children are concentrated in cities with dense educational resources, high electronic device penetration, prevalent tutoring culture, long near work time, and insufficient outdoor activity, while non-Han children have more exposure to natural light, which slows myopia development through retinal dopamine release mechanisms [46].

(5) Diagnostic criteria: Among the 33 included studies, those using diagnostic criterion A showed the highest prevalence (70%), while those using criteria C and E showed the lowest (55%). These differences likely reflect substantial variation between diagnostic criteria. Although no unified myopia diagnostic criteria exist domestically or internationally, they are generally similar. In 2024, the National Health Commission issued the "Myopia Prevention and Control Guidelines (2024 Edition)" [51], recommending that future epidemiological studies on myopia adopt unified diagnostic criteria whenever possible.

3.2 Analysis of Influencing Factors

3.2.1 Individual Characteristics and Background Combined analysis of risk factors revealed that female gender, high school level, grade level, urban residence, maternal myopia, paternal myopia, one myopic parent, both parents myopic, and overweight/obesity were risk factors for myopia in children and adolescents. Maternal, paternal, one parent, and both parents myopic were significant risk factors, consistent with previous research [52-54]. Genetic factors play an important role in myopia onset. Children with myopic mothers

or fathers have correspondingly increased myopia risk, which is further exacerbated when both parents are myopic. The genetic mechanism of myopia is relatively complex, involving interactions between multiple genes and environmental factors [55]. Therefore, for children and adolescents with a family history of myopia, attention should be paid to their visual development, with regular vision examinations to enable early detection and intervention.

Domestic and international studies show that overweight or obese children and adolescents are more likely to be myopic [56-57]. Obesity causes metabolic abnormalities that affect normal ocular development and visual function. Obese children and adolescents tend toward sedentary lifestyles with insufficient outdoor activity and physical exercise, preventing effective ciliary muscle rest after prolonged near work. For overweight or obese children and adolescents, in addition to weight management, increased outdoor activity and physical exercise should be encouraged to reduce near work load and lower myopia risk.

3.2.2 Lifestyle Habits and Ocular Behavior Results showed that incorrect reading/writing posture, reading/screens while lying down, daily screen time >2 hours, daily outdoor activity <2 hours, average daily sleep $ $8 hours, and attending academic tutoring $ $2 hours/week in the past week were risk factors for myopia in children and adolescents. When children and adolescents read or write with their eyes too close to books or with incorrect head and spine posture, ocular burden increases, leading to myopia over time. Reading or viewing screens while lying down causes abnormal accommodation function, keeping ciliary muscles in prolonged tension and accelerating myopia progression. Excessive screen time exposes eyes to harmful blue light, damaging the retina and increasing myopia risk. Research shows outdoor activity promotes exposure to natural light [58], allowing eyes to relax and helping slow myopia progression. Adequate sleep is crucial for visual health in children and adolescents [59]; insufficient sleep (<8 hours) prevents eyes from resting and recovering after prolonged work, easily triggering myopia. Long hours in academic tutoring cause overuse of eyes, and poor learning environments such as inadequate lighting or mismatched desk/chair height further increase myopia risk [60]. Health education should be strengthened to raise awareness of eye hygiene, promote healthy lifestyles, ensure adequate sleep, and encourage reasonable participation in after-school tutoring to reduce myopia onset and progression.

3.2.3 Other Factors Results showed that performing eye exercises, preference for vegetables and fruits, and outdoor activities during recess were protective factors against myopia in children and adolescents. After prolonged near work such as reading, writing, or screen use, eye muscles easily become tense and fatigued, potentially causing morphological changes and myopia development. Eye exercises massage ocular acupoints, adjusting muscle tension and relaxation, improving ocular blood circulation, and relieving eye fatigue [61]. Vegetables and fruits are rich in vitamins, minerals, and antioxidants. Vitamin A is a crucial component of rhodopsin in the retina [62], helping maintain normal vi-

sual function. Preference for vegetables and fruits provides adequate nutritional support for eyes, reducing myopia risk. Outdoor environments have ample light that stimulates retinal release of dopamine and other neurotransmitters, helping inhibit excessive axial elongation [49], allowing eyes to rest adequately and relieving fatigue from prolonged near work, thereby preventing myopia. Relevant departments should emphasize and promote these effective protective factors in future myopia prevention and control efforts.

3.3 Limitations of This Study

1. This study only included cross-sectional studies, not cohort or longitudinal studies, which may introduce bias to some extent.
2. Studies did not use uniform myopia diagnostic criteria, and differences in measurement levels and research methods represent sources of heterogeneity that may affect results.
3. Some influencing factors such as attending academic tutoring $ $2 hours/week in the past week, outdoor activities during recess, and preference for vegetables and fruits were included in few studies, which may affect result reliability.
4. This study only included Chinese and English literature with limited number of studies. Expanding literature search to include more languages and studies from multiple regions and cultural backgrounds would further verify result robustness.

4 Conclusion

This study examined both the prevalence and influencing factors of myopia among Chinese children and adolescents. Results showed a myopia prevalence of 58%. Risk factors included female gender, high school level, grade level, urban residence, maternal myopia, paternal myopia, one myopic parent, both parents myopic, overweight/obesity, incorrect reading/writing posture, reading/screens while lying down, daily screen time >2 hours, daily outdoor activity <2 hours, average daily sleep $ $8 hours, and attending academic tutoring $ $2 hours/week in the past week. Protective factors included performing eye exercises, preference for vegetables and fruits, and outdoor activities during recess. This study established strict inclusion criteria, included a large number of studies with large sample sizes and broad geographic distribution, and thoroughly explored the effects of genetic and environmental factors on myopia. The findings provide scientific evidence for relevant departments to formulate myopia prevention and control policies, helping reduce myopia prevalence and protect visual health in children and adolescents.

Author Contributions: JIANG Shihua conceptualized the study, collected and organized data, drafted and revised the manuscript, and prepared figures and tables. ZHU Zheng, REN Yingying, and ZHU Yaolei conducted literature searches and screening, and collected and cleaned data. WANG Yue performed statistical analysis and interpretation. GAO Xibin revised and proofread the

final version, provided supervision, and takes overall responsibility for the article.

Conflict of Interest: The authors declare no conflict of interest.

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