Global prevalence, trend and projection of myopia in children and adolescents from 1990 to 2050: a comprehensive systematic review and meta-analysis

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ABSTRACT

Background Myopia is a pervasive global public health concern, particularly among the younger population. However, the escalating prevalence of myopia remains uncertain. Hence, our research aims to ascertain the global and regional prevalence of myopia, along with its occurrence within specific demographic groups.

Methods An exhaustive literature search was performed on several databases covering the period from their inception to 27 June 2023. The global prevalence of myopia was determined by employing pooled estimates with a 95% CI, and further analysis was conducted to assess variations in prevalence estimates across different subgroups. Additionally, a time series model was utilised to forecast and fit accurately the future prevalence of myopia for the next three decades.

Results This study encompasses a comprehensive analysis of 276 studies, involving a total of 5 410 945 participants from 50 countries across all six continents. The findings revealed a gradual increase in pooled prevalence of myopia, ranging from 24.32% (95% CI 15.23% to 33.40%) to 35.81% (95% CI 31.70% to 39.91%), observed from 1990 to 2023, and projections indicate that this prevalence is expected to reach 36.59% in 2040 and 39.80% in 2050. Notably, individuals residing in East Asia (35.22%) or in urban areas (28.55%), female gender (33.57%), adolescents (47.00%), and high school students (45.71%) exhibit a higher proportion of myopia prevalence.

Conclusion The global prevalence of childhood myopia is substantial, affecting approximately one-third of children and adolescents, with notable variations in prevalence across different demographic groups. It is anticipated that the global incidence of myopia will exceed 740 million cases by 2050.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The most recent published review solely encompassed myopia-related publications up until 2015; therefore, it is imperative to conduct a literature review that includes studies published after 2015 to gain a comprehensive understanding of the most recent research.

WHAT THIS STUDY ADDS

⇒ Our findings revealed a gradual increase in the pooled prevalence of myopia from 1990 to 2023, and projections indicate a continued increase to 2050. Notably, individuals residing in East Asia or in urban areas, female gender, adolescents, and high school students exhibited a higher proportion of myopic prevalence.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings contribute to the understanding of the global prevalence of myopia, particularly during the COVID-19 pandemic. It emphasises the need for urgent attention to this public health issue in guiding policy decisions.

INTRODUCTION

Myopia has emerged as a major public health concern nowadays, with striking evidence existing for rapid increases in its prevalence, especially for Southeast Asian countries such as Singapore, China and Taiwan.[1 2] Moreover, in urban areas of certain countries, a large majority (80–90%) of children who finish high school suffer from myopia, while a smaller percentage (10–20%) experience high myopia.[3]

Myopia typically starts in early childhood and tends to worsen as individuals progress from childhood to adolescence and eventually into adulthood.[4] Younger students are generally more susceptible and vulnerable to environmental factors compared with adults. This is particularly significant for pre-school children, as they are in a critical period of visual development characterised by high plasticity.[5 6] There is a need to gather data to measure the variations in myopia prevalence among the youth population over time, as there have been noticeable differences in both ethnicity and geography. These differences have also appeared to evolve over time. It is estimated that East Asians are more than twice as likely to be myopic as similar white peers.[7] In addition, there has been an upward trend in myopia prevalence in several countries, particularly in East Asia, among younger people.[7] There is also a regional disparity in myopia prevalence between rural and urban areas, with a lower prevalence in

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rural areas compared with urban areas, and the prevalence in rural areas is increasing over time.[8]

However, the extent of ethnic and regional variation in myopia is difficult to determine due to variations in methodology across different previous studies. This challenge has been created by limitations of prior studies in regard to populations, study types, and definitions of myopia. For example, previous meta-analyses have included both observational and intervention studies for reporting myopia progression, which are prone to confounding variables and biases.[9] On the other hand, the prevalence of uncontrolled myopia in East Asia, especially in China, is alarmingly high compared with the rest of the world, but the previous meta-analysis did not consider the Chinese database, which could introduce publication bias and outcome reporting bias.[10] Notably, during the COVID-19 pandemic, many countries implemented nationwide lockdowns as an emergency domestic quarantine measure to control the transmission of the virus. The Chinese government also initiated a nationwide school closure, which resulted in over 200 million students having to complete their studies online from their homes. However, recent concerns have been raised about the potential negative impact of prolonged lockdowns on eye health, specifically myopia. This is due to the decrease in outdoor activities and increase in screen time that may result from extended periods of staying indoors.[6] However, evidence regarding these aspects remains underreported globally. Finally, given that the most recent published review solely encompassed myopia-related publications up until 2015,[10 11] it is imperative to update the meta-analysis as the evidence base is currently outdated. It is imperative to conduct a literature review that includes studies published after 2015 to gain a comprehensive understanding of the most recent research. Therefore, accurately estimating the global prevalence of myopia is crucial for advocacy efforts, raising awareness, shaping healthcare policy, as well as allocating limited resources to reduce its prevalence and improve outcomes, particularly among children and adolescents. To estimate the current prevalence and predict the future prevalence of myopia in 2050, based on an extensive search strategy, we conducted a meta-analysis that took into account geographical, temporal, and other variations over an extended period among children and adolescents.

METHODS

We followed Cochrane's Handbook guidelines and utilised the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[12] and Meta-analysis of Observational Studies in Epidemiology (MOOSE)[13] to ensure accuracy and completeness in our research methodology. Since our analyses relied on studies that were already published, there was no need for ethical approval or patient consent. This study was registered on the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) with a registration number of INPLASY202380122 (see online supplemental protocol file).

Search strategies and literature selection

We adopted a comprehensive search strategy accordingly for PubMed (via Medline), Embase, Web of Science, CBM, CNKI, VIP, and Wanfang, from their inception to 27 June 2023 without language resection. To conduct a comprehensive search, Medical Subject Headings (MeSH) terms were used in combination with relevant keywords and Boolean operators on the PICOS items: 'Myopia', 'Epidemiology', 'Cross-sectional study', 'Prevalence'. In order to identify the potential relevant publications, a recursive search was conducted which involved manually screening bibliographies of relevant reviews, reviewing government reports, collecting the grey literature, and examining major journals such as *Ophthalmology*, *JAMA Ophthalmology*, and *The Ocular Surface*. Three independent investigators (JHL, YQP, JQC) screened the databases, and any discrepancies were resolved through discussion or by consulting the fourth author (YJC). The specific search queries for each database can be found in online supplemental material A.

The citation management process involved using EndNote X9 software to download and organise all sources (Thompson ISI Research Soft, Clarivate Analytics, Philadelphia, USA). Duplicate items were removed and three investigators (JHL, YQP, JQC) independently reviewed the titles, abstracts, and full texts of publications based on pre-determined criteria to exclude irrelevant studies. Eligible citations were cross-checked to ensure accuracy.

Inclusion and exclusion criteria

Studies were eventually included in our synthesis if they met the eligibility criteria as follows: (1) the study employed a population-based approach, utilising a sample that was generally representative of children and adolescents aged 5–19 years (according to WHO criteria: https://www.who.int/)—in mixed-age population studies, it was necessary to separate and extract the prevalence data of myopia specifically for the 5–19 year age group, and the age categorisation was derived from prior meta-analytical studies[14 15]; (2) the study provided a comprehensive description of the country or region under investigation; (3) specific numerical prevalence estimate of myopia was provided; (4) the optometry method used to determine the spherical equivalent (SE) and the definition of myopia were clearly elucidated—a standardised SE of −0.50 D or less was applied for the definition of myopia, which was the most commonly used definition in published prevalence studies,[16] or other similar or equivalent approaches were used; and (5) the study design was any type of cross-sectional or epidemiology study.

Studies were excluded if they met the following criteria: (1) participants were children and adolescents with organic or psychiatric disorders; (2) studies that were not written in English or Chinese; (3) case–control studies, longitudinal studies, randomised controlled trials; and (4) studies lacking relevant key information in terms of age, sample size, myopia definition, region where the study was conducted, etc.

Data extraction and quality appraisal

Four authors (JHL, YQP, JQC, MLL) independently extracted the pivotal information using a pre-designed and pre-tested comprehensive extraction form which was derived from the data extraction template and followed the Cochrane Consumers and Communication Review Group. The following key items of the included studies were specifically extracted: first author, year of publication, specific country, total sample size, number of myopia patients, gender data (if any), and criteria for myopia. One publication involving surveys of multiple regions or year stages will be split based on the specific stages or regions, and the study was therefore split into two or more records to be included in our meta-analysis. We attempted to contact the principal authors after being unable to locate the desired data for extraction.

The Joanna Briggs Institute (JBI) critical appraisal tool was utilised to evaluate all the included studies based on nine items, which were divided into four elements: Yes (the item met the requirement), No (the item did not meet the requirement), NA (there is no item), and Unclear (it is unclear whether the item met the requirement). A total JBI score was generated based on the Yes numbers, with the total score ranging from 0 to 9, representing the quality of the included study.[17] The Grades of Recommendations Assessment, Development and Evaluation (GRADE) system was applied to rate the quality of the eligible studies. Observational studies were initially rated as low-quality evidence, which were downgraded based on five items (study limitations, imprecision, inconsistency, indirectness, and publication bias) accordingly. The items of study were rated as three levels: no downgrade, downgrade one level (serious), or downgrade two levels (very serious). Following the above assessment, the quality of each study was ultimately rated at four levels of evidence (high, medium, low, or very low).[18] The assessment of JBI and GRADE was conducted independently by two researchers in duplicate.

Statistical analyses

The overall prevalence and its 95% confidence intervals (95% CI) were estimated using the random-effects model, which considers the assumption of statistical heterogeneity among studies and provides an overall estimate weighted by sample size.[19 20] In our analysis, the survey year was adopted to describe the time trend and present the prevalence of myopia. A significant heterogeneity was defined as an I^2 value >50% and a p value <0.1 for Cochran's Q tests.[21]

For evaluating any significant variations among the studies included or to account for the considerable heterogeneity, we conducted multiple subgroup analyses, which are outlined below: gender (males vs females), school level (primary vs secondary vs high), age groups (children vs adolescents), setting (rural vs urban), sample size (<1000, 1000–3000, >3000), publication years (1990–2000, 2001–2010, 2011–2019, 2020–2023), development group (developed countries vs developing/undeveloped countries), UN region (Asia vs Europe vs North America vs Latin America and the Caribbean vs Oceania vs Africa), and China-based region (West, East, Central, Northeast, Special Administrative Regions). To examine the relationship between various sample characteristics and the occurrence of childhood myopia, univariable meta-regression analyses were performed. It is generally advised to have at least 10 data points for each variable in the analysis.[22] Finally, based on the data from the World Population Prospects 2022 issued by the WHO (https://population.un.org/wpp/), we employed the Autoregressive Integrated Moving Average Model to estimate the projected prevalence of myopia among children and adolescents worldwide until 2050. We evaluated the potential for publication bias with the help of adjusted-comparison funnel plots and Egger's statistical test.[23] The aforementioned sequences of statistical analyses were conducted using R language (X64 version 4.2.1, R Foundation for Statistical Computing, Vienna, Austria, https://www.r-project.org/), STATA version 14.0 (StataCorp, College Station, TX, USA) and Jupyter Notebook (6.30) within the Anaconda.

RESULTS

Study characteristics

The initial search of our database resulted in a comprehensive collection of 45 470 records, comprising 38 869 English publications and 6601 Chinese publications. Subsequently, we eliminated 7106 duplicate records. Following a meticulous assessment of titles and abstracts, we excluded 35 451 studies, leaving us with 1123 English and 2037 Chinese studies that were deemed potentially eligible for further scrutiny through a thorough evaluation of their full texts. In total, 276 identified publications were finally included, while 311 were included in our analyses for some publications were split according to reported specific year stages or regions. The PRISMA flow chart is shown in online supplemental figure 1.

Out of the 311 epidemiological studies encompassing a collective sample size of 5 410 945 children or adolescents, wherein 1 969 090 cases of myopia were detected, 239 studies were conducted in Asia (4560.86×10^3 participants), 30 were conducted in Europe (34.00×10^3 participants), 16 were conducted in Africa (693.08×10^3 participants), 12 were conducted in Oceania (23.82×10^3 participants), 11 were conducted in North America (91.82×10^3 participants), and three were conducted in Latin America (7.37×10^3 participants). A total of 101 studies were conducted on children aged 5–12 years, while 24 studies focused on adolescents aged 13–19 years, resulting in a combined sample of 186 studies involving both children and adolescents. The prevailing criterion for defining myopia in the majority of these studies was the standardised SE of −0.50 D or lower. Individuals residing in East Asia (35.22%) or in urban areas (28.55%), female gender (33.57%), adolescents (47.00%), and high school students (45.71%) exhibit a higher proportion of myopia prevalence. Detailed information regarding the characteristics of all the included studies, as well as the key findings, can be found in figure 1 and online supplemental table 6.

Quality of the included studies

In general, the majority of the studies analysed in this research obtained a JBI quality score of 6 or higher, with the highest score being 9 (figure 1). Among the nine criteria used for the JBI quality assessment, the sample framework of 239 studies was deemed appropriate for addressing the target population, 214 studies had sufficient coverage of the identified sample, and 213 studies achieved an adequate response rate. The JBI quality of all included studies is further detailed in online supplemental table 7.

Moreover, the GRADE level of evidence pertaining to the primary outcome of the studies included in the analysis was assessed as being of 'very low' to 'low' quality, as determined by five criteria. The overall GRADE assessment of the included studies were classified as 'very low' quality, as indicated in figure 1 and online supplemental material D.

Trend and global prevalence of myopia

Figure 1 displays the global prevalence estimate of myopia, categorised by demographic variables. The estimated global prevalence estimate of myopia was found to be 30.47% (95% CI 27.98% to 32.96%). Notably, there has been a substantial increase in the global prevalence estimate of myopia during the preceding three decades (1990–2000 (24.32%, 95% CI 15.23% to 33.40%) vs 2001–2010 (25.29%, 95% CI 19.89% to 30.68%) vs 2011–2019 (29.66%, 95% CI 25.67% to 33.65%) vs 2020–2023 (35.81%, 95% CI 31.70% to 39.91%)). When considering the development groups, it was observed that developing or underdeveloped countries (31.89%, 95% CI 29.14% to 34.65%) exhibited a significantly higher prevalence estimate of myopia compared with developed countries (23.81%, 95% CI 18.33% to 29.30%). In terms of disparities across continents, Asia exhibited the highest estimated prevalence of myopia (35.22%, 95% CI 32.39% to 38.05%), while Latin America and the Caribbean demonstrated the lowest prevalence (3.75%, 95% CI 0.07% to 7.42%) among the six continents. The prevalence of

Demographic characteristics	Number of studies[a]	Cases/Total	Pool prevalence, % (95% CI)	Forest plot	I²	P-value: Heterogeneity	P-value: Subgroup Difference	Strengthen of evidence[g]
Global prevalence	311	1,969,090/5,410,945	30.47 (27.98 to 32.96)		99.9	0.100	-	Low (++)
Literature resource								
Chinese	88	291,667/641,375	42.87 (39.01 to 46.73)		99.9	**< 0.001**	**< 0.001**	Very low (+)
English	223	1,677,423/4,769,570	25.57 (22.70 to 28.45)		99.9			Low (++)
Gender								
Males	186	517,103/1,721,590	30.49 (27.33 to 33.66)		99.9	**< 0.001**	0.193	Low (++)
Females		532,396/1,535,871	33.57 (30.19 to 36.95)		99.9			Low (++)
School level								
Primary	101	185,122/1,171,426	25.72 (22.51 to 28.91)		99.9	**< 0.001**	**< 0.001**	Low (++)
Secondary	13	9,458/25,926	33.07 (19.38 to 46.76)		99.9			Low (++)
High	9	6,970/13,920	45.71 (25.56 to 65.86)		99.9			Very low (+)
Mixed[b1]	131	1,729,057/4,054,394	37.57 (33.77 to 41.36)		99.9			Low (++)
Age group (years)								
Children (5 - 12)	101	165,556/470,395	23.44 (20.12 to 26.76)		99.9	**< 0.001**	**< 0.001**	Low (++)
Adolescents (13 - 19)	24	22,285/43,498	47.00 (36.48 to 57.52)		99.9			Very low (+)
Mixed[b1]	186	1,781,249/4,897,052	32.12 (28.81 to 35.43)		99.9			Low (++)
Setting								
Rural	25	8,038/67,461	16.51 (10.71 to 22.31)		99.7	**< 0.001**	**< 0.05**	Very low (+)
Urban	36	42,791/142,997	28.55 (20.80 to 36.29)		99.9			Very low (+)
Mixed[b1]	58	618,734/1,396,406	29.85 (24.37 to 35.33)		99.9			Very low (+)
Sample size (n)								
< 1,000	90	12,190/46,238	24.30 (20.33 to 28.26)		99.5	**< 0.001**	**< 0.001**	Low (++)
1,000 - 3,000	104	60,239/195,667	29.28 (24.78 to 33.79)		99.9			Low (++)
> 3000	117	1,896,661/5,169,040	36.22 (32.16 to 40.28)		99.9			Low (++)
Publication year								
1990 - 2000	14	11,203/44,725	24.32 (15.23 to 33.40)		99.9	**< 0.001**	**< 0.05**	Very low (+)
2001 - 2010	70	61,612/189,866	25.29 (19.89 to 30.68)		99.9			Low (++)
2011 - 2019	124	255,268/1,337,639	29.66 (25.67 to 33.65)		99.9			Low (++)
2020 - 2023	103	1,641,007/3,838,715	35.81 (31.70 to 39.91)		99.9			Low (++)
Males to females ratio								
≥ 1	185	1,189,201/3,588,866	32.48 (29.32 to 35.64)		99.9	**< 0.001**	0.171	Low (++)
< 1	82	110,950/385,920	28.18 (23.01 to 33.34)		99.9			Very low (+)
Myopia definition								
SE ≤ -0.50	256	1,600,726/4,400,211	28.93 (26.29 to 31.58)		99.9	**< 0.001**	0.059	Low (++)
Others	55	368,364/1,010,734	37.62 (31.17 to 44.08)		99.9			Very low (+)
Development group[c]								
Developed countries	55	43,494/145,760	23.81 (18.33 to 29.30)		99.9	**< 0.001**	**< 0.05**	Very low (+)
Developing/Underdeveloped countries	256	1,925,596/5,265,185	31.89 (29.14 to 34.65)		99.9			Low (++)
UN region[d]								
Asia	239	1,917,858/4,560,861	35.22 (32.39 to 38.05)		99.9	**< 0.001**	**< 0.001**	Low (++)
Europe	30	7,498/34,002	22.60 (17.49 to 27.72)		99.9			Low (++)
North America	11	30,262/91,822	21.17 (11.49 to 30.85)		99.9			Very low (+)
Latin America and the Caribbean	3	438/7,369	3.75 (0.07 to 7.42)		99.9			Very low (+)
Africa	16	11,005/693,075	4.77 (3.10 to 6.43)		99.9			Very low (+)
Oceania	12	2,029/23,816	7.93 (3.82 to 12.04)		99.9			Very low (+)
China-based region								
West	45	60,950/144,157	37.78 (32.11 to 43.46)		99.9	**< 0.001**	**< 0.001**	Low (++)
East	69	947,191/2,125,261	46.32 (41.57 to 51.06)		99.4			Low (++)
Central	27	279,179/762,132	37.08 (28.94 to 45.22)		99.9			Very low (+)
Northeast	4	4,833/13,958	28.00 (0.00 to 56.01)		98.6			Very low (+)
Special Administrative Regions[e]	18	25,728/72,621	31.34 (26.16 to 36.51)		97.1			Very low (+)
Mixed[b2]	10	574,105/1,175,987	53.60 (46.45 to 60.76)		99.0			Very low (+)
Quality of included studies[f]								
≥ 6 scores	208	869,587/2,729,824	31.56 (28.39 to 34.74)		99.9	**< 0.001**	**< 0.05**	Low (++)
< 6 scores	68	565,687/1,620,529	25.72 (20.75 to 30.70)		99.9			Very low (+)

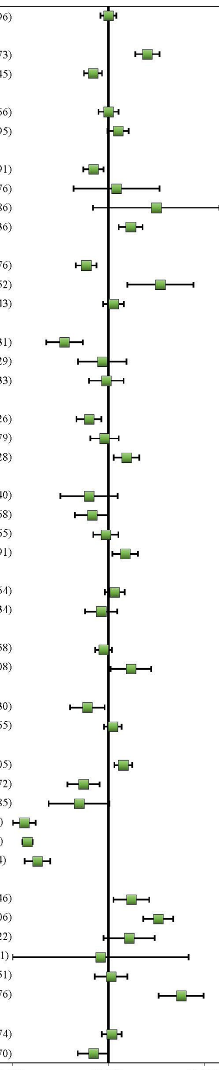

Figure 1 Global estimate prevalence of childhood myopia stratified by demographic variables. The vertical axis of the forest plot represents the global estimate prevalence of myopia (30.47%). P values presented in bold are statistically significant. [a] An article involving surveys of multiple regions or year stages will be split based on the specific year stages or regions, and the article was therefore split into two or more articles to be included in our meta-analysis. A total of 276 identified studies were included in the current meta-analysis, and 311 valid surveys were finally included in our analyses after some articles were split. Each of the 311 studies provided items of age, sample size, year of publication, and specific country. Not every subgroup item was available in each study, which was the reason that the sum of the number of studies under some items was not equal to the number of 311. [b1] 'Mixed' indicated the mixture of all categories under this item. [b2] 'Mixed' involved national area or multiple regions/provinces in China. [c] Developed regions comprise Europe, Northern America, Australia/New Zealand, and Japan; Developing/Underdeveloped regions comprise all regions of Africa, Asia (except Japan), Latin America, and the Caribbean plus Melanesia, Micronesia, and Polynesia. The designation 'Developed regions' and 'Developing/Underdeveloped regions' are intended for statistical purposes and do not express a judgment about the stage reached by a particular country or area in the development process. [d] Countries and areas are grouped geographically into six major areas designated as: Africa, Asia, Europe, Latin America and the Caribbean, Northern America, and Oceania. [e] Special administrative regions of China include Hong Kong, Macau, and Taiwan. Only Hong Kong and Taiwan were involved in this meta-analysis. [f] The JBI critical appraisal tool was utilised to evaluate all the included studies based on nine items, and the total score was 9. [g] Strength of evidence based on the GRADE Working Group grades of evidence. Comparisons were initially rated as low-quality evidence (two plus: ++) and were upgraded accordingly, based on upgrade elements including large effect (large: upgrade one level, +1; very large: upgrade two levels, +2), dose response (evidence of a gradient: upgrade one level, +1), or all plausible residual confounding (would reduce a demonstrated effect: upgrade one level, +1; would suggest a spurious effect if no effect was observed: upgrade two levels, +2). Each item was rated as no downgrade, downgrade one level (serious) or downgrade two levels (very serious). All comparisons were rated as four levels of evidence: (1) High certainty: we are very confident that the true effect lies close to that of the estimate of the effect. (2) Moderate certainty: we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different. (3) Low certainty: our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect. (4) Very low certainty: we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect. Reference available from Balshem *et al*.[18] GRADE, Grades of Recommendations Assessment, Development and Evaluation; JBI, Joanna Briggs Institute; UN, United Nations; SE, spherical equivalent.

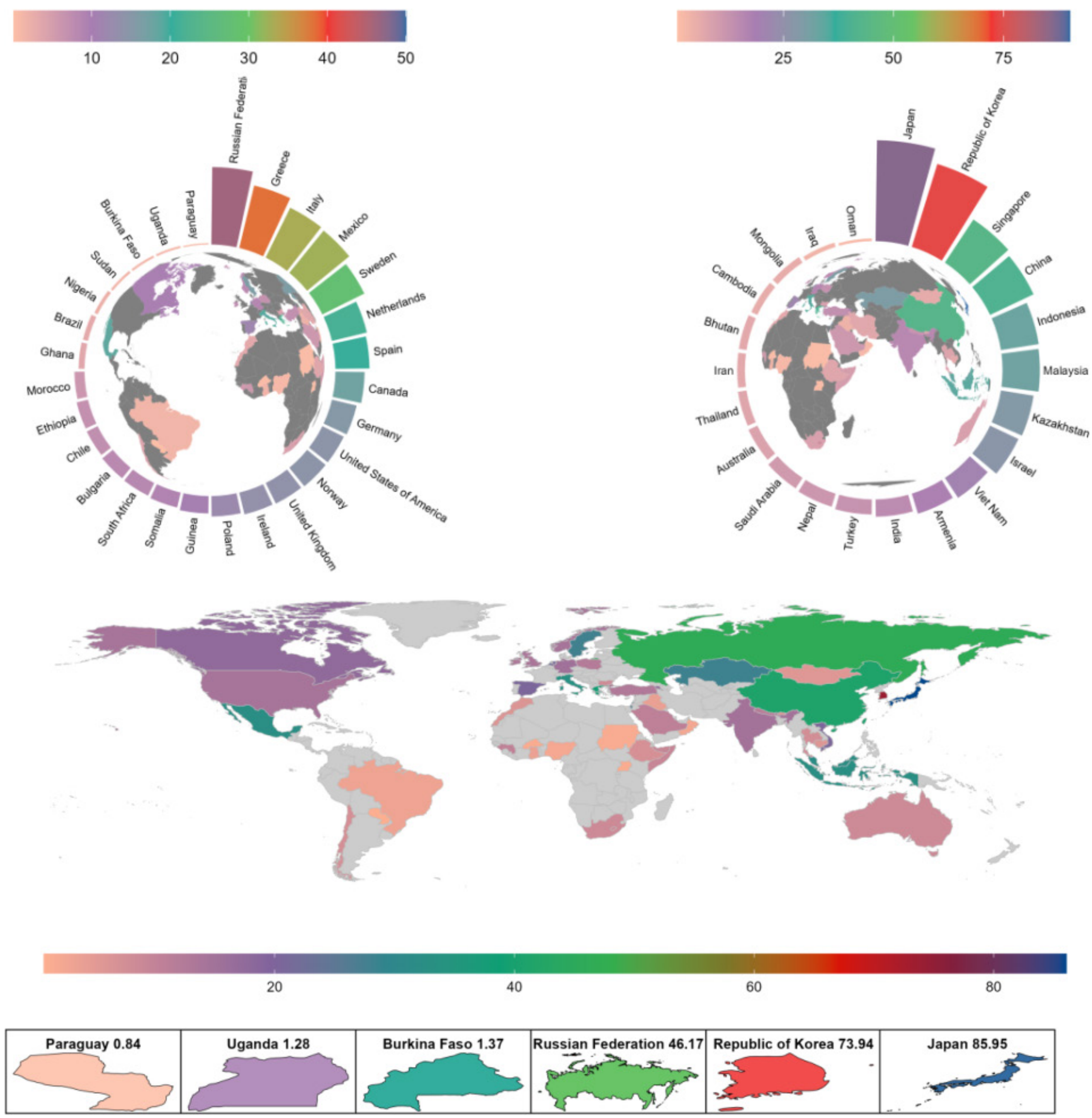

Figure 2 Global prevalence of myopia in children and adolescents (by countries), 1990-2023. A total of 50 countries were included in our study, with 1 969 090 myopia cases among 5 410 945 participants. The prevalence of myopia ranged from 0.84% to 85.95%. Among countries with available data, the myopia prevalence was highest in Japan and lowest in Paraguay.

myopia in the 50 countries included in our study is presented in figure 2, highlighting country-specific levels. Japan (85.95%, 95% CI 84.14% to 87.76%) had the highest estimated myopia prevalence, followed by the Republic of Korea (73.94%, 95% CI 55.64% to 92.25%) and the Russian Federation (46.17%, 95% CI 44.75% to 47.59%). Figure 3 depicts the top 13 countries with the highest prevalence among the 50 countries, with China ranking fifth.

Online supplemental tables 1–3 provide a comprehensive analysis of the global prevalence of myopia, considering survey years, gender, and continents. Notable disparities were observed in the following aspects. First, the prevalence of myopia among adolescents surpassed that of children, peaking at 53.92% (95% CI 31.27% to 76.58%) during the 2020–2023 period. However, the absolute growth rate of myopia prevalence in children from 1990 to 2023 was nearly twice that of adolescents. Second, the overall estimated prevalence of myopia was marginally higher in females (33.57%, 95% CI 30.19% to 36.95%) compared with males (30.49%, 95% CI 27.33% to 33.66%), with rates reaching 45.52% (95% CI 23.96% to 67.08%) among high school girls and 48.82% (95% CI 35.15% to 62.49%) among adolescent girls. Moreover, the incidence of myopia among Asian females (37.66%, 95% CI 34.04% to 41.27%) exhibited the utmost prevalence, surpassing that of Asian males (34.33%, 95% CI 30.92% to 37.74%), and subsequently followed by females (26.93%, 95% CI 14.71% to 39.15%) and males in North America (24.14%, 95% CI 14.35% to 33.94%). Furthermore, the occurrence of myopia in urban children and adolescents surpasses that

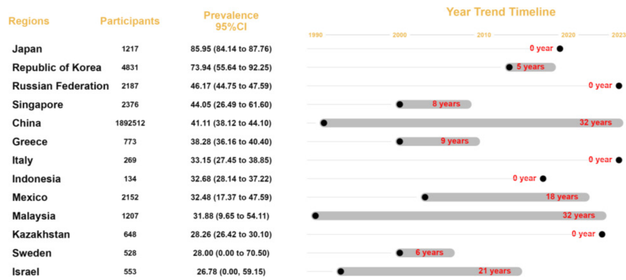

Figure 3 Temporal trends of prevalence rate of myopia in children and adolescents, across the high prevalence countries, from 1990 to 2023. The top 13 countries with the highest prevalence rates of myopia were Japan (85.95%), Republic of Korea (73.94%), Russian Federation (46.17%), Singapore (44.05%), China (41.11%), Greece (38.28%), Italy (33.15%), Indonesia (32.68%), Mexico (32.48%), Malaysia (31.88%), Kazakhstan (28.26%), Sweden (28.00%), and Israel (26.78%). Prevalence has increased more than threefold between 1990 and 2023. The grey part on the right is the available year trend line for the corresponding countries.

in rural regions, with urban females (32.01%, 95% CI 22.73% to 41.30%) displaying a higher prevalence of myopia in comparison to their male counterparts (29.40%, 95% CI 20.55% to 38.24%).

The online supplemental table 4 provides the estimated prevalence of myopia in different regions of China. From 1990 to 2023, the total estimated prevalence of myopia in China was 41.11% (95% CI 38.12% to 44.10%). Notably, the East region (46.32%, 95% CI 41.57% to 51.06%) exhibited the highest prevalence of myopia among children and adolescents. Figure 4 illustrates the estimated prevalence of myopia in various provinces of China. It is worth mentioning that the prevalence of myopia in Chinese girls (43.67%, 95% CI 39.98% to 47.36%) remained higher than that in males (39.70%, 95% CI 36.23% to 43.17%), particularly in Guangxi, where the prevalence among girls reached 72.92% (95% CI 70.32% to 75.53%), followed by girls in Jiangsu (67.39%, 95% CI 45.75% to 89.03%).

Forecast of global myopia prevalence

Table 1 illustrates the trajectory and projection of myopia prevalence among children and adolescents from 2030 to 2050. The estimated global prevalence of myopia is expected to escalate to 599771×10^3 cases in 2030, 664901×10^3 cases in 2040, and 740592×10^3 cases in 2050, indicating a consistent upward trend. By 2030, it is estimated that the global prevalence rate of myopia will reach 32.21%, which is projected to rise to 36.59% by 2040 and 39.80% by 2050. Notably, the prevalence of myopia is anticipated to be higher among females compared with males in 2030 (33.26% vs 31.22%), 2040 (39.82% vs 35.45%), and 2050 (41.95% vs 37.34%), respectively. The prevalence of myopia is expected to be significantly higher among adolescents aged 13–19 years compared with children aged 6–12 years, with projected rates of 42.81% versus 21.21% in 2030, 49.28% versus 24.18% in 2040, and 52.38% versus 27.47% in 2050. Furthermore, it is projected that by 2050, the prevalence of myopia in this age group could reach as high as 52.38%. Developing or underdeveloped countries are expected to have a higher prevalence of myopia compared with developed countries, with a projected rate of 40.77% by 2050. Specifically, Asia is anticipated to have the highest prevalence of myopia among all continents, with rates of 51.65% in 2030, 61.99% in 2040, and a projected rate of 68.78% in 2050.

Meta-regression and publication bias

The findings from the meta-regression analysis indicate that various factors, including school level, setting, sample size, and others, did not contribute to the observed heterogeneity (online supplementary table 5). However, it is possible that the region factor may be responsible for the heterogeneity. The comparison-adjusted funnel plot depicted a conspicuous indication of publication bias (online supplemental figure 2), whereas the findings from the Egger test indicate the absence of statistically significant publication bias in our study ($p<0.05$).

DISCUSSION

The current meta-analysis, encompassing 276 identified studies and a participant pool of 5411×10^3 individuals, provides the most recent and comprehensive estimates of global myopia prevalence, and indicates a persistent upward trend in the prevalence rates of myopia among children and adolescents worldwide, particularly among girls, low- and middle-income nations, and East Asian regions. Moreover, the global prevalence of myopia is projected to increase by 39.80% by 2050, resulting in an estimated 740592×10^3 children and adolescents being affected by myopia. These findings are an important step towards understanding the trends in myopia over time, particularly in populations experiencing rapid transitions in myopia and the significant surge during the special period of the COVID-19 pandemic.

Based on our trend analysis, it has been observed that there has been a significant rise in the occurrence of myopia among children and adolescents globally over the past 30 years, with

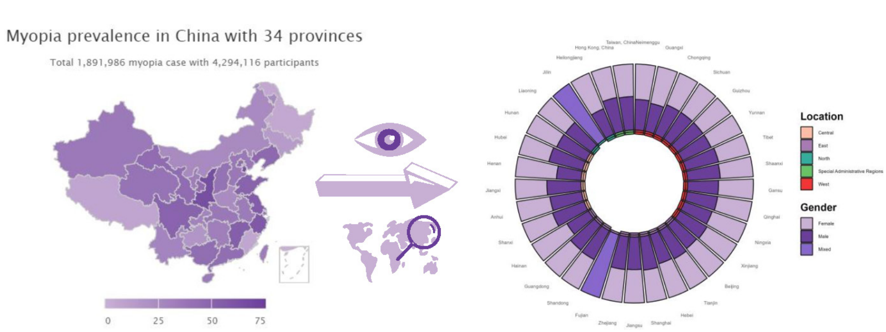

Figure 4 Pooled prevalence of myopia in children and adolescents in China, 1990–2023. The 34 provinces/autonomous regions/municipalities directly under the Central Government/Special Administrative Regions of China included in this analysis were divided into five regions: West (Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang), East (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan), Central (Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan), Northeast (Liaoning, Jilin, Heilongjiang), and the Special Administrative Regions (Hong Kong, Taiwan).

Table 1 Trend and forecast of myopia prevalence applied to United Nations defined population data for age between 6 and 19 years from 2030 to 2050

	Years								
	2030			2040			2050		
Items	Total estimate population*	Total myopia cases	Global prevalence, % (95% CI)	Total estimate population*	Total myopia cases	Global prevalence, % (95% CI)	Total estimate population*	Total myopia cases	Global prevalence, % (95% CI)
Global	1 861 856	599 771	32.21 (12.32 to 52.11)	1 817 253	664 909	36.59 (16.16 to 57.02)	1 860 565	740 592	39.80 (18.04 to 61.57)
Gender									
Males	957 498	298 939	31.22 (0.00 to 72.23)¶	928 713	319 955	35.45 (0.00 to 75.67)¶	948 186	357 882	37.34 (0.00 to 78.82)¶
Females	904 358	300 831	33.26 (24.53 to 42.34)	888 540	344 955	39.82 (13.76 to 65.60)	912 379	382 710	41.95 (3.28 to 79.68)
UN select age group (years)									
6–12	913 612	193 796	21.21 (17.90 to 24.52)	918 612	222 076	24.18 (20.74 to 27.61)	939 026	257 933	27.47 (23.85 to 31.09)
13–19	948 244	405 975	42.81 (33.75 to 51.05)	898 641	442 833	49.28 (41.46 to 58.09)	921 539	482 660	52.38 (43.84 to 60.82)
Development group§									
Developed countries	186 800	46 909	25.11 (21.41 to 30.03)	170 930	47 716	27.92 (2.69 to 53.14)	170 336	51 537	30.26 (4.99 to 56.92)
Developing/ Underdeveloped countries	1 675 056	552 862	33.01 (30.14 to 35.70)	1 646 323	617 193	37.49 (36.82 to 40.64)	1 690 229	689 055	40.77 (37.15 to 44.27)
UN region‡									
Asia	994 760	513 825	51.65 (48.88 to 54.35)	896 436	555 656	61.99 (61.77 to 67.50)	876 939	603 142	68.78 (65.07 to 71.19)
Europe	106 842	25 634	23.99 (3.07 to 44.91)	93 478	25 537	27.32 (5.27 to 49.37)	91 533	28 093	30.69 (7.41 to 53.97)
North America	61 655	15 847	25.70 (0.00 to 81.84)¶	60 562	18 682	30.85 (0.00 to 89.05)¶	62 139	21 803	35.09 (0.00 to 97.62)¶
Latin America and the Caribbean	139 877	9254	–§	129 196	11 157	–§	122 182	13 835	–§
Africa	548 976	34 217	6.23 (0.79 to 11.68)	627 731	52 584	8.38 (1.82 to 14.93)	697 714	72 176	10.34 (2.20 to 18.49)
Oceania	9746	995	10.21 (0.00 to 23.41)	9850	1293	13.13 (0.00 to 30.11)	10 058	1544	15.35 (0.00 to 35.24)

Total estimate population and numbers of total myopia cases are reported in thousands. The UN estimated the total population by gender, age group, region, and subregion annually for 2030–2050 (in thousands) based on the medium fertility variant. July 2022 by United Nations, made available under a Creative Commons licence CC BY 3.0 IGO: http://creativecommons.org/licenses/by/3.0/igo/. Available from: United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022, Online Edition.
*The total populations were estimated based on all age groups.
†Developed regions comprise Europe, Northern America, Australia/New Zealand, and Japan; Developing/Underdeveloped regions comprise all regions of Africa, Asia (except Japan), Latin America, and the Caribbean plus Melanesia, Micronesia, and Polynesia. The designation 'Developed regions' and 'Developing/Underdeveloped regions' are intended for statistical purposes and do not express a judgement about the stage reached by a particular country or area in the development process.
‡Countries and areas are grouped geographically into six major areas designated as: Africa, Asia, Europe, Latin America and the Caribbean, Northern America, and Oceania.
§Latin America and the Caribbean lacked sufficient data to derive predicted myopia prevalence, whose sample size of myopia was derived from the sum subtracted from the other continents.
¶Insufficient relevant data leads to a negative value in the forecast interval, which is recorded as 0.
UN, United Nations.

the prevalence increasing from 24.32% to 35.81%. This increase has been particularly notable after the onset of the COVID-19 pandemic. Previous studies have relied on data before 2015 to assess the myopic prevalence across the all age-group population and indicated a global prevalence of myopia in 2020 at 33.9%.[11] However, it is important to consider other factors that may have influenced myopia prevalence but have not been accounted for in their study, such as the impact of the COVID-19 pandemic. Emerging evidence suggests a potential association between the pandemic and accelerated vision deterioration among young adults.[6] In relation to regional disparities, our observations indicate a significantly elevated prevalence of myopia in Asia, where reported rates range from 22.27% to 39.43%. The prevalence is approximately seven times higher than that observed in Africa. However, certain ethnic groups in Asia, such as those from East or South Asia, exhibit a notable surge in myopia prevalence during the early stages of life, followed by a subsequent stabilisation, indicating a potential plateauing effect and attainment of saturated levels.[24] It appears that populations, specifically East and South Asians, who have undergone swift economic transitions, have also experienced the most accelerated myopic transitions. The elevated incidence of myopia observed in the Asian population, particularly among younger children, as compared with other regions, could potentially account for the observed ethnic disparity. Moreover, a correlation between the duration of education and the occurrence of myopia has been observed, suggesting that the early implementation of formal education in certain East Asian nations could potentially serve as a contributing element.[25 26] For example, in Singapore[27] children as young as 3 years old, and as young as 2 years old in Hong Kong,[24] actively engage in supplementary educational programmes before commencing formal schooling. It is plausible that the earlier introduction to formal educational practices at a young age may influence the incidence of myopia during childhood. Conversely, African populations exhibit a lower prevalence of myopia, likely attributed to lower literacy rates and delayed initiation of formal education, typically occurring between the ages of 6 to 8 years for most children.[28 29]

Our study demonstrated a notable disparity in the occurrence of myopia between genders, with a substantial increase observed during adolescence, leading to a three times higher likelihood of males developing myopia compared with females. These gender differences appear to manifest around the age of 9 years and intensify as individuals grow older, making it improbable to detect gender disparities through comparisons at younger ages.[10] The observed disparities beyond the initial 10 years of life have been attributed to a greater emphasis on educational pursuits and activities involving close proximity in girls, compared with boys.[30] This divergence based on gender may persist into adulthood.[31] The growth and development of girls occur earlier than that of boys, including the development of puberty, which is also more rapid in girls. Additionally, girls in elementary and middle school tend to have shorter durations of outdoor activities compared with boys, resulting in longer periods of close-range activities with their eyes. Consequently, these factors collectively contribute to a higher prevalence of myopia among girls in comparison to boys, and girls tend to experience the onset of myopia at an earlier age.[32 33] Similarly, the prevalence of myopia among senior students is higher compared with that of junior high school and primary school students. This difference may be attributed to the fact that some students have not yet developed good eye habits.[32] With the increase in enrolment pressure, students are experiencing a rise in learning pressure and burden. As a result, they are spending more time focusing on close-range activities with their eyes, which reduces the time they spend on outdoor sports and exercise.[34] This constant strain on the ciliary muscles often leads to eye fatigue and myopia.

According to our projections, there is an anticipated 9% rise in the overall prevalence of myopia between 2023 and 2050, which will lead to a substantial burden of ocular disease, affecting more than $740\,592\times10^3$ children and adolescents. These findings hold great importance considering the escalating prevalence of childhood and adolescent myopia, particularly in developing and underdeveloped regions worldwide. Consequently, there is an imperative requirement to establish evidence-based approaches that are both innovative and comprehensive in order to prevent the occurrence of myopia at both the individual and public health levels. It is important for young individuals to develop the habit of regularly practising eye-protective measures. Students should also increase the amount of time spent on physical activity and decrease the time spent on non-active activities such as watching television and videos, playing computer games, and surfing the internet. In view of the rising prevalence of myopia in school-age children, government health administration departments should implement policies aimed at reducing the burden of excessive homework and off-campus tutoring on young students. Additionally, it is recommended to provide health education on myopia prevention, conduct regular physical examinations, and promote early detection and treatment.

Strengths and limitations

This is the first article, to our knowledge, that summarises the latest and most comprehensive evidence on the global prevalence estimate for myopia. Previous studies with imperfect study methods, particularly those studies with insufficient retrievals, would result in a loss of statistical power and hinder the ability to quantify differences in study design. By employing an extensive search strategy, our findings have incorporated a substantial number of relevant publications that measure the prevalence of myopia globally. This comprehensive approach enables the synthesis of information on the overall prevalence, trends, forecasts, and specific subgroups of myopia among children and adolescents. These findings also significantly contribute to our understanding of the global prevalence of myopia, particularly during the COVID-19 pandemic. It emphasises the need for urgent attention to this public health issue in guiding policy decisions.

Our meta-analysis also has limitations that warrant acknowledgement. The major limitation of the included studies is the disparity in the designs and methods utilised. First, the quality of included epidemiologic studies varied significantly within and among the reviews, ranging from high to low risk of bias. When utilising GRADE to evaluate quality across the included studies, we deemed it necessary to prioritise the inevitable high level of performance bias present in all the observational studies. Despite our efforts to include a large amount of evidence to minimise bias, it was inevitable that selection or measurement bias could still occur. Second, there is a possibility of bias in certain continental results due to uneven distribution of data among countries within a continent. As a result, our reported findings might be biased because they were mainly influenced by data from a limited number of countries. Thirdly, studies included in the analysis varied in terms of criteria and procedures for myopia assessment, and articles that defined myopia as standardised SE of −0.50 D or less or employed other similar or equivalent approaches were included. For example, some studies employed automatic optometry,[35 36] while others utilised different measurements such as the standard logarithmic visual acuity chart (the 5-mark record recommended by the standardisation administration of China).[37] Despite these known limitations, given the large sample size included, our estimates of the prevalence of myopia are considered to be close to the precise numbers.

CONCLUSION

This comprehensive meta-analysis demonstrates a persistent upward trend in the global prevalence of myopia, currently estimated at 30.47%. Moreover, it predicts that by the year 2050, approximately 740 million children and adolescents worldwide will be affected by this condition. This finding highlights the significant variation in myopia prevalence across different regions, emphasising the influence of gender, ethnic and cultural factors. It is crucial to recognise that myopia may become a global health burden in the future. To address this growing epidemic, further research with a more region-specific approach is required to develop effective strategies at the local level.

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