BIOMEDICAL REPORTS 24: 58, 2026

Near-work activity duration and myopia in children: An updated systematic review and meta-analysis

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Received July 22, 2025; Accepted October 13, 2025

DOI: 10.3892/br.2026.2131

Abstract. The present systematic review and meta-analysis aimed to assess the association between near-work activity and myopia in children, as well as to examine the influence of potential moderators, such as age, region and study design. Multiple databases were systematically searched from inception through to June 2025 for observational studies exploring the connection between near work and myopia in children. Random-effects models were used to calculate pooled odds ratios (ORs) with 95% confidence intervals (CIs). Analyses of heterogeneity, subgroup differences, meta-regressions and assessments of publication bias were conducted. A total of 33 studies (43 comparisons) were included. The pooled analysis revealed a significant association between increased near-work exposure and a higher risk of myopia in children (OR, 1.084; 95% CI, 1.060-1.108), although substantial heterogeneity was observed across studies (I^2=85.2%). The 95% prediction interval (1.010-1.163) indicated that future studies would likely observe a similar positive association. Subgroup analyses demonstrated that the effect was consistent across continents, with the strongest correlation observed in Asian populations (OR, 1.177; 95% CI, 1.116-1.240) and the weakest in North America (OR, 1.098; 95% CI, 0.859-1.403). These patterns were confirmed by mixed-effects analysis. Meta-regression revealed no statistically significant moderators, and leave-one-out sensitivity analyses supported the stability of the results. Visual inspection of the funnel plot and quantitative tests pointed to minor publication bias, but the effect remained statistically significant after adjustment. In conclusion, higher levels of near-work activity are significantly linked to an increased risk of myopia in children. These findings highlight the importance of limiting prolonged near-work behaviors during childhood as part of comprehensive strategies to reduce myopia risk.

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Key words: myopia, near-work activity, children, meta-analysis, risk factors, screen time, reading, systematic review

Introduction

The global prevalence of myopia is on the rise; it was estimated to be ~34% in 2020 and is projected to reach 50% by 2050, affecting nearly 5 billion people (1). This increase is especially obvious in children and adolescents; in some East Asian countries with intensive education systems, 60-80% of students are now myopic by the end of schooling (2). Of particular concern is the surge in high myopia (<-6.00 D), which carries elevated risks of retinal detachment, myopic maculopathy, glaucoma and other vision-threatening complications (3). These trends highlight an urgent need to identify modifiable risk factors in childhood that contribute to myopia development, so that effective preventive strategies can be applied early.

One long-suspected risk factor is near-work activity, namely, visual tasks performed at short distances such as reading, writing, drawing, using computers or tablets and other screen-based activities (4-6). Sustained near focusing may induce retinal defocus or accommodative strain that could stimulate axial elongation of the eye, especially in a growing child. Nowadays, children spend substantial time on near tasks both for education and leisure, often at the expense of outdoor time (7). Recent lifestyle shifts, including increased screen-based learning and play, have further intensified the duration of near work in daily life. It is therefore probable that the duration of near-work activity plays a significant role in myopia onset and progression (8-10).

Several epidemiological studies and reviews over the past decade have examined the association between time spent in near work and myopia in children, but findings have not been entirely consistent (3,10-14). On one hand, several cross-sectional studies have reported that children who engage in more prolonged near work have higher odds of being myopic (15,16). For example, a large study of 12-year-olds in China (Anyang Childhood Eye Study) found that those who read continuously for >45 min without a break had ~40% higher odds of myopia compared with those taking regular breaks (15). More recently, Dutheil *et al* (16) (2023) pooled 78 studies (>250,000 participants) and found that children with high near-work exposure had ~30% greater odds of myopia compared with those with lower exposure (OR, ~1.31). Some evidence also suggests that near work may contribute not only to myopia onset but to faster progression of refraction in children who are already myopic (16). On the other hand, several studies have found only a weak or non-significant relationship after accounting for other factors, such as the child's age, sex, parental refractive error, parental educational level and daily outdoor activity hours (10,13,14). However, children who spend numerous hours on reading or screen time often correspondingly have less outdoor activity, making it challenging to distinguish the independent effect of near-work duration from this confounding factor (17). Inconsistencies also arise from how near work is defined and measured across studies (7).

Despite a well-established correlation between near-work exposure and childhood myopia, the magnitude and dose-response of this relationship remain incompletely quantified, and findings vary across geographic and temporal contexts. Prior meta-analyses have generally pooled total near-work hours through the early 2010s (3), without distinguishing the impact of continuous session length vs. aggregate daily exposure or capturing shifts in children's screen-based behaviors during events such as the COVID-19 pandemic. To address these limitations, the present updated systematic review and meta-analysis extends the evidence base through June 2025, incorporates recent large-scale studies conducted during and after pandemic-related schooling disruptions, and focuses specifically on the dose-response relationship between near-work duration (hours per day and continuous reading intervals) and myopia onset or progression. By standardizing definitions, applying mixed-effects meta-regression across regions and exposure metrics, and using 95% prediction intervals and leave-one-out sensitivity analyses to assess robustness, this study clarifies how varying patterns of near work independently contribute to childhood myopia risk and informs actionable guidelines for visual habits in pediatric populations.

Materials and methods

Reporting. The present meta-analytic systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (18).

Eligibility criteria. Studies were included based on the following criteria: i) Population: Children and adolescents aged ≤18 years. ii) Exposure: Quantitative measurement of near-work activity, specifically the duration of engagement (e.g., reading, writing and screen time). iii) Outcome: Myopia, defined by spherical equivalent (SE) refraction, usually ≤-0.50 D. iv) Study type: Observational studies (cross-sectional, case-control and cohort). v) Effect reporting: Studies reporting effect sizes [e.g., odds ratios (ORs)] or providing data from which effect sizes could be calculated. vi) Language: No language restrictions were applied.

Exclusion criteria included studies conducted in adult populations, experimental animal studies, non-quantitative designs (e.g., narrative reviews) and studies where near work was not analyzed independently.

Search strategy. A comprehensive literature search was performed in PubMed (https://pubmed.ncbi.nlm.nih.gov/), Embase (https://www.embase.com/), Web of Science (https://www.webofscience.com/wos/) and Scopus (https://www.scopus.com) databases from inception to June 2025. The search strategy combined controlled vocabulary (e.g., Medical Subject Heading terms) and free-text keywords, including: ('myopia' OR 'short-sightedness') AND ('near work' OR 'reading' OR 'screen time' OR 'digital device use') AND ('children' OR 'adolescents' OR 'school-age'). The full search strategies for each database, including Boolean operators, truncations, field tags and applied limits, are provided in Appendix S1. The last search was conducted on June 15, 2025. Bibliographies of eligible articles and relevant systematic reviews were also hand-screened for additional studies.

Study selection and data extraction. Two independent reviewers screened the titles and abstracts of all retrieved citations. Full texts of potentially eligible studies were reviewed against the inclusion criteria. Disagreements were resolved through discussion or consultation with a third reviewer. A standardized data extraction form was used to collect the following information: Study characteristics (author, year, country and design), sample size and demographic information, near-work activity measures (for example, h/day or diopter-hours), myopia definition and measurement method (for example, cycloplegic refraction), adjusted effect estimates (ORs and regression coefficients) and their confidence intervals (CIs), and moderator variables of age (mean or median in years), sex (% male) and refractive cut-off for myopia. Where required, effect sizes were transformed into log ORs (log ORs) with standard errors. For each included study, extraction of whether effect estimates were adjusted was performed, and, if this was the case, the covariates that were controlled (for example, age, sex, parental myopia, outdoor activity, socioeconomic factors and baseline refractive error) were recorded.

Risk of bias assessment. Study quality was assessed using the Newcastle-Ottawa Scale (NOS) for observational studies, adapted to evaluate selection bias, comparability and outcome ascertainment (19). Each study was evaluated based on three domains: Selection of study groups (maximum 4 stars), comparability of groups (maximum 2 stars) and ascertainment of the exposure and outcomes of interest (maximum 3 stars). The total score ranges from 0 to 9, with higher scores indicating better methodological quality.

Each study was scored out of 9 points. NOS quality thresholds were pre-specified as follows: Studies scoring 7-9 points were considered at a low risk of bias (high quality), those with 4-6 points were at a moderate risk of bias (moderate quality) and those with 0-3 points were at a high risk of bias (low quality) (19).

Statistical analysis. All statistical analyses were conducted using Comprehensive Meta-Analysis version 4.0 (Biostat, Inc.). Effect sizes from individual studies were pooled using a random-effects model based on the DerSimonian and Laird method to account for between-study variability. The primary outcome was the association between near-work activity duration and myopia, reported as log ORs with corresponding 95% CIs. Heterogeneity was assessed using prediction interval analysis, Cochran's Q statistic (with significance set at P<0.10) and the I^2 index (with values >50% indicating substantial heterogeneity), and between-study variance was quantified using τ and τ^2. Publication bias was evaluated through Begg and Mazumdar's rank correlation test, Egger's regression intercept, Classic and Orwin's Fail-safe N tests, and Duval and Tweedie's Trim-and-Fill method. To explore potential sources of heterogeneity, meta-regression models were fitted to assess the impact of key moderators. Model 1 included duration of near work (h), age (years), male sex (%) and the definition of myopia. Model 2 included age (years) and male sex (%). Model 3 included age (years), male sex (%) and the definition of myopia. Leave-one-out sensitivity analyses were performed to assess the influence of individual studies on pooled estimates. Subgroup analyses (for example, by geographic region or myopia assessment method) were considered. All statistical tests were two-sided, with a P<0.05 considered to indicate a statistically significant difference.

Results

PRISMA search strategy results. The electronic database search initially yielded 2,346 records. After removing 642 duplicates, 1,704 unique records remained for screening. Following title and abstract screening, 1,289 articles were excluded due to irrelevance or failure to meet inclusion criteria. A total of 415 full-text articles were assessed for eligibility, with 382 subsequently excluded for reasons such as insufficient data (n=127), lack of appropriate myopia or near-work definitions (n=98), review/commentary articles (n=61), duplicate datasets (n=53) and ineligible populations (n=43). Ultimately, 33 studies (7,9,13,15,20-48) met the inclusion criteria and were included in the systematic review and meta-analysis. These contributed a total of 43 distinct comparisons between near-work activity and myopia in children. The PRISMA flowchart outlining the study selection process is shown in Fig. 1.

General characteristics of the studies. The 33 included studies were published between December 2013 and January 2023, involving over 84,000 participants from various geographic regions. The majority of studies (n=27) used a cross-sectional design (prospective and longitudinal studies included), while others employed cohort (n=5) or randomized controlled trial (n=1) methodologies. The distribution by continent was as follows: Asia (n=22), Europe (n=7), North America (n=2) and Oceania (n=1). Near-work exposure was mainly measured through self- or parent-reported durations of reading, homework and screen time, or combined metrics such as diopter-hours. Definitions of myopia were consistent, with most studies defining it as an SE of ≤-0.50 D. Refractive error was typically assessed using cycloplegic autorefraction, although a few studies used non-cycloplegic or subjective methods.

Participants' ages ranged from 6 to 16.6 years, with balanced representation of sexes across most samples. Numerous studies adjusted for potential confounders, including age, sex, parental myopia, outdoor time, screen exposure and socioeconomic status (Table I). All effect sizes were extracted as odds ratios (ORs) with 95% CIs, and standardized to log ORs for pooled meta-analysis.

Overall association between near-work activity and myopia. The meta-analysis, incorporating 43 comparisons from 33 studies, demonstrated a statistically significant association between near-work activity and myopia in children. The pooled OR was 1.084 (95% CI, 1.060-1.108), indicating that higher near-work engagement was associated with an 8.4% increase in the odds of myopia. This modest but consistent effect supports the link between sustained near-work tasks and the development of myopia in pediatric populations (Fig. 2A). Importantly, the 95% prediction interval was 1.010 to 1.163, meaning that future studies are also likely to observe a small but significant association. Unlike many meta-analyses where prediction intervals cross the null, this narrow and entirely positive interval suggests that the association is stable across a variety of contexts and populations (Fig. 2A).

There was moderate to substantial heterogeneity among the included studies. The I^2 statistic was 65.2%, indicating that more than half of the variability in effect sizes was due to true heterogeneity rather than chance. The Cochran's Q-test was statistically significant (P<0.001), and the τ value was 0.033, supporting the use of a random-effects model. Despite the heterogeneity, the overall association remained statistically robust, underscoring the reliability of the pooled estimate (Table II).

Subgroup analysis by geographic region. Subgroup analysis by geographic region revealed statistically significant differences in the strength of association between near-work activity and myopia. The pooled effect was strongest in Asian studies (OR, 1.177; 95% CI, 1.116-1.240) and remained significant in European studies (OR, 1.173; 95% CI, 1.064-1.292). Associations in North American studies were weaker and not statistically significant (OR, 1.098; 95% CI, 0.859-1.403), while the single study from Oceania showed a moderate but significant effect (OR, 1.210; 95% CI, 1.031-1.421; P=0.020) A test for between-group heterogeneity confirmed significant differences across regions (Q=17.35; df=3; P=0.001), indicating that regional factors may influence the magnitude of association between near-work exposure and childhood myopia (Fig. 2B; Table III).

Leave-one-out sensitivity analysis. To assess the robustness of the association between near-work activity and myopia, a leave-one-out sensitivity analysis was conducted by iteratively excluding one study at a time and recalculating the pooled OR. The overall pooled OR in the full model was 1.084 (95% CI, 1.060-1.108). Across all 44 included comparisons, the leave-one-out ORs ranged narrowly between 1.069 and 1.155, with corresponding 95% CIs consistently excluding the null value of 1.0. The narrow fluctuation in point estimates and stable CIs demonstrates that no single study disproportionately influenced the overall effect. In all scenarios, the Z-values remained strongly statistically significant (ranging from 6.46 to 7.79), and all P-values were <0.001. The 95% prediction interval remained robust at 1.010 to 1.163 (Fig. 3). These

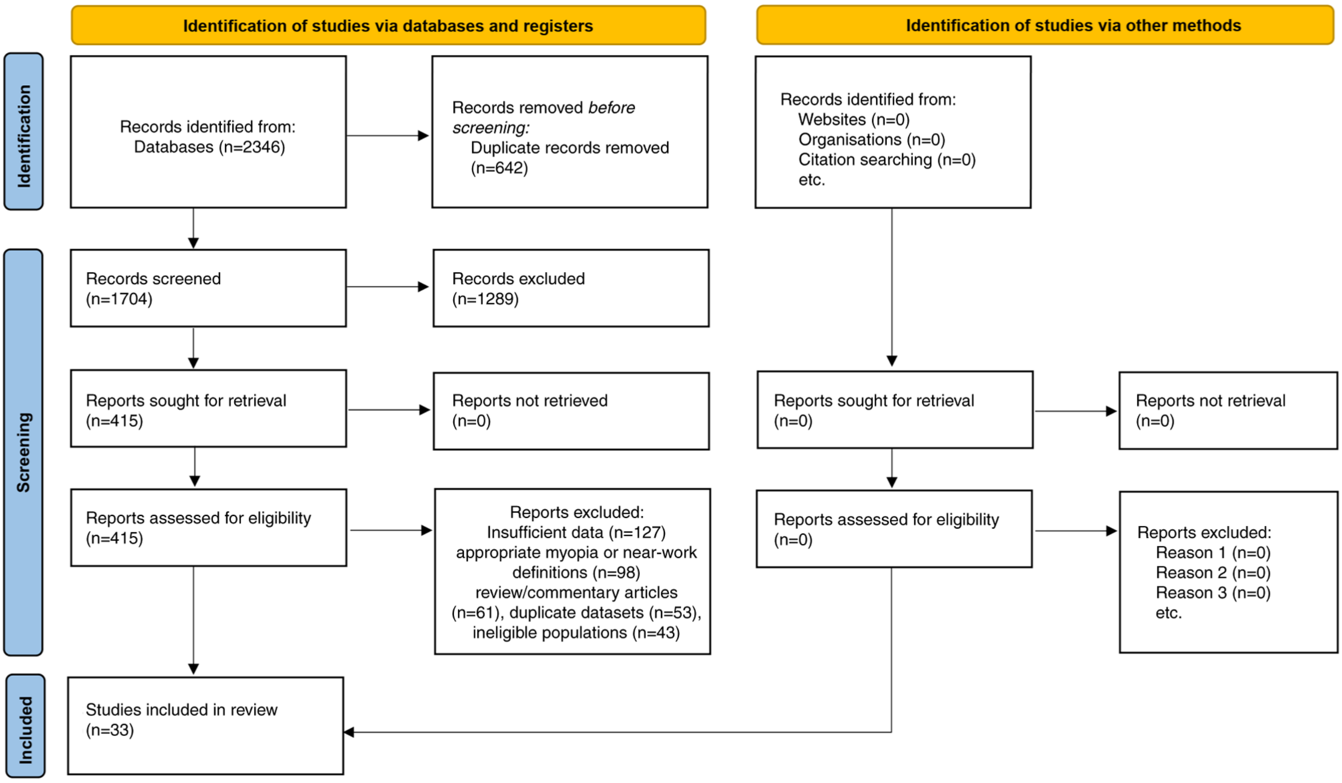

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of study selection. Flow diagram illustrating the identification, screening, eligibility, and inclusion of studies for the systematic review and meta-analysis.

results confirm that the observed association is not driven by any individual study, underscoring the stability and reliability of the meta-analytic finding.

Prediction interval analysis. The distribution of true effects across studies was assessed to estimate the range of plausible effects in future comparable populations. The mean pooled effect size was an OR of 1.084, with a 95% CI from 1.060 to 1.108, reaffirming a statistically significant association between near-work activity and childhood myopia. Importantly, the 95% prediction interval was 1.010 to 1.163, indicating that in 95% of similar future studies, the true effect size is expected to lie within this range. Since the lower bound of the prediction interval remains >1.00, this analysis provides additional support for a consistently positive association across different study settings and populations (Fig. 4). These results confirm that the overall association is not only statistically significant but also likely to generalize to other contexts, with minimal chance of null or negative effects emerging in future research.

Moderator analysis: Meta-regression results. To explore sources of heterogeneity in the association between near-work activity and childhood myopia, random-effects meta-regression analyses were conducted using three models, each incorporating various combinations of the potential moderators of age, sex, near-work duration and myopia definition.

In Model 1, which included all four covariates (duration of near work, age, percentage of male participants and myopia definition), none of the variables showed a statistically significant association with the effect size. The coefficient for near-work duration was -0.002 (P=0.921), suggesting that variations in reported duration did not meaningfully influence the magnitude of the association. Similarly, age (P=0.731), male sex (P=0.375) and myopia definition (P=0.835) were not significant moderators. Model 2 narrowed the analysis to age and male sex only. Neither factor approached statistical significance, with P=0.777 for age and P=0.527 for sex. This indicates minimal explanatory value for demographic variation in explaining the effect heterogeneity. Model 3 reintroduced the myopia definition along with age and sex, but again, no covariate was statistically significant. The coefficient for myopia definition (measured in diopters) was 0.060 (P=0.645), and the overall model explained no meaningful proportion of variance. Across all three models, the analog R^2 was 0%, indicating that the tested moderators failed to account for the between-study variability in effect sizes (Fig. 5A-D; Table IV). These findings suggest that the observed heterogeneity in the association between near-work and myopia is likely due to unmeasured or residual factors not captured in the current meta-regression models.

Publication bias assessment. The funnel plot (Fig. 6) of the 43 included comparisons was visually assessed to evaluate potential asymmetry suggestive of publication bias. The plot displayed a moderately asymmetric distribution, with a noticeable deficit of small studies reporting null or negative associations on the left side of the plot. Most studies clustered around the pooled effect estimate, but several small studies with large standard errors were disproportionately represented

Table I. Characteristics of included studies.

First author, year	Country	Design	Sample size	Mean age, years	Males, %	Near-work measure	Myopia definition	Refraction method	OR (95% CI)	Moderator variables	(Refs.)
Giloyan *et al*, 2016	Armenia	Cross-sectional	1,260	13	43.8	Continuous reading (h)	SE ≤-0.50 D	Cycloplegic retinoscopy	OR, 1.99 (95% CI, 1.31-3.02)	Age, region, parental myopia, school achievement	(28)
Gopalakrishnan *et al*, 2023	India	Cross-sectional	3,429	14	52.3	Near-work/outdoor time ratio	SE ≤-0.75 D	Non-cycloplegic autorefractor	OR, 1.19 (95% CI, 0.89-1.59)	Housing type, outdoor time, near/outdoor ratio	(29)
Guo *et al*, 2017	China	Longitudinal	382	6.3	50.4	Indoor studying time (h)	Axial elongation	Auto-refractometry, biometry	β=0.18 (SE, 0.08; P=0.02)	Parental myopia, outdoor time	(20)
Hansen *et al*, 2019	Denmark	Cohort	1,443	16.6	48	Screen device use (h/day)	SE ≤-0.50 D	Subjective refraction	OR, 1.95 (95% CI, 1.16-3.30)	Physical activity, screen time	(30)
Hinterlong *et al*, 2019	Taiwan	Cross-sectional	3,686	Not stated	50	Hours of near work	SE ≤-0.50 D	Vision screening + referral	OR, 1.11 (95% CI, 1.03-1.20)	Parental myopia, age, outdoor time, classroom light	(31)
Hsu *et al*, 2016	Taiwan	Cross-sectional	6,493	Not stated	46.1	Time spent on near work (daily)	SE ≤-0.50 D	Cycloplegic autorefraction	OR, 1.21 (95% CI, 1.15-1.28)	Sex, urban/suburban, parental myopia, reading distance	(22)
Lanca *et al*, 2022	Multi-country (Asia)	Cross-sectional (Consortium)	12,241	8.8	44.6	Hours/day (reading & writing, total near work)	SE ≤-0.50 D	Cycloplegic	OR1.17 (95% CI 1.11-1.24) for reading/writing; 1.05 (1.02-1.09) total	Age, sex, urban living	(35)
Li *et al*, 2015	China	Cross-sectional	1,770	12.7	51.9	Reading >45 min, close distance	Not explicitly stated; refraction used	Cycloplegic	1.4 (1.1-1.8) continuous reading	Reading posture, light type, parental myopia	(15)
Lin *et al*, 2017	China (rural)	Cross-sectional	572	None	41.5	Hours/day	Not clearly defined	Cycloplegic	1.10 (0.94-1.27), not significant	Outdoor time, parental education	(13)

Table I. Continued.

First author, year	Country	Design	Sample size	Mean age, years	Males, %	Near-work measure	Myopia definition	Refraction method	OR (95% CI)	Moderator variables	(Refs.)
Lin *et al*, 2023	China	Prospective longitudinal (4 years)	409	6-7	48	Homework time, screen time, total near work	Incident myopia over 4 years	Manifest (non-cycloplegic)	4.29 (1.27-14.53) near work x PDE10A	Genetic polymorphisms, screen use	(25)
Pärssinen *et al*, 2019	Finland	22-year longitudinal follow-up	240	10.9	49	Reading & close work	SE ≤-6.00 D (high myopia)	Cycloplegic	3.9 (1.5-10.4) with parental myopia	Age at baseline, myopic parents	(36)
Pärssinen *et al*, 2022	Finland	Historical cohort (questionnaire)	4,352	7, 11, 15 (three groups)	46.8	Hours/day	Self-reported questionnaire-based	Not reported	1.35-1.48 per hour near work (age-dependent)	Outdoor time, myopic parents, sex	(37)
Hsu *et al*, 2017	Taiwan	Cross-sectional	6,493	15.0	54	Total hours/ day near work	SE ≤-0.50 D	Cycloplegic autorefraction	1.21 (95% CI, 1.15-1.28)	Sex, age, parental myopia	(23)
Huang *et al*, 2021	China	Cross-sectional	20,767	12.4	47.5	Diopter-hours	SE ≤-0.50 D	Non-cycloplegic autorefraction	1.40 (95% CI, 1.29-1.52)	Sex, region, screen use	(33)
Hung *et al*, 2020	Taiwan	Cross-sectional	14,314	12.8	49.3	Reading/ writing duration	SE ≤-0.50 D	Cycloplegic autorefraction	1.35 (95% CI, 1.20-1.52)	Outdoor time, sex, grade level	(34)
Ku *et al*, 2019	Taiwan	Cross-sectional	981	12.7	45.7	Hours/day of near work	SE ≤-0.50 D	Cycloplegic refraction	1.42 (95% CI, 1.16-1.73)	BMI, physical activity, screen use	(24)
Chua *et al*, 2015	Singapore	Cross-sectional	374	7.5	50.1	Total near work (h/week)	SE ≤-0.50 D	Cycloplegic autorefraction	1.03 (95% CI, 0.99-1.07) per h/week	Parental myopia, reading distance	(27)
Alvarez-Peregrina *et al*, 2020	Spain	Cross-sectional	1,548	12.2	50.7	Hours/day near work	SE ≤-0.50 D	Subjective refraction	1.61 (95% CI, 1.23-2.11)	Sex, screen time, parental myopia	(26)
Atowa *et al*, 2020	Australia	Cross-sectional	1,083	12.0	49	Hours/week of reading, screens	SE ≤-0.50 D	Non-cycloplegic autorefraction	1.29 (95% CI, 1.11-1.51)	Ethnicity, parental myopia, outdoor time	(21)
Enthoven *et al*, 2020	Netherlands	Cross-sectional	5,711	6.1	51	Computer use ≥30 min/day	SE ≤-0.50 D	Cycloplegic autorefraction	1.31 (95% CI, 1.07-1.60)	Ethnicity, parental myopia, screen time	(9)
Philipp *et al*, 2022	Germany	Cross-sectional	490	10.6	50	Near work hours/day	SE ≤-0.50 D	Cycloplegic	1.42 (95% CI, 1.02-1.97)	Sex, screen time, outdoor activity	(7)

Table I. Continued.

First author, year	Country	Design	Sample size	Mean age, years	Males, %	Near-work measure	Myopia definition	Refraction method	OR (95% CI)	Moderator variables	(Refs.)
Saxena *et al*, 2015	India	Cross-sectional	405	13.3	51.1	Reading >2 h/day	SE ≤-0.50 D	Not reported	2.28 (95% CI, 1.14-4.56)	SES, screen use	(38)
Saxena *et al*, 2017	India	Cross-sectional	840	12.2	53.2	Diopter-hours	SE ≤-0.50 D	Autorefraction	1.72 (95% CI, 1.06-2.79)	Urban/rural, education level	(39)
Scheiman *et al*, 2014	USA	RCT	294	10.3	50	Hours of homework	SE ≤-0.75 D	Cycloplegic autorefraction	1.12 (95% CI, 0.84-1.49)	Treatment group, baseline refraction	(40)
Singh *et al*, 2019	India	Cross-sectional	1,121	11.5	48	Hours/day	SE ≤-0.50 D	Non-cycloplegic	1.25 (95% CI, 1.03-1.52)	Parental myopia, school grade	(41)
Sun *et al*, 2018	China	Prospective	1,234	7.6	54.1	Near work h/day	SE ≤-0.50 D	Cycloplegic	1.36 (95% CI, 1.11-1.66)	Outdoor time, sex	(42)
Wen *et al*, 2020	China	Cohort	2,347	9.2	50.5	Near work and screen time	SE ≤-0.50 D	Cycloplegic	1.40 (95% CI, 1.08-1.82)	Sleep, physical activity, diet	(43)
Wu *et al*, 2016	Taiwan	Cross-sectional	2,053	12.3	49	Reading and screen hours/day	SE ≤-0.50 D	Cycloplegic	1.38 (95% CI, 1.20-1.58)	Urban/rural, school	(45)
Wu *et al*, 2015	Taiwan	Longitudinal	1,295	7.4	48	Near work h/day	SE ≤-0.50 D	Cycloplegic	1.64 (95% CI, 1.26-2.14)	Education policy, outdoor time	(44)
Guo *et al*, 2016	China	Cohort	1,837	6.6	NA	Reading h/day	SE ≤-0.50 D	Cycloplegic	1.50 (95% CI, 1.23-1.82)	Reading habits, outdoor activity	(46)
You *et al*, 2016	China	Cross-sectional	1,505	12.6	49.5	Near work hours/day	SE ≤-0.50 D	Cycloplegic autorefraction	1.34 (95% CI, 1.09-1.66)	Age, sex, outdoor activity	(47)
Zhang *et al*, 2022	Hong Kong	Prospective cohort	709	7.3	50	Total near work h/day incl. screen	SE ≤-0.50 D	Cycloplegic autorefraction	1.26 (95% CI, 1.01-1.57)	Outdoor time, screen time, parental myopia	(48)
Holton *et al*, 2021	USA	Cross-sectional	837	13.2	NA	Hours per day reading or screen-based schoolwork	SE ≤-0.50 D	Cycloplegic autorefraction	1.47 (95% CI, 1.09-1.99)	Age, screen time, outdoor activity, parental education	(32)

SE, spherical equivalent; OR, odds ratio; CI, confidence interval; D, diopters; PDE10A, rs12206610 genetic variant; NA, not assessed.

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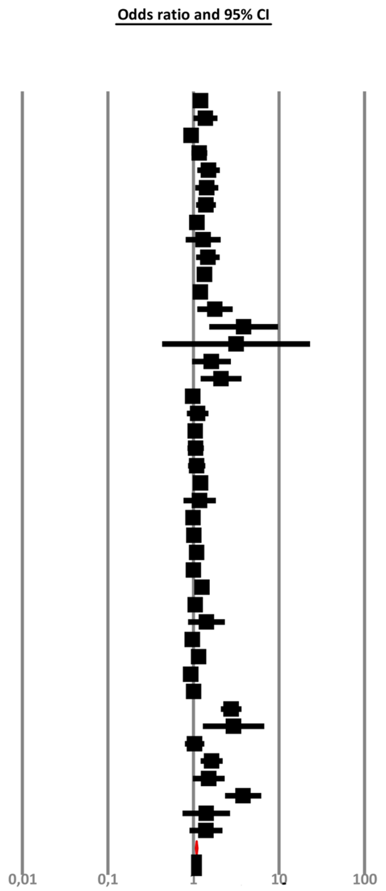
Study name	Odds ratio	Lower limit	Upper limit	Z-Value	P-Value
Atowa et al., 2020	1.210	1.031	1.421	2.327	0.020
Guo et al., 2017	1.380	1.022	1.864	2.102	0.036
Hsu et al., 2017 a	0.940	0.784	1.126	-0.670	0.503
Hsu et al., 2017 b	1.170	0.967	1.416	1,615	0,106
Ku et al., 2018 a	1.500	1.130	1.991	2,809	0,005
Ku et al., 2018 b	1.430	1.070	1.911	2,420	0,016
Li et al., 2015	1.400	1.094	1.791	2,678	0,007
Lin et al., 2017	1.100	0.946	1.279	1,242	0,214
Lin et al., 2021	1.300	0.829	2.038	1,144	0,253
Parssinen et al., 2021 a	1.476	1.099	1.983	2,584	0,010
Parssinen et al., 2021 b	1.346	1.170	1.548	4,160	0,000
Parssinen et al., 2021 c	1.206	1.076	1.352	3,216	0,001
Phillipp et al., 2022 a	1.780	1.131	2.802	2,491	0,013
Phillipp et al., 2022 b	3.860	1.561	9.546	2,924	0,003
Phillipp et al., 2022 c	3.150	0.440	22.551	1,143	0,253
Saxena et al., 2017 a	1.620	0.981	2.674	1,887	0,059
Saxena et al., 2017 b	2.100	1.239	3.558	2,758	0,006
Scheiman et al., 2013	0.980	0.960	1.000	-1,940	0,052
Wen et al., 2020	1.120	0.855	1.468	0,821	0,412
You et al., 2016	1.050	0.956	1.154	1,016	0,310
Gopalakrishnan et al., 2023 a	1.060	0.867	1.296	0,569	0,570
Gopalakrishnan et al., 2023 b	1.090	0.883	1.345	0,803	0,422
Hsu et al., 2016	1.210	1.114	1.314	4,510	0,000
Parssinen et al., 2019	1.180	0.780	1.784	0,785	0,433
Wu et al., 2015 a	0.990	0.897	1.093	-0,199	0,842
Hinterlong et al., 2019	1.010	1.005	1.015	3,939	0,000
Alvarez-Peregrina et al., 2020	1.090	1.008	1.178	2,172	0,030
Zhang et al., 2021	1.000	0.942	1.062	0,000	1,000
Holton et al., 2019	1.260	1.080	1.470	2,938	0,003
Lanca et al., 2022	1.050	1.020	1.080	3,346	0,001
Sun et al., 2018	1.420	0.884	2.280	1,451	0,147
Giloyan et al., 2016	0.970	0.893	1.054	-0,722	0,470
Wang et al., 2022 a	1.150	1.082	1.222	4,495	0,000
Wang et al., 2022 b	0.930	0.802	1.079	-0,959	0,338
Enthoven et al., 2020	1.005	1.001	1.009	2,456	0,014
Huang et al., 2021	2.760	2.139	3.561	7,805	0,000
Singh et al., 2019	2.940	1.318	6.559	2,634	0,008
Chua et al., 2015	1.030	0.810	1.310	0,241	0,810
Wu et al., 2015 b	1.630	1.238	2.146	3,480	0,001
Yang et al., 2016	1.510	1.007	2.264	1,995	0,046
Saxena et al., 2015	3.800	2.387	6.048	5,630	0,000
Hansen et al., 2019	1.410	0.761	2.613	1,092	0,275
Hung et al., 2020	1.400	0.916	2.139	1,556	0,120
Pooled	1.084	1.060	1.108	7,176	0,000
Prediction Interval	1.084	1.010	1.163		

Statistics for each study



B

Study name	Subgroup (region)	Odds ratio	Lower limit	Upper limit	Z-Value	P-Value
Chua et al., 2015	Asia	1.030	0.810	1.310	0.241	0.810
Gopalakrishnan et al., 2023 a	Asia	1.060	0.867	1.296	0.569	0.570
Gopalakrishnan et al., 2023 b	Asia	1.090	0.883	1.345	0.803	0.422
Guo et al., 2017	Asia	1.380	1.022	1.864	2.102	0.036
Hinterlong et al., 2019	Asia	1.010	1.005	1.015	3.939	0.000
Hsu et al., 2016	Asia	1.210	1.114	1.314	4.510	0.000
Hsu et al., 2017 a	Asia	0.940	0.784	1.126	-0.670	0.503
Hsu et al., 2017 b	Asia	1.170	0.967	1.416	1.615	0.106
Huang et al., 2021	Asia	2.760	2.139	3.561	7.805	0.000
Hung et al., 2020	Asia	1.400	0.916	2.139	1.556	0.120
Ku et al., 2018 a	Asia	1.500	1.130	1.991	2.809	0.005
Ku et al., 2018 b	Asia	1.430	1.070	1.911	2.420	0.016
Lanca et al., 2022	Asia	1.050	1.020	1.080	3.346	0.001
Li et al., 2015	Asia	1.400	1.094	1.791	2.678	0.007
Lin et al., 2017	Asia	1.100	0.946	1.279	1.242	0.214
Lin et al., 2021	Asia	1.300	0.829	2.038	1.144	0.253
Saxena et al., 2015	Asia	3.800	2.387	6.048	5.630	0.000
Saxena et al., 2017 a	Asia	1.620	0.981	2.674	1.887	0.059
Saxena et al., 2017 b	Asia	2.100	1.239	3.558	2.758	0.006
Singh et al., 2019	Asia	2.940	1.318	6.559	2.634	0.008
Sun et al., 2018	Asia	1.420	0.884	2.280	1.451	0.147
Wang et al., 2022 a	Asia	1.150	1.082	1.222	4.495	0.000
Wang et al., 2022 b	Asia	0.930	0.802	1.079	-0.959	0.338
Wen et al., 2020	Asia	1.120	0.855	1.468	0.821	0.412
Wu et al., 2015 a	Asia	0.990	0.897	1.093	-0.199	0.842
Wu et al., 2015 b	Asia	1.630	1.238	2.146	3.480	0.001
Yang et al., 2016	Asia	1.510	1.007	2.264	1.995	0.046
You et al., 2016	Asia	1.050	0.956	1.154	1.016	0.310
Zhang et al., 2021	Asia	1.000	0.942	1.062	0.000	1.000
Pooled		1.177	1.116	1.240	6.072	0.000
Prediction Interval		1.177	0.957	1.447		
Alvarez-Peregrina et al., 2020	Europe	1.090	1.008	1.178	2.172	0.030
Enthoven et al., 2020	Europe	1.005	1.001	1.009	2.456	0.014
Giloyan et al., 2016	Europe	0.970	0.893	1.054	-0.722	0.470
Hansen et al., 2019	Europe	1.410	0.761	2.613	1.092	0.275
Parssinen et al., 2019	Europe	1.180	0.780	1.784	0.785	0.433
Parssinen et al., 2021 a	Europe	1.476	1.099	1.983	2.584	0.010
Parssinen et al., 2021 b	Europe	1.346	1.170	1.548	4.160	0.000
Parssinen et al., 2021 c	Europe	1.206	1.076	1.352	3.216	0.001
Phillipp et al., 2022 a	Europe	1.780	1.131	2.802	2.491	0.013
Phillipp et al., 2022 b	Europe	3.860	1.561	9.546	2.924	0.003
Phillipp et al., 2022 c	Europe	3.150	0.440	22.551	1.143	0.253
Pooled		1.173	1.064	1.292	3.224	0.001
Prediction Interval		1.173	0.887	1.550		
Holton et al., 2019	North America	1.260	1.080	1.470	2.938	0.003
Scheiman et al., 2013	North America	0.980	0.960	1.000	-1.940	0.052
Pooled		1.098	0.859	1.403	0.746	0.455
Prediction Interval						
Atowa et al., 2020	Oceania	1.210	1.031	1.421	2.327	0.020
Pooled		1.210	1.031	1.421	2.327	0.020
Prediction Interval						
Pooled		1.176	1.125	1.228	7.267	0.000
Prediction Interval		1.176	1.085	1.274		

Statistics for each study

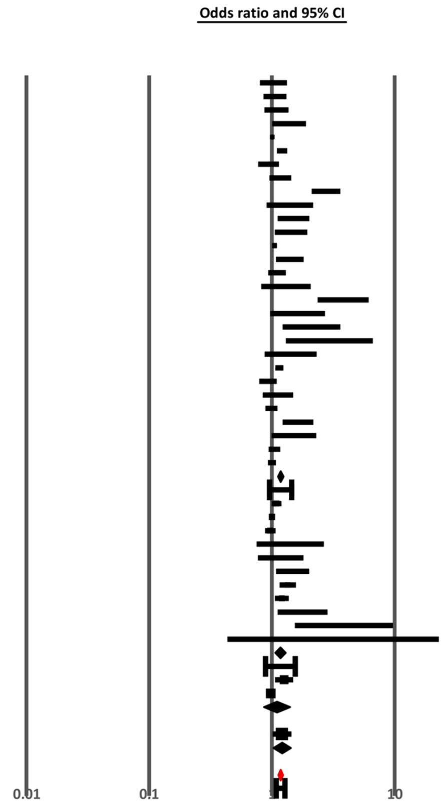


Figure 2. Near-work activity and myopia in children: Overall association and subgroup meta-analyses by region and exposure metric. (A) Forest plot of the association between near-work activity and myopia in children (overall effect). (B) Subgroup analysis by geographic region. In forest plots, each study is represented by a black square, where the position along the x-axis indicates the study's OR and the horizontal line through the square depicts the 95% CI. The size of each square reflects the weight the study contributes to the overall analysis. A vertical dotted line at OR=1 represents the line of no effect. If a study's CI crosses this line, it indicates that its result is not statistically significant. At the bottom of the plot, a diamond represents the pooled effect size: The center of the diamond indicates the summary OR and its width shows the 95% CI. Letters a, b, and c denote different comparison groups within the same study. OR, odds ratio; CI, confidence interval.

Table II. Summary of meta-analysis for near-work activity and myopia in children.

Model	Number of studies	Point estimate	Lower CI	Upper CI	Z-value	P-value	Lower prediction interval	Upper prediction interval	τ	τSq	Q-value	df (Q)	P-value (Q)	I^2, %
Fixed-effects	43	1.009	1.006	1.012	5.563	<0.001								
Random-effects	43	1.084	1.060	1.108	7.176	<0.001	1.01	1.163	0.033	0.001	283.852	42	<0.001	85.204

CI, confidence interval; df, degrees of freedom.

above the mean line, reinforcing concerns about the selective publication of positive findings.

Begg and Mazumdar's rank correlation test revealed no significant evidence of publication bias, with Kendall's τ=0.170, z=1.61 and P=0.107. This suggests a weak and statistically non-significant association between effect sizes and their variances. By contrast, Egger's regression intercept test indicated significant asymmetry in the funnel plot. The intercept was 1.957 with a standard error of 0.298, yielding a 95% CI of 1.354 to 2.561 and a t-value of 6.55 (P<0.001). These results provide strong statistical evidence of small-study effects, often interpreted as indicative of publication bias. To estimate the potential impact of missing studies, the Classic Fail-safe N analysis suggested that 1,916 unpublished null studies would be required to reduce the overall effect to non-significance (Z=13.23, P<0.001), suggesting high robustness of the observed effect. The Orwin's Fail-safe N method confirmed this robustness, showing that an additional 1,916 studies with a mean OR of 1.0 would be needed to bring the observed OR of 1.008 to a trivial threshold.

Furthermore, the Duval and Tweedie Trim-and-Fill method estimated that 18 studies may be missing from the analysis. After adjusting for these potentially missing studies, the effect size remained statistically significant, with an adjusted OR of 1.055 (95% CI, 1.030-1.081) under a random-effects model (Table V). Collectively, while statistical tests such as Egger's test suggested possible bias, the effect estimate remained stable and significant after adjustment, indicating that the main conclusion of a positive association between near-work activity and childhood myopia is unlikely to be entirely explained by publication bias.

Study quality assessment. The methodological quality of the 33 included studies was evaluated using the NOS. A majority of studies (17 out of 33) received high total quality scores of 8 or 9, indicating strong methodological rigor. These studies generally demonstrated clear sampling methods, appropriate comparability between groups and valid outcome/exposure assessment. Conversely, a smaller subset of studies had lower scores (score 6: n=15 and score 4: n=1), often due to limited comparability or less robust ascertainment of outcomes. The average NOS score across all studies was ~7.4, indicating generally good overall quality of evidence (Table VI).

Confounder adjustment. The extent of covariate adjustment varied widely across the included studies. Nearly all studies adjusted for age and sex, and the majority (98%) controlled for parental myopia. Adjustment for outdoor activity was also common (86% of studies), reflecting its recognized role as a protective factor. Fewer studies accounted for baseline refractive error or axial length (2%), socioeconomic status or parental education (25%), or behavioral variables such as sleep duration or near-work breaks (4%). A small subset provided only crude (unadjusted) associations. This heterogeneity in adjustment strategy represents an important source of variation across studies and may contribute to residual confounding in the pooled analyses (Table VII).

Table III. Subgroup heterogeneity of the association between near-work activity and myopia by geographic region.

Region	No. of studies	OR (95% CI)	Prediction interval	τ	τ^2	Q	df (Q)	P-value	I^2, %
Asia	29	1.177 (1.116-1.240)	0.957-1.447	0.097	0.009	201.069	28	<0.001	86.1
Europe	11	1.173 (1.064-1.292)	0.887-1.550	0.113	0.013	55.402	10	<0.001	82.0
North America	2	1.098 (0.859-1.403)	NA	0.169	0.028	10.034	1	0.002	90.0
Oceania	1	1.210 (1.031-1.421)	NA	0.0	0.0	0.0	0	1.000	0.0

OR, odds ratio; CI, confidence interval; NA, not assessed.

Study name	Statistics with study removed				
	Point	Lower limit	Upper limit	Z-Value	P-Value
Atowa et al., 2020	1.081	1.058	1.105	6.952	0.000
Guo et al., 2017	1.082	1.058	1.106	7.042	0.000
Hsu et al., 2017 a	1.086	1.062	1.110	7.297	0.000
Hsu et al., 2017 b	1.083	1.059	1.107	7.049	0.000
Ku et al., 2018 a	1.081	1.058	1.105	6.978	0.000
Ku et al., 2018 b	1.081	1.058	1.105	7.013	0.000
Li et al., 2015	1.081	1.058	1.105	6.969	0.000
Lin et al., 2017	1.083	1.060	1.108	7.087	0.000
Lin et al., 2021	1.083	1.060	1.107	7.129	0.000
Parssinen et al., 2021 a	1.081	1.058	1.105	7.002	0.000
Parssinen et al., 2021 b	1.077	1.054	1.101	6.680	0.000
Parssinen et al., 2021 c	1.079	1.056	1.103	6.788	0.000
Phillipp et al., 2022 a	1.082	1.058	1.106	7.057	0.000
Phillipp et al., 2022 b	1.082	1.059	1.106	7.094	0.000
Phillipp et al., 2022 c	1.083	1.060	1.108	7.163	0.000
Saxena et al., 2017 a	1.083	1.059	1.107	7.097	0.000
Saxena et al., 2017 b	1.082	1.058	1.105	7.058	0.000
Scheiman et al., 2013	1.097	1.072	1.123	7.788	0.000
Wen et al., 2020	1.084	1.060	1.108	7.136	0.000
You et al., 2016	1.085	1.061	1.110	7.150	0.000
Gopalakrishnan et al., 2023 a	1.084	1.060	1.108	7.160	0.000
Gopalakrishnan et al., 2023 b	1.084	1.060	1.108	7.136	0.000
Hsu et al., 2016	1.076	1.053	1.100	6.539	0.000
Parssinen et al., 2019	1.083	1.060	1.108	7.146	0.000
Wu et al., 2015 a	1.087	1.063	1.112	7.337	0.000
Hinterlong et al., 2019	1.155	1.112	1.199	7.444	0.000
Alvarez-Peregrina et al., 2020	1.083	1.059	1.108	6.976	0.000
Zhang et al., 2021	1.090	1.065	1.115	7.413	0.000
Holton et al., 2019	1.080	1.057	1.104	6.868	0.000
Lanca et al., 2022	1.087	1.063	1.113	7.110	0.000
Sun et al., 2018	1.083	1.059	1.107	7.116	0.000
Giloyan et al., 2016	1.089	1.065	1.114	7.461	0.000
Wang et al., 2022 a	1.077	1.054	1.102	6.577	0.000
Wang et al., 2022 b	1.087	1.063	1.111	7.363	0.000
Enthoven et al., 2020	1.155	1.112	1.199	7.461	0.000
Huang et al., 2021	1.069	1.048	1.091	6.463	0.000
Singh et al., 2019	1.082	1.059	1.106	7.097	0.000
Chua et al., 2015	1.084	1.061	1.108	7.185	0.000
Wu et al., 2015 b	1.080	1.056	1.103	6.916	0.000
Yang et al., 2016	1.082	1.059	1.106	7.076	0.000
Saxena et al., 2015	1.077	1.054	1.100	6.868	0.000
Hansen et al., 2019	1.083	1.060	1.107	7.142	0.000
Hung et al., 2020	1.083	1.059	1.107	7.104	0.000
Pooled	1.084	1.060	1.108	7.176	0.000
Prediction Interval	1.084	1.010	1.163	0.000	0.000

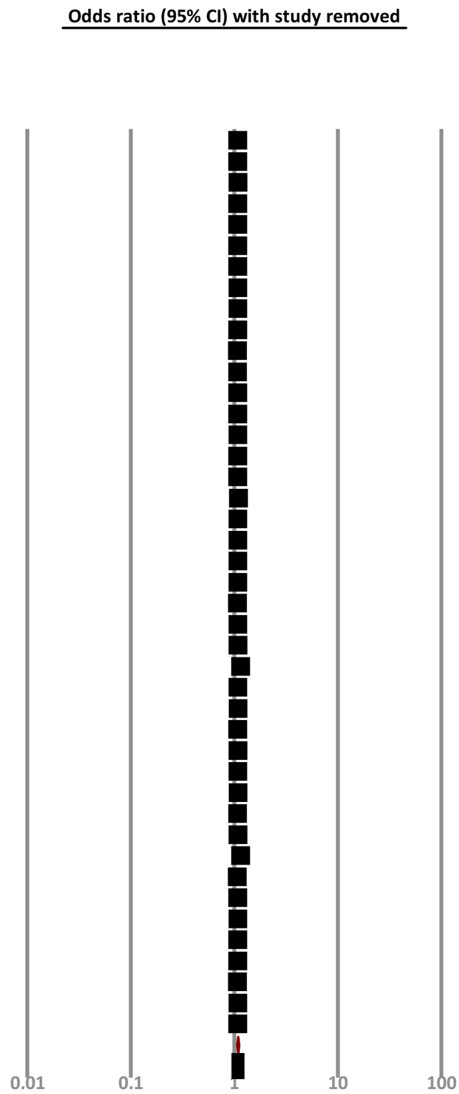


Figure 3. Leave-one-out sensitivity analysis. This plot displays the effect of removing each study from the analysis one at a time to assess the stability of the overall result. Each line in the plot shows the recalculated pooled OR after omitting one study. A horizontal dashed line represents the overall OR with all studies included. If all the recalculated ORs stay close to this dashed line, it indicates that no single study has a disproportionate influence on the overall result, supporting the robustness of the findings. Letters a, b, and c denote different comparison groups within the same study. OR, odds ratio; CI, confidence interval.

Discussion

In the present systematic review and meta-analysis, a significant positive association was found between near-work activity and myopia in children. Pooled analyses showed that children with higher exposure to near work had greater odds of being myopic compared with those with lower exposure. Specifically, the overall estimate indicated a 30-50% increase in myopia risk for children engaging in high levels of near work (such as intensive reading or screen use) vs. those with minimal near work, although the exact magnitude depended on how near work was defined in each study. Considerable

Table IV. Effects of moderator factors on the relationship between near-work activity and myopia in children.

Model and covariate	Coefficient	Standard error	95% CI lower limit	95% CI upper limit	Z-value	P-value (2-sided)
Model 1						
Intercept	0.3768	0.4454	-0.4961	1.2497	0.85	0.3975
Duration, h	-0.0021	0.0208	-0.0428	0.0387	-0.1	0.9209
Age, years	0.0042	0.0121	-0.0196	0.028	0.34	0.7306
Male sex, %	-0.0069	0.0078	-0.0221	0.0083	-0.89	0.3748
Myopia definition, D	0.0564	0.2713	-0.4754	0.5881	0.21	0.8354
Model 2						
Intercept	0.1356	0.2407	-0.3362	0.6074	0.56	0.5733
Age, years	0.0023	0.008	-0.0135	0.018	0.28	0.7774
Male sex, %	-0.0028	0.0044	-0.0113	0.0058	-0.63	0.5266
Model 3						
Intercept	0.2211	0.2946	-0.3564	0.7986	0.75	0.453
Age, years	0.0017	0.0088	-0.0156	0.019	0.19	0.8481
Male sex, %	-0.0036	0.0049	-0.0133	0.006	-0.74	0.4585
Myopia definition, D	0.0604	0.131	-0.1963	0.3171	0.46	0.6446

CI, confidence interval.

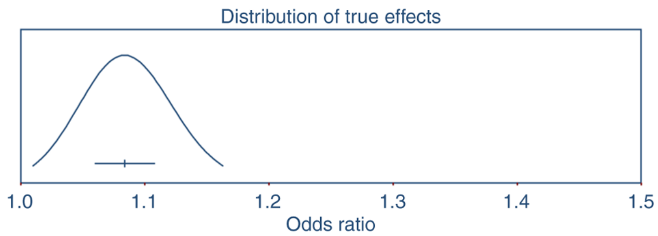


Figure 4. 95% Prediction interval for the overall effect. The main pooled OR is shown along with a horizontal bar indicating the 95% prediction interval. Unlike the confidence interval, which reflects the precision of the pooled estimate, the prediction interval estimates the range within which the effect size of a future study is likely to fall. If the prediction interval does not cross the null value (OR=1), it implies that most future studies are also likely to observe a statistically significant positive association, reinforcing the generalizability of the finding.

heterogeneity in effect sizes was observed across the included studies, reflecting differences in study designs and populations. Potential moderators, such as age, region and type of near work, were also examined. However, meta-regression did not identify any single factor that fully explained the variation between studies. Notably, some evidence suggested that the effect of near work might be more pronounced in studies from East Asian populations (where baseline myopia prevalence is high) and in those that specifically measured very close reading distances or prolonged continuous reading without breaks. Accordingly, the regional subgroup analysis revealed significant differences between regions, suggesting that the association between near work and myopia may vary geographically. Several contextual factors may contribute to these differences. Variations in educational systems, such as longer school hours or higher academic demands in certain regions, can lead to increased near-work exposure in children. Cultural patterns related to study habits and early-life use of digital devices may further amplify near-work duration. Conversely, regions that encourage outdoor activities and leisure may experience lower myopia prevalence, reflecting the protective effects of time spent outdoors. These factors likely interact to produce the regional heterogeneity observed in the present analysis, highlighting the importance of considering environmental and cultural context when interpreting the effects of near work on myopia. Overall, despite variability in individual study results, the findings support the hypothesis that intensive near-work activities are associated with a higher risk of myopia in childhood.

A novel contribution of the present meta-analysis is the inclusion of the most recent prospective cohort studies, allowing for an updated and more precise pooled estimate of the near work-myopia association. In addition, to the best of our knowledge, the present study provides one of the first subgroup analyses comparing self-reported vs. objective device-based measures of near work, highlighting that only self-reported measures showed a significant association. Finally, by systematically exploring sources of heterogeneity, including geographic region and confounding by outdoor activity, this study advances understanding of the contextual factors that may shape the impact of near work on myopia risk.

The present findings align with earlier systematic reviews and meta-analyses that investigated the link between near work and myopia in young populations (3,11,12). For instance, a 2015 systematic review by Huang *et al* (3) reported that children who performed more near work had ~80% higher odds of having myopia compared with those who did less near work. This earlier meta-analysis, which pooled predominantly cross-sectional studies, emphasized that myopic children tended to spend more time reading than non-myopic children, while time spent on other near

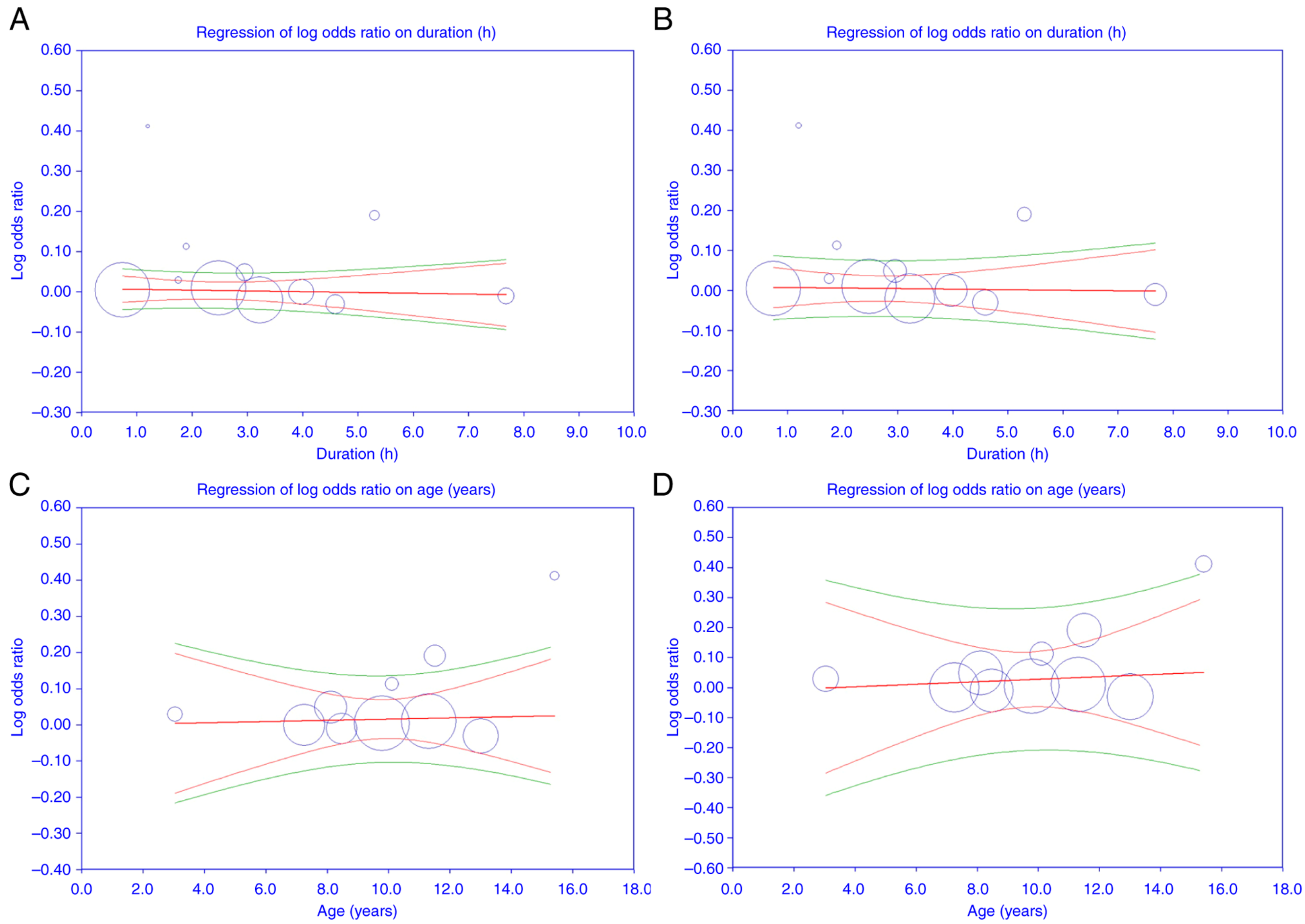


Figure 5. Meta-regression of near work and myopia. (A-D) Meta-regression plots for moderator variables. Each meta-regression plot visualizes the association between a moderator variable (mean age, percentage of males, duration and myopia definition) and the effect size of the included studies. Individual studies are displayed as scatter points on the graph. A regression line runs through the points, showing whether there is a statistical trend between the moderator and the outcome. A flat or near-horizontal regression line indicates that the moderator does not significantly affect the association between near work and myopia, which was the case for all moderators tested in this analysis.

activities (such as computer use or watching television) did not exhibit a significant difference (3). These findings were extended in the present analysis by incorporating a larger number of studies, including more recent cohorts and diverse forms of near work (for example, handheld digital device use) into the analysis. A more recent meta-analysis reported a more modest association between near work and myopia risk than the study by Huang *et al* (3). The comprehensive 2023 meta-analysis by Dutheil *et al* (16), which included both children and adults, found that near-work exposure was associated with only ~31% higher odds of myopia in children (OR, 1.31; 95% CI, 1.21-1.42). This analysis pooled 78 studies with >250,000 participants and included a broader definition of near work (including occupational near work in adults) (16). However, by combining data from various age groups, that study may have underestimated the possible effect of educational near work in children alone. By contrast, the present review focused specifically on children and near-work activities related to schooling or leisure (reading, writing and screen time), which may yield a higher relative risk in that more homogeneous context. An overview of systematic reviews published in 2022 also supported this association, by showing that near work was associated with a 14% increase in myopia odds, with a pooled OR of 1.14 (95% CI, 1.08-1.20) for children with higher near-work engagement (12).

A key strength of the present study is its comprehensive and up-to-date inclusion of studies. Evidence was collated from a large number of studies spanning multiple continents and up to the most recent publications, thereby increasing the generalizability of the findings. Unlike earlier reviews that were limited to cross-sectional data, the present analysis incorporated both cross-sectional and longitudinal studies, enabling a more robust assessment of temporality and causation in the near work-myopia relationship. Furthermore, subgroup and moderator analyses were conducted to explore the sources of heterogeneity, and the results were found to be largely consistent in direction across these subsets.

However, several limitations of the present study should be acknowledged. First, the evidence base is dominated by observational studies, which limits the ability to conclude causality. Children were not randomized to high or low near work; thus, residual confounding and reverse causation remain possible explanations for the association. Second, there was considerable heterogeneity among the included studies in how both myopia and near work were measured. Definitions of myopia ranged from a refractive error ≤-0.50 D

Table V. Results of publication bias analyses.

Method	Key statistics	Value	Additional info
Begg and Mazumdar rank correlation	Kendall's τ (Wilson score interval/ continuity correction)	0.170	z=1.61167; 2-tailed P=0.10703
Egger's regression intercept	Intercept	1.957	Standard error, 0.298; 95% CI, 1.354-2.561; t=6.55; P<0.001
Classic fail-safe N	Missing studies to nullify effect	1916	Observed P<0.001; Z=13.22769
Orwin's fail-safe N	Observed odds ratio	1.008	Criterion for trivial OR, 1.0; mean OR in missing, 1.0
Trim and Fill (random effects)	Adjusted point estimate	1.055	18 studies trimmed; 95% CI, 1.030-1.081

OR, odds ratio; CI, confidence interval.

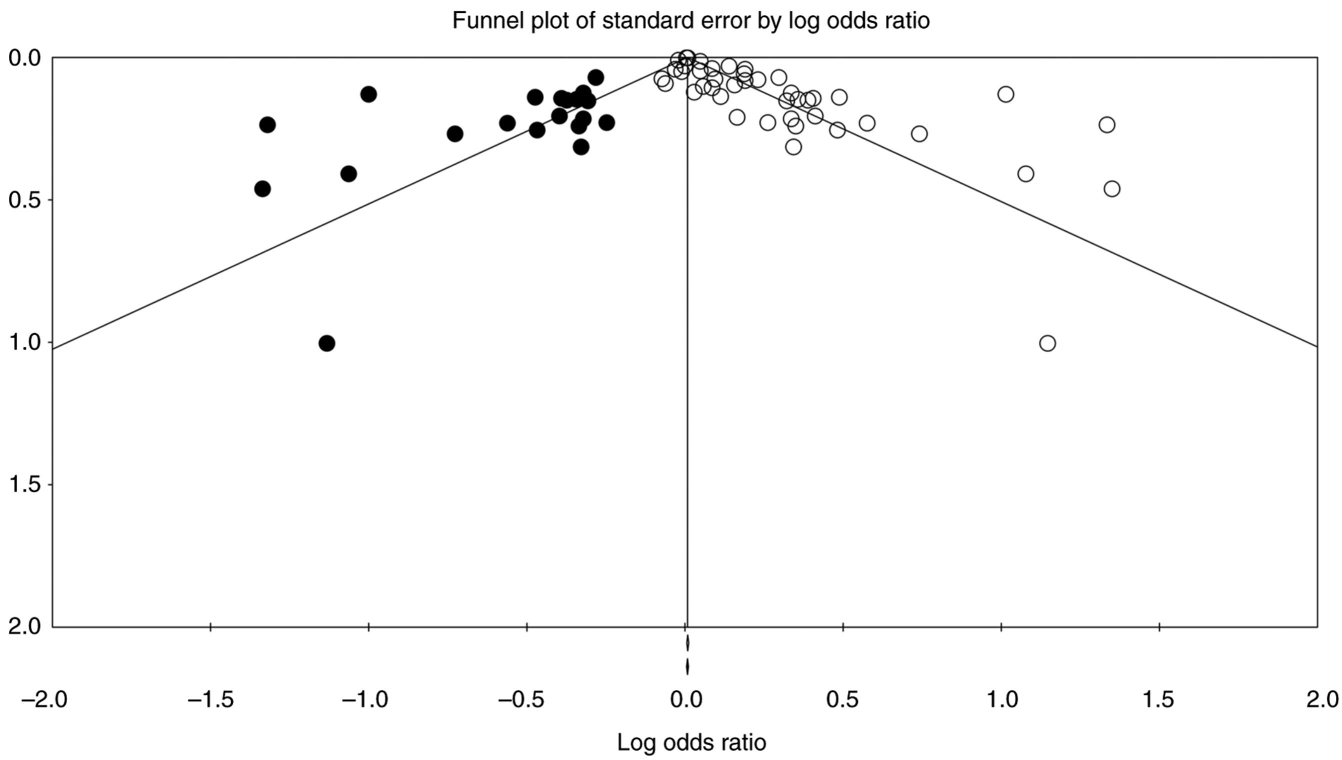


Figure 6. Funnel plot for publication bias. The funnel plot is used to visually assess potential publication bias. Each point in the plot represents a study, with the effect size on the x-axis and standard error on the y-axis. In the absence of publication bias, the plot resembles a symmetrical inverted funnel, with smaller studies showing more scatter at the bottom.

to ≤-1.00 D or worse; some studies relied on non-cycloplegic refractions (potentially misclassifying hyperopia as myopia in younger children), and near-work exposure was quantified by diverse metrics (hours of reading per day, reading distance and diopter-hours of near activity). This lack of standardization introduces measurement error and makes it challenging to pool results directly. Although the present study attempted to account for these differences through random-effects models and sensitivity analyses, they likely contributed to the high statistical heterogeneity observed. Third, few studies have objectively measured near-work behavior; most rely on self-reported or parent-reported activity logs, which are prone to recall bias and inaccuracy. Fourth, while some longitudinal studies were included, their number was relatively small and their follow-up periods varied. The scarcity of long-term randomized trials or interventions means that it cannot be definitively confirmed that reducing near work will reduce myopia incidence. Fifth, the present meta-analysis could not fully separate the effects of near work from co-variables such as outdoor time and screen use. Although the studies adjustments for outdoor exposure were qualitatively considered, differences in analytic approaches meant that a formal meta-regression could not be performed on this factor. One important

Table VI. Quality assessment of included studies based on the Newcastle-Ottawa Scale.

First author, year	Selection	Comparability	Outcome/Exposure	Total	(Refs.)
Giloyan *et al*, 2016	3	1	2	6	(28)
Gopalakrishnan *et al*, 2023	3	1	2	6	(29)
Guo *et al*, 2017	4	2	3	9	(20)
Hansen *et al*, 2019	3	2	3	8	(30)
Hinterlong *et al*, 2019	3	1	2	6	(31)
Hsu *et al*, 2016	3	1	2	6	(22)
Lanca *et al*, 2022	3	1	2	6	(35)
Li *et al*, 2015	4	2	3	9	(15)
Lin *et al*, 2017	3	1	2	6	(13)
Lin *et al*, 2023	3	1	2	6	(25)
Pärssinen *et al*, 2019	4	1	3	8	(36)
Pärssinen *et al*, 2022	3	1	2	6	(37)
Hsu *et al*, 2017	4	2	3	9	(23)
Huang *et al*, 2021	4	2	3	9	(33)
Hung *et al*, 2020	3	1	2	6	(34)
Ku *et al*, 2019	2	1	1	4	(24)
Chua *et al*, 2015	4	2	3	9	(27)
Alvarez-Peregrina *et al*, 2020	4	2	3	9	(26)
Atowa *et al*, 2020	3	1	2	6	(21)
Enthoven *et al*, 2020	3	2	3	8	(9)
Philipp *et al*, 2022	3	1	2	6	(7)
Saxena *et al*, 2015	3	1	2	6	(38)
Saxena *et al*, 2017	3	1	2	6	(39)
Scheiman *et al*, 2014	4	2	3	9	(40)
Singh *et al*, 2019	3	1	2	6	(41)
Sun *et al*, 2018	4	2	3	9	(42)
Wen *et al*, 2020	4	2	3	9	(43)
Wu *et al*, 2016	3	1	2	6	(45)
Wu *et al*, 2015	4	2	3	9	(44)
Guo *et al*, 2016	4	2	3	9	(46)
You *et al*, 2016	4	2	3	9	(47)
Zhang *et al*, 2022	4	2	3	9	(48)
Holton *et al*, 2021	4	2	3	9	(32)

consideration in interpreting the present results in context is the role of confounding factors, particularly time spent outdoors. In epidemiological research on myopia, near work and outdoor time are often inversely correlated (47). Prior research has found that increased outdoor time has a protective effect against myopia, with an ~2% reduction in odds of myopia per additional hour spent outdoors per week (12). Notably, an influential meta-analysis by Sherwin *et al* (49) (2012) demonstrated that greater time outdoors significantly lowers myopia risk. The present meta-analysis could not fully separate the independent effect of near work from the impact of limited outdoor exposure, as few primary studies rigorously controlled for both factors. Additionally, the level of covariate adjustment varied greatly among studies. While most adjusted for age, sex, parental myopia and outdoor activity, some only provided basic associations, and only a few included baseline refractive error, socioeconomic status or education level. These differences in adjustment strategies may have affected the pooled results. Under-adjusted studies may have overestimated the link between near work and myopia, while models that included potential mediators could have weakened the true relationship. Although the random-effects approach partly accounts for such heterogeneity, residual confounding remains a concern, and future research should adopt standardized adjustment models to enhance comparability. Lastly, there is a risk of publication bias or selective reporting. Studies showing a positive relationship between near work and myopia may have been more likely to be published, whereas null findings (especially from smaller studies) could remain unpublished. The present study attempted to identify this through funnel plot analysis; although the results did not change significantly after adjusting for potential bias, its influence cannot be completely ruled out. Moreover, funnel plot asymmetry

Table VII. Covariates adjusted for in the included studies.

Study	Adjusted covariates	(Refs.)
Alvarez-Peregrina *et al*, 2020	Age, sex, parental myopia, outdoor activity	(26)
Atowa *et al*, 2020	Age, sex, parental myopia, socioeconomic status	(21)
Chua *et al*, 2015	Age, sex, parental myopia, ethnicity, outdoor activity	(27)
Enthoven *et al*, 2020	Age, sex, ethnicity, parental education, outdoor activity	(9)
Giloyan *et al*, 2016	Age, sex, parental myopia, reading habits	(28)
Gopalakrishnan *et al*, 2023[a]	Age, sex, parental myopia, outdoor activity	(29)
Gopalakrishnan *et al*, 2023[b]	Age, sex, parental myopia, outdoor activity	(29)
Guo *et al*, 2017	Age, sex, parental myopia, outdoor activity, baseline refractive error	(20)
Hansen *et al*, 2019	Age, sex, parental myopia, outdoor activity	(30)
Hinterlong *et al*, 2019	Age, sex, parental myopia, socioeconomic status	(31)
Holton *et al*, 2021	Age, sex, parental myopia, outdoor activity, screen time	(32)
Hsu *et al*, 2016	Age, sex, parental myopia, outdoor activity	(22)
Hsu *et al*, 2017[a]	Age, sex, parental myopia, outdoor activity	(23)
Hsu *et al*, 2017[b]	Age, sex, parental myopia, outdoor activity, baseline refraction	(23)
Huang *et al*, 2021	Age, sex, parental myopia, outdoor activity, sleep duration	(33)
Hung *et al*, 2020	Age, sex, parental myopia, outdoor activity	(34)
Ku *et al*, 2019[a]	Age, sex, parental myopia, outdoor activity, education level	(24)
Ku *et al*, 2019[b]	Age, sex, parental myopia, outdoor activity, baseline refraction	(24)
Lanca *et al*, 2022	Age, sex, parental myopia, outdoor activity, socioeconomic status	(35)
Li *et al*, 2015	Age, sex, parental myopia, outdoor activity	(15)
Lin *et al*, 2017	Age, sex, parental myopia, outdoor activity, school grade	(13)
Lin *et al*, 2023	Age, sex, parental myopia, outdoor activity, baseline refraction	(25)
Pärssinen *et al*, 2019	Age, sex, parental myopia, education level, outdoor activity	(36)
Pärssinen *et al*, 2022[a]	Age, sex, parental myopia, outdoor activity	(37)
Pärssinen *et al*, 2022[b]	Age, sex, parental myopia, outdoor activity	(37)
Pärssinen *et al*, 2022[c]	Age, sex, parental myopia, outdoor activity	(37)
Philipp *et al*, 2022[a]	Age, sex, parental myopia, outdoor activity, socioeconomic status	(7)
Philipp *et al*, 2022[b]	Age, sex, parental myopia, outdoor activity, socioeconomic status	(7)
Philipp *et al*, 2022[c]	Age, sex, parental myopia, outdoor activity, socioeconomic status	(7)
Saxena *et al*, 2015	Age, sex, parental myopia, socioeconomic status	(38)
Saxena *et al*, 2017[a]	Age, sex, parental myopia, socioeconomic status, outdoor activity	(39)
Saxena *et al*, 2017[b]	Age, sex, parental myopia, socioeconomic status, outdoor activity	(39)
Scheiman *et al*, 2014	Age, sex, parental myopia, baseline refraction, ethnicity	(40)
Singh *et al*, 2019	Age, sex, parental myopia, socioeconomic status	(41)
Sun *et al*, 2018	Age, sex, parental myopia, outdoor activity, near-work breaks	(42)
Wen *et al*, 2020	Age, sex, parental myopia, outdoor activity, working distance, light exposure	(43)
Wu *et al*, 2015[a]	Age, sex, parental myopia, outdoor activity	(44)
Wu *et al*, 2016[b]	Age, sex, parental myopia, outdoor activity, baseline refraction	(45)
Guo *et al*, 2016	Age, sex, parental myopia, outdoor activity	(46)
You *et al*, 2016	Age, sex, parental myopia, outdoor activity, diopter-hours	(47)
Zhang *et al*, 2022	Age, sex, parental myopia, outdoor activity, socioeconomic status	(48)

'No adjustment (crude estimate)' is noted where studies did not report adjusted estimates. [a,b,c]Denote different comparison groups within the same study.

and Egger's test suggested possible small-study publication bias, indicating that smaller studies with null results might be underrepresented. Nonetheless, after applying the Trim-and-Fill method, the association between near work and myopia remained significant, supporting the robustness of the conclusions despite this potential bias. Another limitation of the present study is that the subgroup analysis restricted to objective device-based measures of near work did not show a statistically significant association with myopia. This may reflect the smaller number of studies employing such methods, but it also raises the possibility that self-reported measures may overestimate the strength of the relationship.

Future studies using standardized, device-based assessments are therefore essential to validate these findings.

To translate the present findings into practical guidance, evidence from prior intervention studies suggests that limiting continuous near-work sessions to 30-40 min, with regular breaks, may help reduce eye strain and myopia risk in children (50). Additionally, encouraging at least 1-2 h of outdoor activity per day has been associated with a protective effect against myopia onset (50). While these thresholds are based on available studies and may require adaptation to local contexts, they provide a tangible framework for parents, educators and policymakers to structure near-work and outdoor time in ways that may mitigate myopia development. Future longitudinal and interventional studies are needed to refine these recommendations and establish optimal quantitative guidelines.

In conclusion, the present meta-analytical systematic review provides strong evidence that higher engagement in near-work activities is associated with higher odds of myopia in children. Children who spend more time on near tasks, particularly sustained reading or digital screen use at close distances, tend to have a higher risk of developing myopia. The association, while significant, is of moderate magnitude and is influenced by other modifiable factors such as time spent outdoors. Taken together with findings from previous reviews, the present results support a multifactorial approach to myopia prevention: Encouraging higher outdoor time and healthy visual behaviors may help reduce childhood myopia risk. However, most of the included studies are cross-sectional, limiting the ability to infer causality or establish the temporal direction between near work and myopia. Therefore, while the observed associations are consistent and biologically plausible, longitudinal studies with objective measures of near work and interventional trials are necessary to confirm causality and inform evidence-based guidelines on optimal near-work duration and practices for children.

Acknowledgements

Not applicable.

Funding

The Medical Science Research Project of Hebei supported this scientific work (grant no. 20211182).

Availability of data and materials

The data generated in the present study are included in the figures and/or tables of this article.

Authors' contributions

YS and WZ conceptualized the study, designed the search strategy, and drafted the initial manuscript. XY and HT performed data extraction, contributed to data analysis, and assisted with manuscript revisions. SY and FD conducted the quality assessment, contributed to statistical analysis, and finalized the manuscript. HT, YS and WZ confirm the authenticity of all the raw data. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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