The Impact of Hyperopia on Academic Performance Among Children: A Systematic Review

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Purpose: To assess the impact of uncorrected hyperopia and hyperopic spectacle correction on children's academic performance.

Design: Systematic review and meta-analysis

Methods: We searched 9 electronic databases from inception to July 26, 2021, for studies assessing associations between hyperopia and academic performance. There were no restrictions on language, publication date, or geographic location. A quality checklist was applied. Random-effects models estimated pooled effect size as a standardized mean difference (SMD) in 4 outcome domains: cognitive skills, educational performance, reading skills, and reading speed. (PROSPERO registration: CRD-42021268972).

Results: Twenty-five studies (21 observational and 4 interventional) out of 3415 met the inclusion criteria. No full-scale randomized trials were identified. Meta-analyses of the 5 studies revealed a small but significant adverse effect on educational performance in uncorrected hyperopic compared to emmetropic children {SMD −0.18 [95% confidence interval (CI), −0.27 to −0.09]; $P < 0.001$, 4 studies} and a moderate negative effect on reading skills in uncorrected hyperopic compared to emmetropic children [SMD −0.46 (95% CI, −0.90 to −0.03); $P = 0.036$, 3 studies]. Reading skills were significantly worse in hyperopic than myopic children [SMD −0.29 (95% CI, −0.43 to −0.15); $P < 0.001$, 1 study]. Qualitative analysis on 10 (52.6%) of 19 studies excluded from meta-analysis found a significant ($P < 0.05$) association between uncorrected hyperopia and impaired academic performance. Two interventional studies found hyperopic spectacle correction significantly improved reading speed ($P < 0.05$).

Conclusions: Evidence indicates that uncorrected hyperopia is associated with poor academic performance. Given the limitations of current methodologies, further research is needed to evaluate the impact on academic performance of providing hyperopic correction.

Key Words: glasses, hyperopia, learning, refractive error, school-age children

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As this study is a systematic review and meta-analysis, there are no primary data to be shared.

The authors have no conflicts of interest to declare.

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Education lays the foundation for sustainable economic growth and the development of a country.[1] It is regarded as a fundamental human right[2] and is the focus of Sustainable Development Goal 4 (SDG4) established by the United Nations, ensuring "inclusive and equitable quality education" for all.[3] In 2017, it was reported that fewer than 50.0% of children and adolescents globally were achieving minimum proficiency levels[4] in reading and mathematics.[5] The highest regional proportion of adolescents failing to reach minimum proficiency levels worldwide were in sub-Saharan Africa (89.0%), followed by Central Asia and Southern Asia (80.0%), and Western Asia and Northern Africa (64.0%).[5]

Uncorrected refractive error is the leading cause of vision impairment in children globally.[6] An estimated 12.8 million children aged 5 to 15 years are vision impaired due to this cause.[7] A systematic review and meta-analysis of the regional and global prevalence of refractive errors across childhood found the pooled prevalence estimates of myopia, hyperopia [spherical equivalent (SE) ≥+2.00 diopters (D)], and astigmatism to be 11.7% [95% confidence interval (CI), 10.5–13.0], 4.6% (95% CI, 3.9–5.2), and 14.9% (95% CI, 12.7–17.1), respectively.[8]

Vision is a crucial component of a child's learning and education. Studies have reported that uncorrected and under-corrected refractive errors can affect a child's academic performance,[9–14] social participation,[15,16] and future economic productivity.[17] However, a recent review identified several gaps in the evidence related to the impact of refractive errors on academic performance.[18] Additionally, much of the evidence is undermined by suboptimal research methods, including small sample sizes and a lack of robust trial designs, limiting the ability to determine associations or causation. As a result, efforts have recently been undertaken to strengthen the evidence base, with trials reporting improvements in academic achievement after spectacle intervention to correct myopia.[19–21] Other trials have also shown that refractive correction improves educational outcomes but have not distinguished the type of refractive error.[14,22,23]

Hyperopia is common in young children, with the prevalence of moderate hyperopia (≥+2.00 D) in 6- to 72-month-olds ranging between 13.0% and 29.0%.[24,25] A meta-analysis reported hyperopia (≥+2.00 D) prevalence in 5-year-old children was between 2.7% and 26.3%, depending on the measurement methods and geographic location.[26] Research has underscored the connection between uncorrected hyperopia, near visual function and early literacy development,[27,28] reading speed,[29] and academic achievement in children.[12,30–33] For example, the Vision in Preschoolers–Hyperopia in Preschoolers (VIP-HIP) study concluded that 4- and 5-year-old children with uncorrected hyperopia ≥+4.00 D or uncorrected hyperopia ≥+3.00 D with reduced binocular near visual acuity/stereoacuity, performed significantly worse on early literacy tests compared to age-matched controls.[28]

School vision screening programs are relatively common in high-income countries, where they have been successfully incorporated into health care and educational systems.[34] However, such programs predominantly rely on distance visual acuity as a measure and therefore, are biased to detect amblyopic risk factors, myopia, and astigmatism.[35,36] The detection of uncorrected hyperopia could be crucial for successful reading,[27,28] yet is frequently overlooked. Furthermore, modest hyperopia in children is regarded as relatively benign, as it is expected that children have sufficient accommodative (focusing) ability to overcome it.[37]

Besides the impact on learning, uncorrected moderate-high hyperopia in children is associated with a higher risk of strabismus[38,39] and amblyopia.[39–42] Amblyopia is the leading cause of unilateral vision impairment in children.[43] Although treatment of amblyopia often involves correction of hyperopia to improve visual acuity, the hyperopia itself is not the impetus for clinical decision-making to prescribe spectacles.[44] Current guidelines on prescribing for hyperopic correction for children under 4 years of age, in the absence of amblyopia and strabismus, are largely based on clinical experience rather than evidence derived.[45,46] The absence of robust and standardized criteria makes it impossible to make unequivocal evidence-based recommendations for managing school-age children with hyperopia.

A majority of school learning activities, including reading and writing, are performed at close range over prolonged periods.[47] In addition, with the advent of portable electronics, such as smartphones, tablets, and e-readers, the use of screens at close working distances over prolonged periods has become increasingly important and widely used for both educational and recreational purposes.[48] Given that uncorrected hyperopia is the refractive error with the most significant impact on near vision, this increases the potential impact of uncorrected hyperopia on learning.[49–51] Although uncorrected hyperopes can produce additional accommodation to overcome their refractive error temporarily. The sustained additional accommodative demand can result in asthenopia and headaches.[52] This could lead to an unconscious avoidance of near tasks due to visual discomfort. In addition, children with hyperopia may not be aware that their vision is not "typical" or may not explain what they experience. A recent study reported that hyperopic correction improved accommodative performance for sustained reading tasks for the majority of participants.[53]

All these findings are imperative to understand the impact of hyperopia on education and learning. However, to the best of our knowledge, no systematic review or meta-analysis of the impact of hyperopia on children's academic performance has been published or registered to date. This review investigates the impact of uncorrected hyperopia and hyperopic spectacle correction on academic performance among children in the published literature and systematically synthesizes the findings.

METHODS

Data Sources and Search Methods

This systematic review and meta-analysis were conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses and the Cochrane handbook.[54–56] The study protocol was registered on the International Prospective Register of Systematic Reviews database (PROSPERO reference number CRD-42021268972).

A comprehensive search strategy was applied to all electronic databases, using medical subject headings and a combination of keywords related to hyperopia, children, and academic performance. We searched the following databases: MEDLINE ALL (Ovid), EMBASE (Ovid), PsycINFO (Ovid), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science, PubMed, International Clinical Trials Registry Platform, Cochrane Database of Systematic Reviews, and the Cochrane Central Register of Controlled Trials in the Cochrane Library, from database inception to July 26, 2021. One reviewer (SM) performed an additional grey literature search on Google Scholar, Open Grey, and ProQuest. No language, publication date, or geographic location restrictions were applied. Reference manager software (Endnote 20, Thomson Reuters) was used to collect references and exclude duplicates. Reference lists were also searched for all included articles and previous reviews to identify other relevant studies. The search strategy is shown in the supplementary file for the searches in the electronic databases (Supplementary Digital Content, File 1, http://links.lww.com/APJO/A125).

Eligibility Criteria

Inclusion criteria were as follows: any language, publication date, or geographic location; primary investigations and reviews;

observational or interventional studies; participants were children and adolescents[57] attending school between 4 and 17 years of age who had been diagnosed with uncorrected hyperopia of any degree, and with or without astigmatism, without any ocular comorbidities, including strabismus and amblyopia. Studies with mixed participant groups (eg, children and adults/cohorts including children with strabismus and/or amblyopia) that did not report data separately for the above participants were excluded. The primary outcome was academic performance assessed through standardized or nonstandardized testing or teachers' evaluation of academic progress. Studies including only child self-reported measures of performance were excluded.

Data Extraction and Quality Appraisal

Two reviewers (IB and SM) independently checked the titles and abstracts retrieved by our searches against the review's eligibility criteria, resolving disagreements by discussion. The full texts of all potentially eligible articles were retrieved, and full-text screening was done by 2 reviewers (IB and SM) if eligibility was confirmed. Data were extracted separately from the included studies into a predesigned and piloted data spreadsheet (Excel; Microsoft Corp, Redmond, WA). For each included study, extracted data included author, year, geographic location, study setting, title, study design, sample size, participant characteristics, sampling method, reported outcome(s), and comparator groups. Two reviewers (IB and SM) checked the data for errors, and discrepancies were resolved through discussion and consensus.

Two reviewers (ACY and SM) independently evaluated the quality of each included study. Discrepancies were resolved through discussion and consensus. The Joanna Briggs Institute Critical Appraisal Checklist tools were used to assess the included studies' quality and risk of bias.[58]

Data Synthesis and Analysis

We first described study characteristics, such as design, country, setting, refractive error, type, and category of the academic assessment tool, and then provided meta-analyses of the findings for reported outcomes. Studies were classified according to the World Bank classification of income level.[59] All outcome measurement tools identified in the included studies were categorized by specific outcome measures and outcome domains: cognitive skills, educational performance, reading skills, and reading speed. This was undertaken by 4 reviewers (VFC, GV, IB, and SM) and discussed with the wider team if there were unresolved disagreements between these reviewers.

Hedges' g effect size (ES)[60] and 95% CI were calculated to characterize the association between uncorrected hyperopia and academic performance on each relevant domain for each study. Hedges' g represents the standardized mean difference (SMD) between uncorrected hyperopic children and the 2 control groups: emmetropic and myopic children. Outcome measures from the included studies were all continuous and reported on different scales. Therefore, when studies used different outcome measurement tools in 1 academic domain, such as educational performance or reading skills, the ES was averaged to ensure that each study only added 1 ES to the final analysis. SMD and its 95% CI were used to summarize the estimated effects from individual studies reporting outcomes on the same scale. The random-effects model was used to generate a pooled ES. The magnitude of the SMDs was defined according to the guidelines laid out by Cohen: small (SMD = 0.2–0.5), medium (SMD = 0.5–0.8), and large (SMD = >0.8).[61] An ES of less than zero indicates impaired academic performance. The threshold for statistical significance was set at $P < 0.05$, and all P values were 2-sided.

Heterogeneity between study estimates was presented visually and statistically through inspection of forest plots and the I^2 statistic.[62] I^2 values were interpreted using the threshold recommendations outlined in the Cochrane Handbook.[63] Analyses were performed to assess whether academic performance differed as a function of the intended focus of the academic tool, for example, tools addressing reading skills or educational performance. All statistical analyses were performed using Stata statistical software (version 17.0, Stata Corp, College Station, TX). Sensitivity analysis was performed to evaluate each study's influence on the overall ES, using the leave-one-out method, by removing 1 study each time and repeating the analysis. We also performed a narrative synthesis of the association between uncorrected hyperopia and educational outcomes.

RESULTS

Study Selection

The electronic database search yielded 3746 titles and abstracts, 338 of which were duplicates. An additional 7 studies were identified by manually searching reference lists of the included studies. During title and abstract screening, 3302 studies were excluded as they were not relevant to the research question. One hundred thirteen studies were considered for eligibility, of which a total of 88 (77.9%) studies were excluded for the following reasons: outcome measures not reported (n = 56), simulated hyperopia was reported (n = 2), the type of refractive error could not be differentiated (n = 11), conference and meeting abstracts (n = 15), and unable to translate full text into English (n = 4, 3 in German, 1 in French). A total of 25 eligible studies were included in this review (Fig. 1). No additional studies were identified through the grey literature search.

Characteristics of the Eligible Studies

The 25 selected studies were comprised of 21 observational studies (16 cross-sectional studies,[12,27,28,31,33,64–74] 3 longitudinal studies,[75–77] and 2 case-control studies[78,79]) and 4 interventional studies (1 cross-sectional study[53] and 3 longitudinal intervention studies[10,29,80]). No full-scale randomized control trials were identified. A majority (n = 22, 88.0%) of included studies were conducted in high-income countries.[10,12,27–29,31,33,53,66–69,71–80] One (4.0%) study was conducted in an upper middle-income country,[70] and 2 (8.0%) were conducted in lower-middle-income countries (LMICs).[64,65] The 25 studies included 23,883 school children [mean sample size 1038, standard deviation (SD) 2095, range 32–8245] with an age range of 3 to 17 years, across 12 countries. The sex distribution ranged from 34.3% to 63.0% males. Fourteen studies (56.0%) did not report on the sex distribution of participants.[10,29,31,53,64,66–69,72,73,75,77,79] Studies were conducted in schools,[10,29,31,33,64–70,74,77] community settings,[12,71,72,75,78] or in health care facilities[27,28,53,76,79,80] whereas 1 study did not report the setting.[73]

Classification of Hyperopia and Measurement Tools

The selected studies used a wide variety of definitions to classify hyperopia and utilized different refractive methods. A

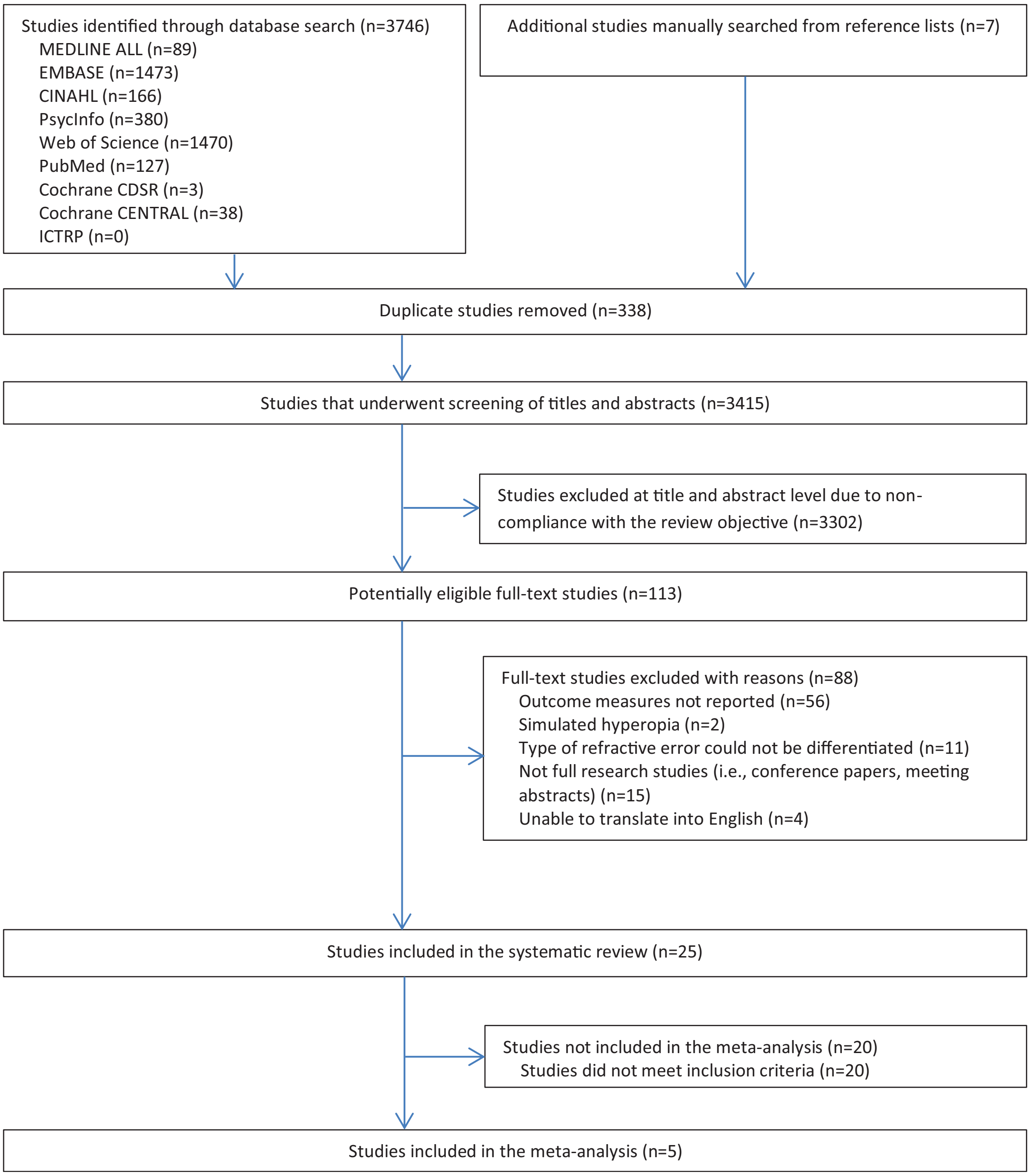

Figure 1. Flow chart of the study selection process. Reported according to the PRISMA guidelines. Some studies contributed to both the narrative review and meta-analysis. PRISMA indicates Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

total of 7 studies explained the cutoff thresholds used to define hyperopia.[12,27,33,53,64,69,74] Four (16.0%) studies used the plus-lens test to identify participants with hyperopia.[12,29,66,71] Three out of these 4 studies, further defined hyperopia using the SE.[12,29,66] One study (4.0%) used distance and near visual acuity to classify participants with refractive error.[72] Seven studies (33.3%, n = 7/21) used a threshold between ≥+1.00 D and <+2.00 D on children aged between 5 and 13 years old.[10,12,31,53,74,78,79] The remaining studies used a variety of threshold definitions for hyperopia from 0.00 D to ≥+4.00 D.[27–29,33,64–70,75,76,80] Two studies did not provide details regarding how hyperopia was measured, for example, failure on the hyperopia test[77] and "far-sighted enough to warrant use of glasses."[73]

Regarding methodology to determine refractive status, 10 studies performed cycloplegic refraction,[10,27,28,33,53,64,65,74,76,80] 6 performed noncycloplegic refraction,[31,68–70,75,78] and 4 did not clearly state whether cycloplegia was used.[67,73,77,79] A variety of techniques were used to measure hyperopia. The 2 most common modalities were retinoscopy (32.0%, n = 8) and autorefraction (28.0%, n = 7) whereas 5 (20.0%) studies[10,73,76,77,79] did not specify the instrument used and 4 (16.0%) studies[12,29,66,80] used a combination of techniques.

Categorization of Academic Performance by Domain

All 25 included studies assessed 1 or more outcome domains: 3 (12.0%) studies in the cognitive skills domain[65,67,80]; 12 (48.0%) studies were in the educational performance domain[12,28,31,33,64,66,68,70,71,75,77,79]; 5 (20.0%) studies in the reading skills domain[10,27,73,74,78]; 1 (4.0%) study in the reading speed domain[53]; and 4 (16.0%) studies reported more than 1 domain (Table 1).[29,69,72,76]

Table 1. Study Design Characteristics of Selected Studies Included in the Systematic Review and Meta-Analysis (N = 25)

Author (y)	a) Country b) Study Type c) Setting d) Sociodemographic Category	a) Total Sample Size b) Sex (%) c) Age, y Mean ±SD (Range)	a) Definition of Hyperopia b) Method c) Control Cohort	a) Outcome Measure(s) b) Outcome Measurement Tool(s)	Summary of Findings
Alvarez-Peregrina et al[71] (2021)	a) Spain b) Cross-sectional c) Community d) Not specified	a) 6673, total hyperopic not specified b) 58.7% male c) Not specified (6–12)	a) Failure on the plus-lens test b) Plus-lens test (+2.00 D) c) Not specified	a) Educational performance b) Parent-reported school performance*	The probability of poor academic performance increased with hyperopia ($P = 0.001$).
Atkinson et al[75] (2007)	a) UK b) 6-y follow-up, longitudinal c) Community d) Broad	a) 171, total hyperopic not specified b) Not specified c) 6.9 ± 0.5 (not specified)	a) ≥+4.00 D in at least 1 meridian b) Noncycloplegic retinoscopy† c) Emmetropia	a) Educational Performance b) British Picture Vocabulary Scale (BPVS); Phonological Abilities Test (PAT); and the Children's Test of Nonword Repetition (CN-Rep)	On the BPVS test, a deficit in the hyperopic group was reported ($P = 0.023$). CN-Rep and PAT reported no differences between the 2 groups.
Akrami et al[65] (2012)	a) Iran b) Cross-sectional c) School d) Not specified	a) 137, total hyperopic n = 19 b) 34.3% male c) 10.4 ± 0.6 (10–14)	a) ≥+0.50 D SE b) Cycloplegic autorefraction c) Emmetropia; myopia; and astigmatism	a) Cognitive skills b) Teacher-based assessment	Children with both myopia and astigmatism performed poorly compared to emmetropic children ($P < 0.05$). No significant differences were reported in the hyperopic group.
Chebil et al[64] (2014)	a) Tunisia b) Cross-sectional c) School d) Not specified	a) 162, all hyperopic b) Not specified c) 9.7 ± 0.4 (6–14)	a) ≥+2.00 D SE in at least 1 eye b) Cycloplegic autorefraction c) No control group	a) Educational performance b) Repeating ≥1 school year	Academic delay of at least 1 y was noted in 75.9% of hyperopic children (n = 123). No significant association was reported between hyperopia and school performance ($P = 0.41$).
Eames[73] (1955)	a) US b) Cross-sectional c) Not specified d) Not specified	a) 171, total hyperopic n = 73 b) Not specified c) Not specified	a) Far-sighted enough to warrant use of glasses b) Not specified c) Grade-matched controls; emmetropia; and myopia	a) Reading skills b) The Gates Silent Reading Test	The reading assessment was conducted on age-matched controls (n = 50) to establish the reading level. Grade 3 and 4 children (n = 121) received complete eye examinations. 63.0% (n = 46/73) of hyperopic children failed the reading test compared to 47.1% (n = 8/17) of myopic and 32.3% (n = 10/31) of emmetropic children. Hyperopia may contribute considerably to reading failure.
Fulk and Goss[68] (2001)	a) US b) Cross-sectional c) School d) Not specified	a) 266, total hyperopic n = 32 b) Not specified c) Not specified (4–15)	a) ≥+0.75 D SE in either eye b) Noncycloplegic autorefraction c) Emmetropia; and myopia	a) Educational performance b) Teacher-based assessment	34.4% (n = 11/32) of hyperopic children falling into the lower one-fourth compared to 12.5% (n = 4/32) of myopic and 13.9% (n = 28/202) of emmetropic children. Uncorrected hyperopia was associated with poor academic outcomes ($P = 0.015$).
Harrington et al[33] (2021)	a) UK b) Cross-sectional c) School d) Broad	a) 1612, total hyperopic (6- to 7-year-old) n = 21, total hyperopic (12- to 13-year-old) not specified b) 54.2% male c) Not specified (6–7 and 12–13)	a) ≥+3.50 D b) Cycloplegic autorefraction c) Emmetropia; existing hyperopic correction; myopia; and astigmatism	a) Educational performance b) Parent/guardian-reported school performance‡	Uncorrected hyperopia was associated with low performance ($P = 0.04$); amongst the younger cohort (n = 21), low performance was reported in 23.8% (n = 5) of uncorrected hyperopic children compared to 9.5% (n = 2) of children with hyperopic correction.
Hirsch[67] (1959)	a) US b) Cross-sectional c) School d) Not specified	a) 197, total hyperopic n = 72 b) Not specified c) Not specified (14–17)	a) 0.00 D to >+2.00 D for the horizontal meridian in the right eye only b) Retinoscopy, not specified c) Myopia	a) Cognitive skills b) California Test for Mental Maturity	Hyperopic children (≥+1.00 D) have intelligence test scores (range 106–109) below the mean intelligence quotient (IQ) (113 ± 17). Low IQ scores were associated with uncorrected hyperopia ($P = 0.001$).
Hopkins et al[74] (2017)	a) Australia b) Cross-sectional c) School d) Disadvantaged	a) 508§, total hyperopic n = 465 b) 49.4% male c) Not specified (6–7 and 12–13)	a) ≥+1.50 D in either eye b) Cycloplegic retinoscopy c) Hyperopic correction ≥+1.50 D	a) Reading skills b) Neale test of reading ability assessing: reading accuracy and reading comprehension	No differences were reported in reading accuracy ($P = 0.77$) and comprehension ($P = 0.52$) between children with and without uncorrected hyperopia (≥+1.50 D). Similarly, no differences were reported for varying cut-offs of hyperopia; reading accuracy ($P = 0.19$) and comprehension ($P = 0.08$) in corrected and uncorrected hyperopia (≥+2.00 D); and reading accuracy ($P = 0.24$) and comprehension ($P = 0.28$) in corrected and uncorrected hyperopia (≥+3.00 D).
Köhler and Stigmar[66] (1981)	a) Sweden b) Cross-sectional c) School d) Advantaged	a) 118, total hyperopic n = 16 (identified with the plus-lens test) b) Not specified c) 8.0 (Not specified)	a) Failure on the plus-lens test, further defined by ≥+2.50 D b) Plus-lens test (+1.50 D and + 2.00 D)¶ c) Emmetropia; and myopia	a) Educational performance b) Teacher-based assessment‖	Hyperopic children were not representative of the poor readers group. Hyperopia was not associated with poor reading and writing skills.
Krumholtz[77] (2000)	a) US b) 2-y follow-up longitudinal c) School d) Disadvantaged	a) Not specified**, total hyperopic (1996–1997) n = 155, total hyperopic (1998–1999) n = 110 b) Not specified c) Not specified (5–12)	a) Failed on the hyperopia test b) Hyperopia test†† c) No control group	a) Educational performance b) New York citywide test	Poor academic performance was associated with hyperopia for Grade 1 ($P = 0.01$) and Grade 4 ($P = 0.05$) in the 1996–1997 cohort; and Grade 4 ($P = 0.05$) in the 1998–1999 cohort. Twenty-five students were given vision correction (predominantly spectacles), and of this sample, 84.0% (n = 21) gained at least a 20 percentage-point increase in their achievement test percentile rank.

Table 1. (Continued)

Author (y)	a) Country b) Study Type c) Setting d) Sociodemographic Category	a) Total Sample Size b) Sex (%) c) Age, y Mean ±SD (Range)	a) Definition of Hyperopia b) Method c) Control Cohort	a) Outcome Measure(s) b) Outcome Measurement Tool(s)	Summary of Findings
Lança et al[69] (2014)	a) Portugal b) Cross-sectional c) School d) Not specified	a) 587, total hyperopic n = 16 b) Not specified c) Not specified[‡‡] (6–11)	a) ≥+3.75 D b) Noncycloplegic autorefraction c) Normal Visual Function (NVF); anisohyperopia; and astigmatism	a) Reading skills and reading speed b) Reading errors; Reading accuracy; and Reading Speed	Children with uncorrected hyperopia had poor reading performance ($P = 0.003$) than emmetropic controls.
Ntodie et al[53] (2021)	a) UK b) Cross-sectional c) Other (school; university eye clinic; and community) d) Not specified	a) 63, all hyperopic b) Not specified c) 7.8 ± 1.7 (5–10)	a) ≥+1.00 D and <+5.00D SE in the less-hyperopic eye postrefraction b) Cycloplegic retinoscopy c) No control group	a) Reading speed b) Wilkin Rate of Reading test	Hyperopic spectacle correction significantly improved reading speed ($P < 0.001$)
Palomo-Álvarez and Puell[78] (2010)	a) Spain b) Case-control c) Community d) Broad	a) 119, total hyperopic n = 30 b) 63.0% male c) 9.2 (8–13)	a) <+2.00 D b) Noncycloplegic retinoscopy c) Normal readers	a) Reading skills b) The Battery of Evaluation of Reading Processes (PROLEC) for Grades 3 and 4; and the Battery of Evaluation of Reading Processes for Secondary Education Students (PROLEC-SE) for Grade 5	The poor readers group[§§] comprised of 25 (28.7%) hyperopic children, whereas 5 (15.6%) of the normal readers were hyperopic.
Roch-Levecq et al[80] (2008)	a) US b) 6-wk follow-up longitudinal c) Other (university eye clinic or mobile eye clinic) d) Disadvantaged	a) 70, total hyperopic n = 35 b) 40.0% male c) 4.6 (3–5)	a) ≥+4.00 D bilateral b) Cycloplegic retinoscopy[¶¶] c) Emmetropia	a) Cognitive skills b) The Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R)	Children with uncorrected hyperopia scored significantly lower on the performance scale ($P = 0.01$) than the emmetropic controls. After wearing spectacle correction for 6 wk, the hyperopic group improved on the WPPSI-R performance scale but did not reach statistical significance ($P = 0.17$). Hyperopic correction was undercorrected by 1.50–2.50 D or by 3.00 D if hyperopia was ≥+7.00 D.
Rosner and Rosner[79] (1987)	a) US b) Case-control c) Other (university eye clinic) d) Not specified	a) 576, total hyperopic n = 140 b) Not specified c) Not specified (6–12)	a) ≥+1.00 D to >2.25 D b) Not specified c) Myopia; and astigmatism	a) Educational performance b) With or without learning difficulties (LD)[‖‖]	Hyperopia was more prevalent in children with LD (n = 123): 32.5% (n = 40) with moderate hyperopia (≥+1.00 D to + 2.25 D) and 21.1% (n = 26) with significant hyperopia (>+2.25 D).
Rosner and Rosner[31] (1997)	a) US b) Cross-sectional c) School d) Advantaged	a) 782, total hyperopic n = 83 b) Not specified c) Not specified	a) ≥+1.25 D b) Noncycloplegic retinoscopy c) Emmetropia; and myopia	a) Educational performance b) Iowa Test of Basic Skills	32.7% of myopic children were high scorers (>75th percentile), compared with only 13.3% of the hyperopic children. Children with hyperopia (≥+1.25 D) had significantly lower test scores ($P = 0.014$). Test scores were significantly lower in hyperopic children compared to myopic children ($P = 0.017$).
Shankar et al[27] (2007)	a) Canada b) Cross-sectional c) Other (university clinic) d) Not specified	a) 32, total hyperopic n = 13 b) 46.9% male c) Not specified[***] (4–7)	a) ≥+2.00 D along the most hyperopic meridian, bilaterally b) Cycloplegic retinoscopy[†††] c) Emmetropia	a) Reading skills b) The Wide Range Achievement Test (WRAT-III); The Peabody Picture Vocabulary Test-III (PPVT); The Rosner Test of Auditory Analysis (TAAS); and the Emergent Orthography test	Children with uncorrected hyperopia performed poorly compared to emmetropic children in letter and word recognition ($P = 0.049$), receptive vocabulary ($P = 0.004$) and emergent orthography ($P = 0.03$). There was no difference between the 2 groups in phonological awareness ($P = 0.54$)
Slavin et al[10] (2018)	a) US b) Mean 3.7 ± 1.7 mo follow-up longitudinal c) School d) Disadvantaged	a) 262, total hyperopic n = 101 b) Not specified c) Not specified	a) ≥+1.00 D b) Cycloplegic refraction, not specified c) Emmetropia; and myopia	a) Reading skills b) Letter-Word Identification and Word Attack scales from the Woodcock Language Proficiency Battery	Children with uncorrected refractive errors had poor reading performance, but none of these differences was statistically significant. The effect of receiving eyeglasses was only statistically significant for myopic children ($P < 0.03$), not hyperopic children ($P < 0.10$).
Stewart-Brown et al[72] (1985)	a) UK b) Cross-sectional c) Community d) Not specified	a) 8245, total hyperopic n = 323 b) Not specified c) 10.0 (Not specified)	a) Hyperopia, distance vision 6/6 near vision ≤9 b) Visual acuity c) Emmetropia; existing hyperopic correction; and myopia	a) Cognitive skills; reading skills; and educational performance b) British Ability Scales; Edinburgh Reading Test[‡‡‡]; and a mathematics test	Children with uncorrected hyperopia were underachieving in reading. Reading scores were higher in children (n = 22) with existing hyperopic spectacle correction, but the difference was not statistically significant.
van Rijn et al[29] (2014)	a) The Netherlands b) Four to 6-mo follow-up longitudinal c) School[§§§] d) Broad	a) 166, total hyperopic n = 107 b) Not specified c) Not specified (9–10)	a) Failure on the plus-lens test, further defined as >0.00 D SE b) Plus-lens test (+1.50 D) and noncycloplegic autorefraction[¶¶¶] c) Myopia <0.00 D	a) Reading skills; and reading speed b) Klepel; and One-Minute Test	Children with myopia had approximately 11% higher One-minute scores ($P = 0.005$) than children with uncorrected hyperopia. At follow-up, the hyperopic full correction group improved its One-Minute score by about 13% more than both the no-spectacle group ($P = 0.012$) and +0.50DS group ($P = 0.019$).

Table 1. (Continued)

Author (y)	a) Country b) Study Type c) Setting d) Sociodemographic Category	a) Total Sample Size b) Sex (%) c) Age, y Mean ±SD (Range)	a) Definition of Hyperopia b) Method c) Control Cohort	a) Outcome Measure(s) b) Outcome Measurement Tool(s)	Summary of Findings
VIP-HIP Study Group[28] (2016)	a) US b) Cross-sectional c) Other (university eye clinic or mobile-eye clinic) d) Disadvantaged	a) 492, total hyperopic n = 244 b) 49.2% male c) 4.9 ± 0.5 (4–5)	a) ≥+3.00 D to ≤+6.00 D in the most hyperopic meridian of at least 1 eye b) Cycloplegic autorefraction c) Emmetropia	a) Educational performance b) Test of Preschool Early Literacy (TOPEL)	The mean TOPEL score was significantly lower in children with uncorrected hyperopia than emmetropia ($P = 0.004$).
Williams et al[76] (1988)	a) New Zealand b) 4-y follow-up longitudinal c) Other (research clinic) d) Broad	a) 503, total hyperopic n = 26 b) 53.7% male c) Not specified (7–11)	a) >+2.25 D bilaterally b) Cycloplegic refraction, not specified c) Emmetropia; myopia; and premyopia	a) Cognitive skills; and reading speed b) Wechsler Intelligence Scale for Children – Revised form (WISC-R) IQ test[‖‖‖]; and the Burt Word Reading Test	At age 11, the hyperopic group had significantly lower verbal and performance IQ scores than the emmetropic group ($P < 0.05$). No significant differences were reported in reading scores between the groups.
Williams et al[12] (2005)	a) UK b) Cross-sectional c) Community d) Not specified	a) Not specified, total hyperopic n = 101 b) 51.0% male c) 8.0 (Not specified)	a) Failure on the plus-lens test, further defined hyperopia as ≤+3.00 D or >+3.00 D bilaterally; ≤+1.25 D or >+1.25 D in the better eye b) Plus-lens test (+4.00 D)[****] c) Nonreferred group; and nonfogging referral group	a) Educational performance b) National Foundation for Education Research (NFER); and Standardised assessment tests (SATs) attaining core subject indicator (CSI) level 2	The hyperopic (≤+3.00 D) group scored the highest on NFERs and SATs, whereas the lowest scores were seen in the more strongly hyperopic (>+3.00 D) group (NFER) and nonfogging test referrals (SATs). No significant differences were identified between the test groups.
Yang et al[70] (2021)	a) China b) Cross-sectional c) School d) Not specified	a) 1971, total hyperopic not specified b) 55.1% male c) Not specified (6–15)	a) ≥+0.50 D SE b) Noncycloplegic autorefraction c) Emmetropia	a) Educational Performance b) Nationwide standard examination in the following: Chinese language; English; and mathematics	Hyperopia was associated with lower academic scores in Grade 1 children ($P = 0.01$). Hyperopia was significantly associated with the worst academic performance in the Chinese language test ($P = 0.02$) and the mathematics test ($P = 0.01$) among Grade 1 children.

D indicates diopter; SE, spherical equivalent.

*Failure of ≥1 subject at the end of the previous year.

†At the first visit, noncycloplegic retinoscopy was conducted to identify participants with hyperopia who were followed up with cycloplegic retinoscopy thereafter.

‡Performance measured as follows: high performance (much better than classmates); average performance (about the same as classmates); and low performance (not and classmates).

§All participants (n = 508) completed the reading accuracy component of the reading test, and 465 participants completed the reading comprehension component, with the remaining 43 participants most likely experienced difficulties with the reading task. 22.8% (n = 116) of children had uncorrected hyperopia and 68.7% (n = 349) of children had hyperopic correction.

¶Hyperopic participants were identified by failing screening with the plus-lens test. Then cycloplegic retinoscopy was conducted.

||Assessment based on reading and writing difficulties, using a 4-graded scale: none; slight; moderate; and severe.

**Reported top and bottom 25%.

††No specific detail is given on the hyperopia test, and refraction was undertaken but not reported.

‡‡Normal Visual Function cohort mean age 7.7 ± 1.2 y.

§§Poor readers identified as those who scored below the 30th percentile in the reading subtests.

¶¶Cycloplegic retinoscopy was conducted on all participants, and most had cycloplegic autorefraction conducted.

||||Learning Difficulties (LD) are defined as school achievement record not matching the predicted IQ score.

***Mean 5.6 ± 1.1, emmetropic cohort; and mean 4.8 ± 1.0, hyperopic cohort.

†††Refractive status was categorised based on cycloplegic retinoscopy, but participants also underwent precycloplegic and cycloplegic testing with 2 autorefractors.

‡‡‡Shortened form of test.

§§§One or 2 subsequent visits to a regional optician for additional measurements.

¶¶¶Participants with visual acuity <0.8 or a difference of >2 lines; or participants who failed the plus-lens test (a decrease in visual acuity by ≤2 lines) or ≥+0.75 D in either eye measured by noncycloplegic autorefraction were then referred for cycloplegic retinoscopy. For the intervention study, only participants with uncorrected hyperopia were considered eligible.

||||||Comprehension and Picture Arrangement subtests were omitted.

****Failure on the plus lens test (+4.00 D) and then referred for optometric assessment.

Cognitive skills encompassed a variety of labels, for example, general intelligence in children such as full-scale intelligence quotient (IQ), verbal IQ, performance IQ, working memory, and processing speed. Standardized intelligence tests including the Wechsler Preschool and Primary Scale of Intelligence-Revised, Wechsler Intelligence Scale for Children-Revised, and the California Test for Mental Maturity and British Ability Scales were used to assess cognitive function. Four of the 5 studies assessing cognitive skills used standardized tests[67,72,76,80] and 1 study utilized teacher-based assessments to determine cognitive functioning.[65]

The domain of educational performance was comprised of many measures of academic performance such as mathematics, language, early literacy skills, and the number of schooling years that were repeated. Early literacy skills are reading and writing skills developed from birth to approximately 5 years old that strongly predict later conventional literacy skills.[81,82] Seven (53.8%) of the 13 studies used nonstandardized tests to assess educational performance.[33,64,66,68,71,72,79] Reading skills were categorized into constructs of overall reading or clusters/subtests to assess a range of tasks, for example, reading comprehension, letter-word identification, picture vocabulary, reading accuracy, and errors. Seven (87.5%) out of 8 studies used standardized testing to assess reading levels in children.[10,27,29,72–74,78] All 4 studies assessing reading speed have reported outcome measures separately; therefore, reading speed was evaluated as a separate domain.[29,53,69,76] Three studies used standardized tests to measure and report reading speed.[29,53,76] Lança et al[69] reported the validity of the tool used to assess reading skills and speed.

Assessment of Quality and Risk of Bias

The studies were assessed for their methodological quality using the Joanna Briggs Institute Critical Appraisal Checklist tools.[58] In brief, the quality of the studies was assessed by determining whether the studies have (1) included a rigorous selection of representative participants, (2) the undertaking of cycloplegic refraction to define refractive error, (3) identified confounding factors, and (4) used valid and reliable outcome measurements with robust statistical analyses, underpinned by a detailed methodological description of the study. By applying these criteria, the quality of a majority (88.0%) of the included studies was moderate-low.[10,12,29,31,33,64–80] Three studies were considered high quality.[27,28,53] Notably, out of these 3 studies, the VIP-HIP study[28] used a large sample size of hyperopic children. The most common issues included: (1) small sample size of exposure group[27,31,53,65,68,69,72,74,79,80]; (2) failure to measure hyperopia using a valid, clearly-defined, reliable method across all study participants[12,33,64,65,67–73,75–79]; (3) failure to measure academic performance using a clearly-defined, valid, and reliable tool across all study participants[31,33,64–66,68,71,73,76,77,79]; and (4) limitations inherent in the cross-sectional design. A summary of the methodological quality is shown in Table 2.

Meta-Analyses Findings

Separate meta-analyses were conducted to assess 2 indicators of the association between uncorrected hyperopia and academic performance: (1) educational performance and (2) reading skills. Among the 25 included studies, 5 (20.0%) could be included in our meta-analysis.[27,28,31,69,72] All included studies are presented narratively. The 16 (64.0%) studies that could not be included in the meta-analysis did not provide the SD,[12,67,74,76] reported median values but not the means and SDs,[73] failed to investigate a sufficient number of hyperopic participants,[70,75,77,78] or did not measure academic performance objectively.[33,64–66,68,71,79] Four studies that reported on the impact of hyperopic spectacle correction on academic performance were excluded from the meta-analysis for the following reasons: 1 study did not provide the SD,[29] and the remaining 3 studies could not be pooled to estimate the effect of hyperopic spectacle correction.[10,53,80]

Pooled estimates of educational performance from 4 studies with 9551 total participants, ranging in age from 4 to 10 years, showed children with uncorrected hyperopia had worse educational performance than emmetropic children, with a pooled SMD of −0.18 (95% CI, −0.27 to −0.09; $P < 0.001$) (Fig. 2). There was no evidence of a difference between hyperopic and myopic children, but the estimate was imprecise [SMD −0.08 (95% CI, −0.29 to 0.13; $P = 0.474$)] (Fig. 3). Low statistical heterogeneity was observed between studies using an emmetropic control group ($I^2 = 0.0\%$), suggesting a consistent effect across studies. Moderate statistical heterogeneity was observed between studies using a myopic control group ($I^2 = 47.5\%$). Regarding study design features, we found 1 study[27] with a small sample size that showed a greater ES, but this had little effect on overall heterogeneity (Fig. 2).

Pooled estimates of reading skills from 3 studies including 8855 participants, ranging in age from 4 to 11 years, showed children with uncorrected hyperopia had worse reading skills than emmetropic children, with a pooled SMD of −0.46 (95% CI, −0.90 to −0.03; $P = 0.036$) (Fig. 4). One study found that participants with uncorrected hyperopia had significantly worse reading skills than those with myopia [SMD −0.29 (95% CI, −0.43 to −0.1; $P < 0.001$)] (Fig. 5). Substantial statistical heterogeneity was observed between studies using an emmetropic control group ($I^2 = 68.0\%$) (Fig. 4).

Sensitivity Analysis

In the leave-one-out sensitivity analyses conducted, the removal of most studies unsurprisingly rendered the nonsignificant pooled ES estimate due to loss of precision, considering the small number of studies in each meta-analysis (Figs. 6, 7).

Narrative Findings From Studies Not Included in the Meta-Analysis

The 20 eligible studies excluded from the meta-analysis included 16 observational (11 cross-sectional studies,[12,33,64–68,70,71,73,74] 3 longitudinal studies,[75–77] 2 case-control[78,79]) and 4 interventional studies (1 cross-sectional study[53] and 3 longitudinal studies[10,29,80]). The findings of all the studies are described in Table 1. Of the 19 studies that assessed the association between uncorrected hyperopia and academic performance, ten[29,33,67,68,70,71,75–77,80] found a significant ($P < 0.05$) detrimental impact on academic performance. Of these studies, 2 reported that uncorrected hyperopia was associated with poor academic performance compared to both emmetropic and myopic comparator groups[33,68]; 4 found a significant association between uncorrected hyperopia and poorer academic outcomes compared to emmetropia[70,75,76,80]; 2 reported poorer academic outcomes in children with uncorrected hyperopia compared to myopia[29,67]; and 2 reported impaired academic outcomes in children with uncorrected hyperopia but did not include a comparator group.[71,77] For those studies that did

Table 2. The Checklist Results for Assessing the Methodological Quality of the Selected Studies (N = 25)

Case-Control Study	Academic Performance Indicator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Palomo-Álvarez and Puell[78] (2010)	Reading skills	±	☑	☑	☒	☑	☒	◆	☑	◆	☒
Rosner and Rosner[79] (1987)	Educational performance	±	☑	☑	±	±	☒	◆	☒	◆	☒

Longitudinal Study		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Slavin et al[10] (2018)	Reading skills	☑	☑	☑	±	☑	☑	☑	±	±	◆	☑
van Rijn et al[29] (2014)	Reading skills and reading speed	☑	☑	☑	±	±	☑	☑	☑	☑	☑	±
Roch-Levecq et al[80] (2008)	Cognitive skills	☑	☑	☑	☑	☑	☑	☑	±	☑	☑	☑
Atkinson et al[75] (2007)	Educational performance	☑	☑	±	±	◆	±	☑	☑	±	±	☑
Krumholtz[77] (2000)	Educational performance	☑	☑	±	☒	☒	±	±	±	±	◆	±
Williams et al[76] (1988)	Cognitive skills and reading speed	☑	☑	±	☑	☑	☑	±	☑	☑	◆	☑

Cross-Sectional Study		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Alvarez-Peregrina et al[71] (2021)	Educational performance	±	±	☒	☒	☑	☑	☒	☑
Harrington et al[33] (2021)	Educational performance	☑	☑	±	±	☑	☑	☒	☑
Ntodie et al[53] (2021)	Reading speed	☑	☑	☑	☑	☑	☑	☑	☑
Yang et al[70] (2021)	Educational performance	☑	☑	☒	±	☑	☑	☑	☑
Hopkins et al[74] (2017)	Reading skills	±	☑	☑	☑	☑	☑	☑	☑
VIP-HIP Study Group[28] (2016)	Educational performance	☑	☑	☑	☑	☑	☑	☑	☑
Chebil et al[64] (2014)	Educational performance	±	☑	±	☑	☑	☒	☒	±
Lança et al[69] (2014)	Reading skills and reading speed	☑	☑	☒	☒	☑	☑	☑	±
Akrami et al[65] (2012)	Cognitive skills	☑	☑	±	±	±	☑	☒	☑
Shankar et al[27] (2007)	Reading skills	☑	☑	☑	☑	☑	☑	☑	☑
Williams et al[12] (2005)	Educational performance	☑	☑	☒	±	☒	◆	☑	±
Fulk and Goss[68] (2001)	Educational performance	±	☑	☒	±	☒	◆	☒	±
Rosner and Rosner[31] (1997)	Educational performance	☑	±	☑	☑	±	±	±	±
Stewart-Brown et al[72] (1985)	Cognitive skills; reading skills; and educational performance	±	☑	☒	☒	☑	☑	☑	☑
Köhler and Stigmar[66] (1981)	Educational performance	☑	☑	☑	☒	☒	◆	☒	±
Hirsch[67] (1959)	Cognitive skills	☑	±	☒	☑	☒	◆	☑	☑
Eames[73] (1955)	Reading skills	±	±	☒	±	☒	◆	±	☒

Question key: JBI tool questions for case-control assessment: Q1 = "Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?," Q2 = "Were cases and controls matched appropriately?," Q3 = "Were the same criteria used for identification of cases and controls?," Q4 = "Was exposure measured in a standard, valid and reliable way?," Q5 = "Was exposure measured in the same way for cases and controls?," Q6 = "Were confounding factors identified?," Q7 = "Were strategies to deal with confounding factors stated?," Q8 = "Were outcomes assessed in a standard, valid and reliable way for cases and controls?," Q9 = "Was the exposure period of interest long enough to be meaningful?," Q10 = "Was appropriate statistical analysis used?" (Joanna Briggs Institute, 2020).

JBI tool questions for longitudinal study assessment: Q1 = "Were the 2 groups similar and recruited from the same population?," Q2 = "Were the exposures measured similarly to assign people to both exposed and unexposed groups?," Q3 = "Was the exposure measured in a valid and reliable way?," Q4 = "Were confounding factors identified?," Q5 = "Were strategies to deal with confounding factors stated?," Q6 = "Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?," Q7 = "Were the outcomes measured in a valid and reliable way?," Q8 = "Was the follow up time reported and sufficient to be long enough for outcomes to occur?," Q9 = "Was follow up complete, and if not, were the reasons to loss to follow up described and explored?," Q10 = "Were strategies to address incomplete follow up utilised?," Q11 = "Was appropriate statistical analysis used?" (Joanna Briggs Institute, 2020).

JBI tool questions for cross-sectional study assessment: Q1 = "Were the criteria for inclusion in the sample clearly defined?," Q2 = 2 Were the study subjects and the setting described in detail?," Q3 = "Was the exposure measured in a valid and reliable way?," Q4 = "Were objective, standard criteria used for measurement of the condition?," Q5 = "Were confounding factors identified?," Q6 = "Were strategies to deal with confounding factors stated?," Q7 = "Were the outcomes measured in a valid and reliable way?," Q8 = "Was appropriate statistical analysis used?" (Joanna Briggs Institute, 2020).

Answers legend: ☑ = yes the study satisfactorily met the respective quality criterion; ☒ = no the study did not meet the respective quality criterion; ◆ = not applicable; and ± = unclear whether the study has met the respective quality criterion.

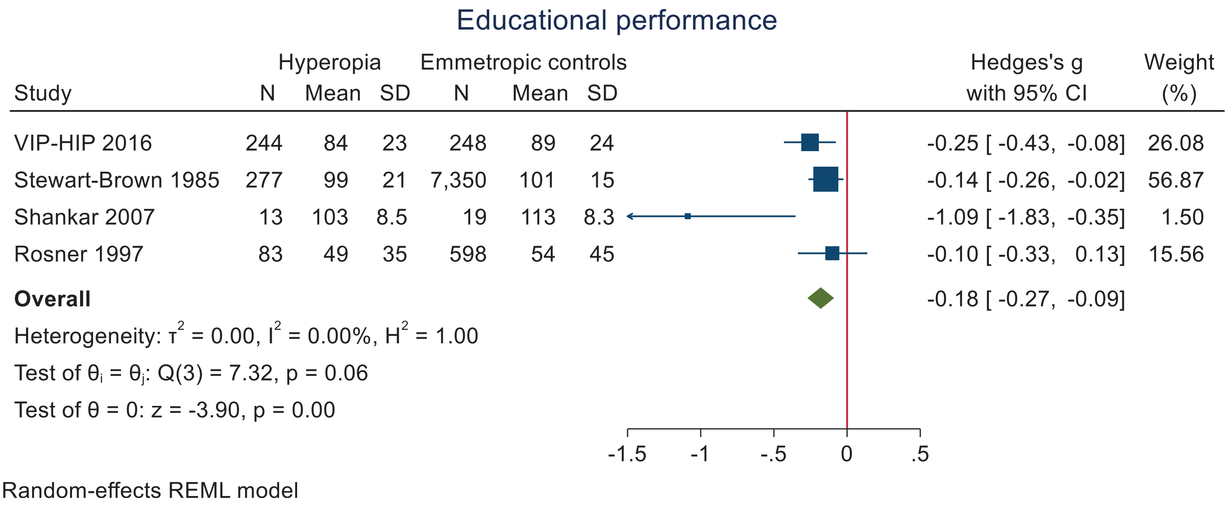

Figure 2. Results of random-effects meta-analysis for educational performance between hyperopic children and emmetropic control group. The number of hyperopic children and the emmetropic control group is shown for each study. Forest plots show effect sizes on educational performance using standard deviation scores (Hedges' g).

not find a significant association between uncorrected hyperopia and poor academic performance, some reported a significant difference (although *P* values were not reported) between uncorrected hyperopia and educational performance.[73,79] Two of the 4 interventional studies found a significant improvement in reading speed[29,53] with hyperopic spectacle correction, whereas the remaining 2 did not.[10,80] One study failed to report measured outcomes on a sufficient number of hyperopic participants.[78]

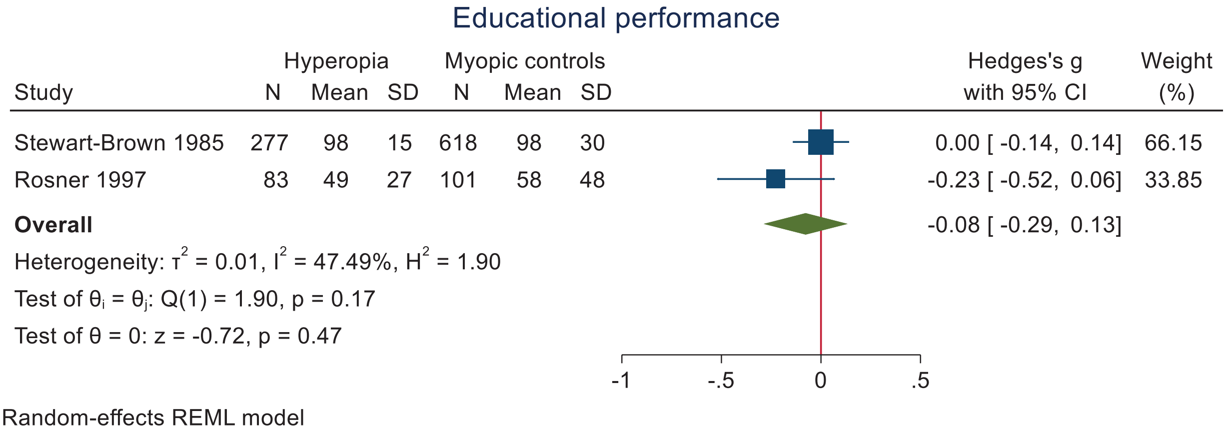

Figure 3. Results of random-effects meta-analysis for educational performance between hyperopic children and myopic control group. The number of hyperopic children and the myopic control group is shown for each study. Forest plots show effect sizes on educational performance using standard deviation scores (Hedges' g).

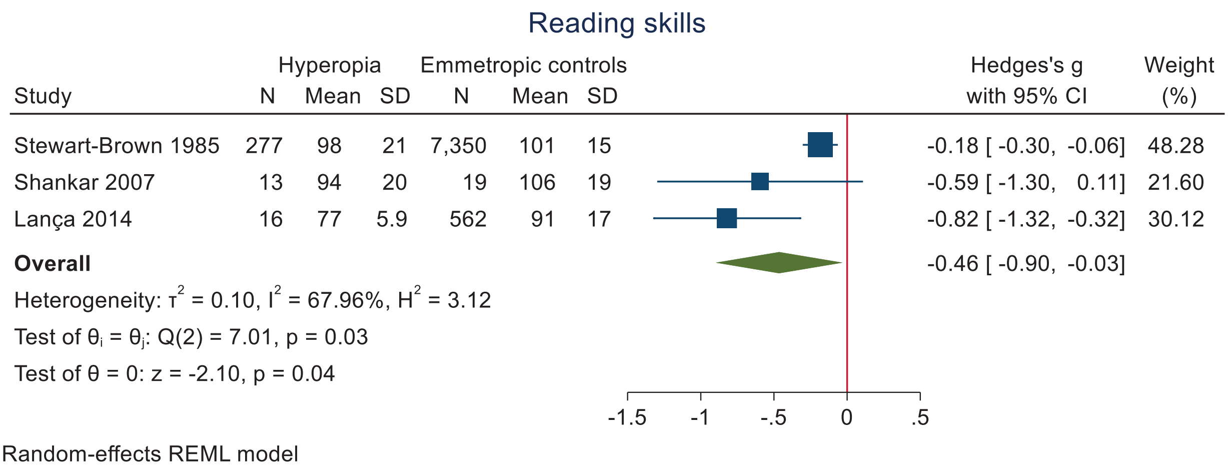

Figure 4. Results of random-effects meta-analysis for reading skills between hyperopic children and emmetropic control group. The number of hyperopic children and the emmetropic control group is shown for each study. Forest plots show effect sizes on reading skills using standard deviation scores (Hedges' g).

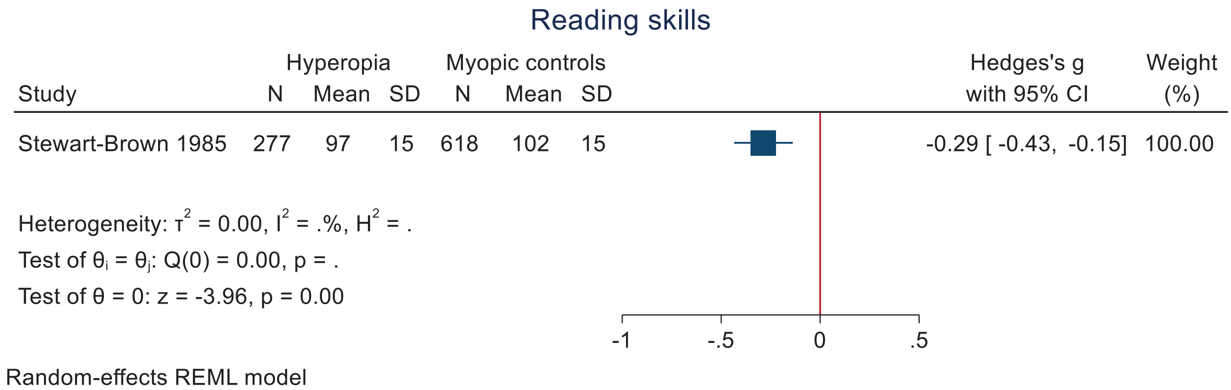

Figure 5. Results of random-effects meta-analysis for reading skills between hyperopic children and myopic control group. The number of hyperopic children and the myopic control group is shown for each study. Forest plots show effect sizes on reading skills using standard deviation scores (Hedges' g).

DISCUSSION

This systematic review summarizes the existing evidence from 25 eligible studies across 12 countries investigating the relationship between hyperopia and academic performance. The meta-analyses from 5 studies found a statistically significant association between uncorrected hyperopia and poor academic performance, whereas the narrative synthesis including all 20 studies found mixed results.

Our findings from the meta-analyses of 5 studies showed that children with uncorrected hyperopia had worse educational performance than the emmetropic children [SMD −0.18 (95% CI, −0.27 to −0.09)]. However, a significant difference was found when compared with myopic children [SMD −0.08 (95% CI, −0.29 to 0.13)]. A statistically significant difference was seen in the reading skills of uncorrected hyperopic children when compared with both emmetropic children [SMD −0.46 (95% CI, −0.90 to −0.03)] and myopic children [SMD −0.29 (95% CI, −0.43 to −0.15)]. Over half (52.6%, n = 10/19) of the studies included in the narrative synthesis reported a statistically significant association between uncorrected hyperopia and impaired academic performance.[29,33,67,68,70,71,75–77,80] Additionally, 2 interventional studies reported improvement in reading speed[29,53] when hyperopic spectacle correction was provided.

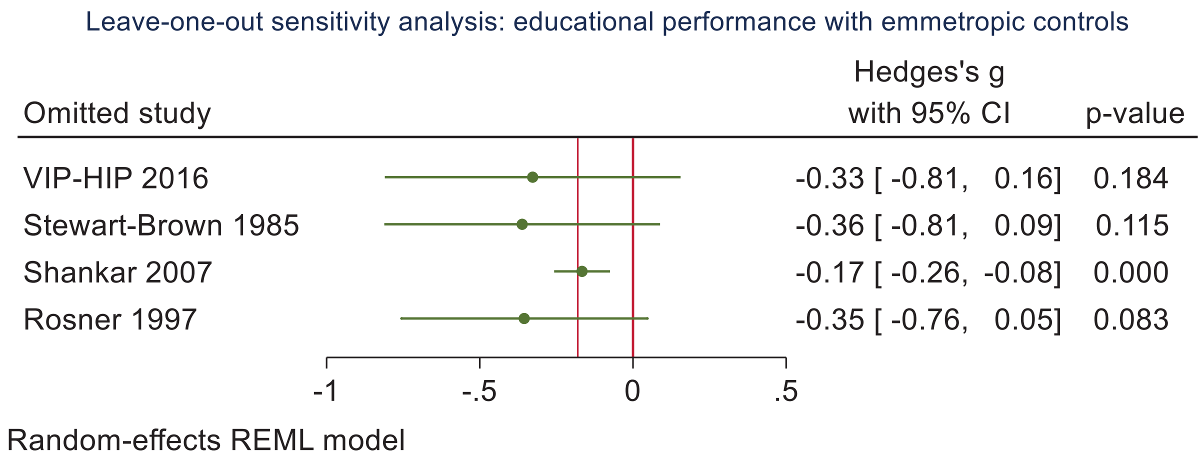

Figure 6. Results of leave-one-out sensitivity analysis for educational performance with the emmetropic control group.

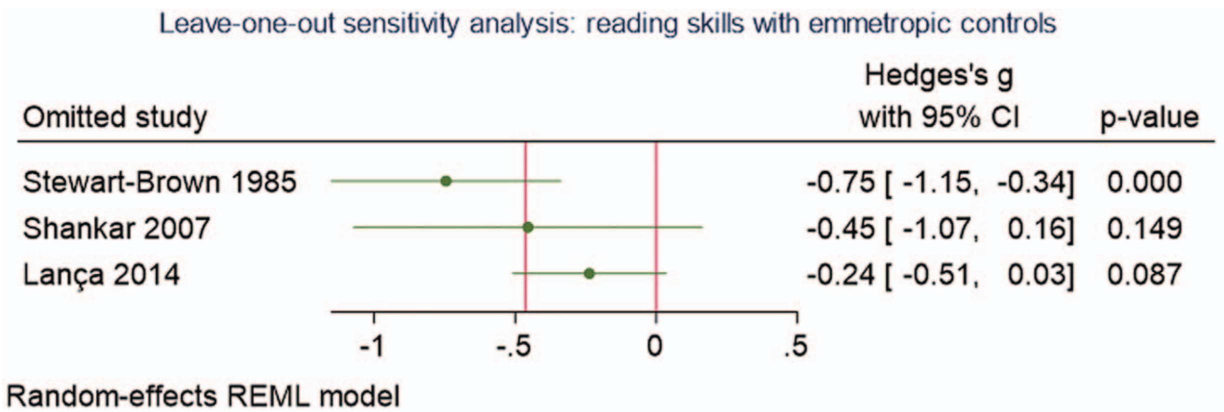

Figure 7. Results of leave-one-out sensitivity analysis for reading skills with the emmetropic control group.

Based on the 2 meta-analyses, greater ESs were seen in smaller studies, which could be confounded by methodological quality. The VIP-HIP study[28] was designed with sufficient statistical power to make comparisons between children with moderate hyperopia and emmetropia who underwent early literacy testing; this study found significant deficits in early literacy in children with uncorrected moderate hyperopia (+3.00 to +6.00 D) as compared to children with emmetropia, with the greatest deficits in hyperopic children with reduced near visual function (near stereoacuity, binocular near visual acuity, accommodative response). Further analysis of children participating in VIP-HIP also showed a significant association between reduced near visual function and moderate hyperopia ($P < 0.001$).[51] Children with low to moderate hyperopia also demonstrated worse near visual acuity, stereopsis, and accommodative responses (larger lags of accommodation).[83]

The majority of these studies indicate that uncorrected hyperopia is associated with impaired academic performance. However, the quality appraisal indicates that many of these studies provide only moderate to low evidence. A full-scale randomized clinical trial is needed to determine the causal association between hyperopic correction and academic performance. A further issue that remains unresolved is whether correction of hyperopia restores academic performance. Although the majority of studies have used different refractive groups as comparators, comparison between uncorrected and corrected hyperopic groups would provide valuable insights as to whether the correction of hyperopia contributes to improved academic performance in children.

Causality in the relationship between hyperopia and educational attainment has recently been tested in a Mendelian randomization study, which used a nonlinear relationship with refractive error to simultaneously model both myopia and hyperopia on data from adults participating in the UK Biobank study.[84] The study found little evidence to suggest hyperopia is a causal risk factor for lower years of educational attainment. However, there were significant methodological flaws, such as only including adult participants born in England or Wales and those of European ancestry. Some of whom were adequately corrected with spectacles for hyperopia during childhood.[84] Further, educational attainment was only measured by self-reported years of education, and self-report of spectacle wear during childhood as an adult may have introduced recall bias. The paper is nonetheless relevant to any consideration of the impact of hyperopia on educational attainment and underscores the need for randomized trials in the area to provide more reliable evidence.

Accommodation is important when assessing a child's visual function because it essentially dictates the retinal image quality.[85] Blur from poor accommodative response might go some way to explain the impact of uncorrected hyperopia on reading performance.[49,72,86] It has been suggested that hyperopes with milder degrees of uncorrected hyperopia can readily accommodate and therefore may not require optical correction.[87] However, recent studies have reported that the greater the magnitude of a child's hyperopia, the greater the variability of accommodation leading to more blur at near distances.[88–90] This can impact the accommodative-convergence interaction during near work, increasing difficulty in letter and word identification and potentially hindering a child's ability to read. Interventional studies investigating the impact of correcting hyperopia on academic performance have reported a statistically significant improvement in reading speed.[29,53] However, another yet unknown factor in interpreting the impact of hyperopic correction is the difference early or late intervention has in terms of academic performance. For example, if hyperopia correction occurs later in a child's educational years, does this diminish the benefit that hyperopic correction may otherwise yield?

Hyperopia prevalence is thought to be higher [by 1.82 times (95% CI, 1.03–3.23)] in children from disadvantaged compared to advantaged socioeconomic backgrounds.[91] Our review found only 5 studies that reported on participants from disadvantaged socioeconomic backgrounds.[10,28,74,77,80] However, the majority ($n = 13$, 52.0%) did not specify the sociodemographic setting.[12,27,53,64,65,67–73,79] We also found only 2 studies from LMICs.[64,65] Little emphasis has been placed on accurately measuring the prevalence of hyperopia and its impact on educational outcomes, especially among children in underserved settings, particularly in LMICs.

The lack of focus on hyperopia has led to methodological differences in its assessment and variation in outcome measurement tools, limiting comparisons across studies. A further difficulty in comparing studies is that the variation in the tools used to measure the magnitude of hyperopia can increase imprecision due to high inter-observer variability and measurement errors. For research studies investigating the prevalence of refractive error in children, cycloplegic refraction is the gold-standard method.[92] However, clinically, dry retinoscopy and subjective refraction are also used to measure refractive error, and the use of cycloplegia may vary. Cycloplegic refraction requires the use of drugs and protocols for administration, including multiple instillations of eyedrops and additional use of topical anesthetics for some populations to ensure an appropriate effect. Such regimes are more invasive, take more time and resources, and require trained professionals. Understandably, study protocols have considered alternative routes. This review's inclusion criteria were not limited to those studies that performed cycloplegic refraction. Nevertheless, without adopting cycloplegic methods to assess refractive error in children, studies using a definition from noncycloplegic conditions would very likely be under-reporting hyperopia.

A recent study highlighted the low sensitivity of noncycloplegic approaches for detecting hyperopia, reporting sensitivity for hyperopia defined as $>+0.50$ D and $>+1.00$ D in children and young adults aged 5 to 20 years using noncycloplegic autorefraction to be 38.9% and 22.1%, respectively.[93] Similar studies have also reported noncycloplegic measurement errors using autorefraction.[94,95] This reinforces the importance of conducting cycloplegic refraction to determine the true power and prevalence of hyperopia.[92]

The United Nations Educational Scientific Cultural Organization uses indicators to monitor and report each country's progress toward achieving the SDGs.[96] Despite increased participation in primary and lower secondary education globally since the World Declaration of Education for All in 1990,[97] only 37.0% of lower-secondary school children achieve minimum proficiency in reading according to the (adjusted) SDG Indicator 4.1.1.[96] Children in sub-Saharan Africa and Central and Southern Asia face greater challenges in education than any other regions, with only 15.0% and 21.0%, respectively, meeting minimum proficiency levels in lower-secondary education.[96] This highlights the need for interventional studies in schools to determine whether the early detection and correction of refractive errors could facilitate the success of early reading and writing programs.

Strengths and Limitations

This systematic review is the first to report the impact of hyperopia on academic performance, while combining both meta-analyses and narrative synthesis. The strengths of this review include a comprehensive search of the literature and the use of 2 authors to independently screen and select studies and extract data. Nonetheless, there are several limitations. The study synthesis of the existing literature under review was limited due to methodological differences, inconsistent measurement tools, the small number of hyperopic children recruited in most cohorts, and the lack of information about the severity of hyperopia, which could have led to inaccurate findings. Furthermore, the definition of hyperopia differs considerably across studies, further limiting overall comparability. Many of the included studies are cross-sectional, which limits inference regarding causality. Our findings were limited by the variation in tests used to identify hyperopia, with 4 studies (16.0%) using the plus-lens test, which may not reliably detect low to moderate hyperopia.[98] Because of the paucity of studies that have investigated visual attention[53,75] and visual-motor integration,[27,74,75,80] we could not explore the association between hyperopia and these domains in this review. However, 2 more recent studies[83,99] have reported poorer visual attention and visual-motor integration in those with hyperopia, and these higher functions are promising areas that warrant further investigation. Because fewer than 10 studies were included in our meta-analyses, we could not test for publication and reporting biases, which are likely in observational studies that do not require prior registration. Also, most (n = 22, 88.0%) studies were conducted in high-income countries. Therefore, their data might not represent LMICs, making it difficult to inform policy in such settings, where the majority of the world's children live.

CONCLUSIONS

This is the first systematic review and meta-analysis to focus on the impact of uncorrected hyperopia and hyperopic spectacle correction on academic performance globally. We found an association between uncorrected hyperopia and children's poor educational performance and reading skills. However, firm conclusions are difficult to draw due to considerable heterogeneity in study design features and methodology, definitions of hyperopia used, assessment of academic performance, and the small number of hyperopic children recruited in some studies. Hyperopia in children, if left undetected, could have a significant negative effect on economic and academic opportunities throughout life. Standardized definitions, survey methodologies, and practical screening methodologies, together with randomized controlled trials, are required to determine the magnitude of the issue and develop evidence-based solutions to tackle it.

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