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Zakaria Omar Sheck
sheck.zakaria@studwc.kiu.ac.ug
Kampala International University
Mohamed Farah Ismail
Kampala International University
Intisar Khalafalla
Kampala International University
Chalachew Muche Alemayehu
Kampala International University
Isse Muse Osobow
Kampala International University
Theoneste Hakizimana
Mbarara University of Science and Technology

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Prevalence and Patterns of Refractive Errors Among College Students in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis

Zakaria Omar Sheck[1], Mohamed Farah Ismail[1], Intisar Khalafalla[1], Chalachew Muche Alemayehu[1], Isse Muse Osobow[2], Theoneste Hakizimana[3]

AFFILIATIONS

[1] Department of Ophthalmology and Visual Sciences, Faculty of Clinical Medicine and Dentistry, Kampala International University, Bushenyi, Uganda

[2] Department of Internal Medicine, Faculty of Clinical Medicine and Dentistry, Kampala International University, Bushenyi, Uganda

[3] Department of Obstetrics and Gynecology, Faculty of Clinical Medicine and Dentistry, Kampala International University, Bushenyi, Uganda

Corresponding author:

Zakaria Omar Sheck

Department of Ophthalmology and Visual Sciences, Faculty of Clinical Medicine and Dentistry, Kampala International University, Bushenyi, Uganda

Email: sheck.zakaria@studwc.kiu.ac.ug

Abstract

Background: Uncorrected refractive error is the leading cause of correctable visual impairment worldwide, and students in visually demanding curricula may be at particular risk, yet routine vision screening is inconsistent across low- and middle-income countries (LMIC). We estimated the pooled prevalence and pattern of refractive error among college and university students in LMIC.

Methods: We searched PubMed/MEDLINE and complementary regional and web-based sources for cross-sectional studies reporting refractive error prevalence among college or university students in low- or middle-income countries (World Bank classification); the review was registered in PROSPERO (CRD420261475059). Study-level proportions were logit-transformed and pooled using a random-effects model with restricted maximum likelihood estimation and the Knapp–Hartung adjustment. Robustness was assessed by sensitivity, leave-one-out and subgroup analyses and under two alternative model specifications.

Results: Fourteen cross-sectional studies from 12 low- and middle-income countries, comprising 5,431 students, were included; 2,663 had refractive error of any type, 1,947 myopia, 908 astigmatism and 254 hyperopia. The pooled prevalence of any refractive error was 50.7% (95% CI 35.0–66.3%; 95% prediction interval 8.0–92.5%). Myopia predominated (28.7%, 18.9–41.1%), followed by astigmatism (11.6%, 5.4–23.0%) and hyperopia (4.2%, 2.3–7.6%). Heterogeneity was extreme for every outcome (I^2 93.7–98.9%), and the pooled estimate was stable across all robustness analyses (46.7–54.6%). In exploratory, post-hoc subgroup analysis, pooled myopia prevalence was 24.9% where categories were mutually exclusive versus 44.3% where they could overlap (P = .032, unadjusted for multiple comparisons), with no difference for any refractive error (P = .533). No clear funnel-plot asymmetry was detected for the primary outcome; subtype asymmetry tests were difficult to interpret because the logit standard error depends on the proportion itself.

Conclusions: Around half of college students in the LMIC settings sampled have refractive error, predominantly myopia, but extreme heterogeneity means the pooled figure should be read alongside its wide prediction interval rather than as a generalisable value. These findings support consideration of routine, low-cost vision screening at tertiary-education entry and greater methodological standardisation in future primary studies.

Keywords: refractive error; myopia; astigmatism; hyperopia; college students; university students; low- and middle-income countries; systematic review; meta-analysis

Introduction

Uncorrected refractive error is the leading cause of correctable visual impairment and a major cause of blindness worldwide. At least 2.2 billion people globally have a near or distance vision impairment, and in almost half of these cases the impairment could have been prevented or has yet to be addressed (1). In 2020 alone, an estimated 3.7 million people were blind, and 157 million had moderate-to-severe vision impairment specifically due to uncorrected refractive error, a 21.8% increase in blindness and a 72.0% increase in moderate-to-severe impairment attributable to this cause since 2000, even as blindness from most other causes has declined (1) (2). Only around one-third of people with refractive error worldwide have access to a pair of spectacles adequate to restore functional vision, and this access gap is concentrated disproportionately in low- and middle-income countries (LMIC): South Asia and the combined East Asia–Southeast Asia–Oceania super-region together account for roughly 70% of the global caseload (2).

Young adults in tertiary education represent a population in whom refractive error carries a distinctive set of costs. Near-work-intensive study (reading, screen use and, for health-profession students in particular, microscopy and fine clinical work) has long been implicated as a risk factor for myopia onset and progression. A recent international meta-analysis of myopia and near work reported a pooled myopia prevalence of 35% (95% CI 30–41%) across the populations studied, rising to 46% (95% CI 30–62%) among adults, and identified sustained near work as a consistent correlate (3). Broader syntheses spanning children through adults across all income settings have estimated considerably higher pooled rates of astigmatism (40.4%) and hyperopia (30.9%) in unselected adult populations than of myopia (26.5%) (4), but these income-unrestricted, all-age estimates are not specific to the tertiary-education population, nor stratified by country income classification, and so offer limited direct guidance for LMIC student vision policy.

A substantial body of single-institution, cross-sectional literature has accumulated across individual LMIC settings over the past decade, from Ghana to Nepal and from Jordan to Paraguay, with each study reporting refractive error prevalence within a defined student cohort. Individually, these studies are difficult to generalise: sample sizes are modest (105 to 1,462 participants in the literature identified for this review), refraction protocols and diagnostic thresholds vary between studies, and no single study can characterise the burden across the diversity of LMIC settings and academic disciplines. To our knowledge, no prior systematic review has quantitatively pooled refractive error prevalence specifically among college and university students within LMIC, as distinct from reviews restricted to a single country, to school-age children, to unselected general adult populations or to high-income settings.

This systematic review and meta-analysis therefore aimed to (i) estimate the pooled prevalence of any refractive error, and of myopia, hyperopia and astigmatism specifically, among college and university students in LMIC; (ii) characterise the pattern of refractive error subtypes across included studies and regions; and (iii) evaluate the sources, extent and robustness of between-study heterogeneity, including a risk-of-bias sensitivity analysis and formal assessment of small-study effects and funnel-plot asymmetry.

Methods

Study design and reporting framework

This systematic review and meta-analysis was conducted to estimate the pooled prevalence and pattern of refractive error (any refractive error, myopia, hyperopia and astigmatism) among college and university students in low- and middle-income countries. The review was prepared in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines, and the completed PRISMA 2020 checklist is provided in the supplementary file. The certainty of the pooled prevalence estimates was not formally graded; interpretation instead considered risk of bias, heterogeneity, prediction intervals and the sensitivity analyses reported below. Since the study was based entirely on previously published, publicly available data, ethical approval and informed consent were not required.

Protocol and registration

The review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD420261475059.

Eligibility criteria

Studies were eligible if they (i) sampled undergraduate or graduate students enrolled at a college, university or equivalent tertiary institution; (ii) were conducted in a country classified as low- or middle-income by the World Bank at the time of publication; (iii) used a cross-sectional design or reported the cross-sectional baseline of a longitudinal study; (iv) reported, or provided sufficient data to calculate, the prevalence of any refractive error or of myopia, hyperopia or astigmatism specifically, with a clearly defined denominator; and (v) were published as full-text, peer-reviewed articles in English or Spanish. Studies were excluded if they sampled school-age children, non-student adult populations or an exclusively high-income-country cohort; reported only risk-factor associations without extractable

prevalence data; were narrative reviews, case reports or conference abstracts without sufficient data; or represented a duplicate sample already captured by another included study.

Information sources and search strategy

We searched PubMed/MEDLINE on 5 August 2026 using terms for refractive error ("refractive error", "myopia", "hyperopia", "astigmatism"), population ("student", "college", "university", "undergraduate") and study type ("prevalence", "cross-sectional"), retrieving 863 records. We supplemented this with systematic searches of Google Scholar, African Journals Online (AJOL), Nepal Journals Online (NepJOL), Scientific Research Publishing (SCIRP), Semantic Scholar, regional repositories (including the Revistas Científicas of the Universidad Nacional de Asunción and the Journal of Women Medical and Dental College), and backward citation searching of all retrieved full texts. We used a single indexed database for the structured search because preliminary scoping indicated that the relevant LMIC student-refraction literature is predominantly published in regional or institutional journals not indexed in major commercial databases; the supplementary sources were therefore treated as a pre-planned, systematic component of retrieval rather than an incidental add-on, and the same eligibility criteria were applied uniformly across all sources. The full search strategy, information sources and search-output audit trail are provided in the supplementary file; the limitations of this approach are addressed in the Discussion.

Study selection and data extraction

Records were screened independently in two stages (title/abstract, then full text) by two reviewers, with disagreements resolved by discussion or, where necessary, a third reviewer. For each included study, data were extracted in duplicate onto a standardised form capturing author, publication year, country, geographic region, academic discipline sampled, sampling frame and method, refraction protocol (cycloplegic versus non-cycloplegic; objective autorefraction, retinoscopy or subjective refraction versus self-report), sample size and the number of participants with any refractive error and with myopia, hyperopia and astigmatism specifically. Fourteen studies met all eligibility criteria (Figure 1) and all fourteen were included in the primary quantitative synthesis (Table 1). One study (Mvilongo et al., Cameroon; N = 131) reported a participation rate of 54.6%, substantially lower than any other included study. Because a low participation rate is a source of selection bias rather than a criterion of ineligibility, this study was retained in the primary synthesis, rated at high risk of bias in the domain concerned (Table 2), and its influence on the pooled estimate quantified in a risk-of-bias sensitivity analysis (see Statistical analysis). It was also the only study to employ cycloplegic refraction; because cycloplegia is the reference

standard in this age group, this is recorded as a methodological strength and a source of between-study diversity, not as a reason for exclusion.

Risk of bias assessment

Risk of bias in individual studies was appraised independently by two reviewers using a checklist adapted from the Newcastle–Ottawa Scale for cross-sectional studies (5), covering the sampling frame and method, sample size, reporting of response rate and objectivity of refractive error ascertainment (clinical refraction versus self-report). Each domain was rated and an overall risk-of-bias judgement of low, moderate or high was assigned per study (Table 2) using explicit decision rules defined operationally for this review rather than taken from the source instrument: a study was rated high risk if refractive error was not ascertained by clinical refraction or if a reported participation rate was below 60%; low risk if it drew a probability-based sample from a population-based sampling frame, examined at least 400 participants and used clinical refraction; and moderate risk otherwise, which in practice meant a single-institution non-probability sample assessed by clinical refraction. The 60% participation and 400-participant thresholds are review-specific operational cut-offs, not thresholds specified by the Newcastle–Ottawa Scale, and are stated here so that every rating in Table 2 can be reproduced. The full instrument, the permissible judgement for each domain and these rules are reproduced in the supplementary file. No study was excluded from the primary synthesis on risk-of-bias grounds alone; risk-of-bias-related sources of heterogeneity were instead explored narratively (see Discussion).

Statistical analysis

All statistical analyses were performed in JASP 0.98.1 (JASP Team). For each outcome (any refractive error, myopia, hyperopia, astigmatism), study-level proportions were logit-transformed with the corresponding standard error and pooled using a random-effects model with restricted maximum likelihood (REML) estimation of the between-study variance (τ^2) and the Knapp–Hartung adjustment to confidence intervals, which is recommended for meta-analyses with a small number of studies. Pooled logit estimates and their 95% confidence intervals were back-transformed to prevalence percentages for presentation. Heterogeneity was quantified using τ, τ^2, I^2 and Cochran's Q, and 95% prediction intervals were calculated to indicate the range of prevalence expected in a comparable future study. A risk-of-bias sensitivity analysis assessed the robustness of the pooled estimate for any refractive error to the exclusion of the single study rated at high risk of selection bias on account of its low participation rate. This analysis, and the two further sensitivity analyses described below, were specified after the protocol was registered and are therefore reported as post hoc. Two further, post hoc sensitivity analyses were performed: the

pooled estimates were recalculated with the single study that ascertained refractive error by self-report removed, and a leave-one-out analysis was conducted in which each study in turn was omitted and the pooled estimate for any refractive error re-estimated. Small-study effects and potential publication bias were assessed for each outcome using funnel plots and two complementary asymmetry tests: a meta-regression (Egger-type) test of effect size on standard error, and its variance-weighted counterpart. Statistical significance was set at $p < .05$ throughout.

Two further analyses, both post hoc and not part of the registered protocol, were added to explore heterogeneity and to test the robustness of the model specification. First, subgroup analyses were conducted for geographical region, for the case-definition convention used for astigmatism (mutually exclusive categories versus categories permitted to coexist with a spherical diagnosis), and for academic discipline; subgroups containing a single study were described but not pooled, and differences between subgroups were tested with a between-group Q statistic. Formal meta-regression was not attempted, because with 14 studies such models are substantially underpowered and prone to spurious findings.

Second, because pooled prevalence can depend on the variance-stabilising transformation chosen, each outcome was re-estimated under two alternative specifications: a random-effects model on the Freeman–Tukey double-arcsine transformation, back-transformed using the harmonic mean sample size, and a binomial-normal generalised linear mixed model with a random study intercept, fitted by maximum likelihood with adaptive Gauss–Hermite quadrature and profile-likelihood confidence intervals.

Results

Study selection

The search and screening process is summarised in the PRISMA 2020 flow diagram (Figure 1). The structured PubMed/MEDLINE search returned 863 records and the supplementary sources returned a further 486, giving 1,349 records in total. After 317 duplicates were removed, 1,032 records were screened on title and abstract, of which 912 were excluded. All 120 reports sought for retrieval were obtained and assessed in full, and 106 were excluded: 27 were not conducted in a low- or middle-income country, 66 did not sample college or university students and 13 reported no extractable prevalence data. Fourteen cross-sectional studies, comprising 5,431 university and college students across 12 low- and middle-income countries, met all eligibility criteria and contributed data to the quantitative synthesis. The included studies were published between 2016 and 2025. Five studies were conducted in Africa

(Cameroon, Ghana, Nigeria, Uganda and Zambia), four in Asia (India, n = 2; Nepal; Pakistan), four in the Middle East (Iran, Jordan and Saudi Arabia, n = 2) and one in South America (Paraguay).

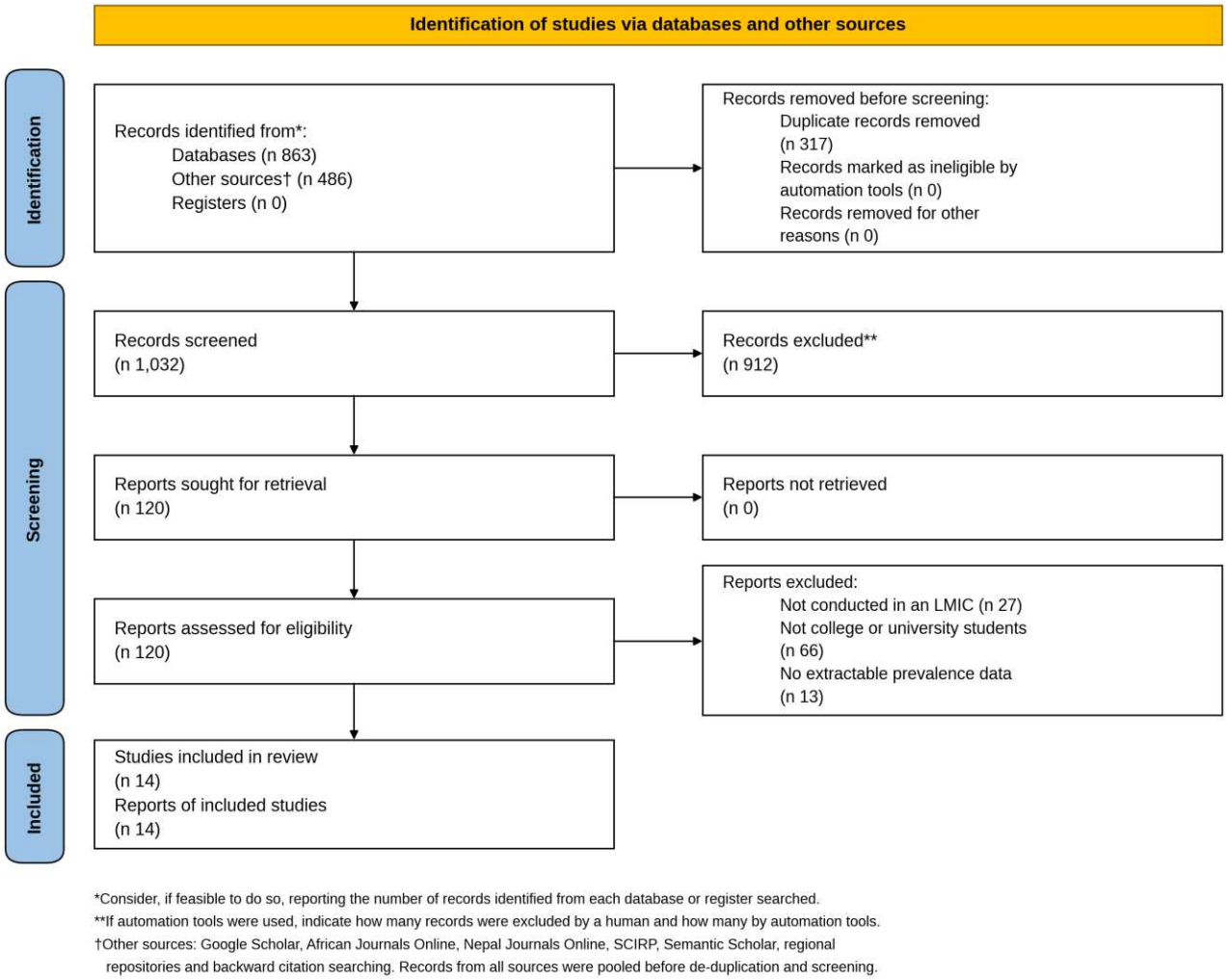


Figure 1. PRISMA 2020 flow diagram for the identification, screening and inclusion of studies. Records retrieved by the structured PubMed/MEDLINE search and by the supplementary sources were pooled before de-duplication and screening. AJOL, African Journals Online; NepJOL, Nepal Journals Online; SCIRP, Scientific Research Publishing. Diagram adapted from the PRISMA 2020 flow diagram template (Page MJ, et al. BMJ 2021;372:n71), used under CC BY 4.0.

Characteristics of included studies

The 14 studies contributed 5,431 examined students in total, of whom 2,663 had refractive error of any type. Sample sizes ranged from 105 participants (Darko-Takyi et al., Ghana (6)) to 1,462 (Hashemi et al., Iran (9)), the latter contributing 26.9% of the total pooled sample. Thirteen of the 14 studies employed clinical refraction: twelve used non-cycloplegic autorefraction with subjective verification or retinoscopy, and one (Mvilongo et al. (19)) used cycloplegic refraction; the remaining study (Alqudah et al. (15)) ascertained refractive error status by self-report. Twelve studies recruited students of medicine or the health sciences; one sampled optometry undergraduates (Darko-Takyi et al. (6)) and one sampled students

of engineering and information technology (Arslan & Yasin (18)). One study (Hashemi et al. (9)) employed multi-stage cluster sampling across all four universities in a single city and was the only population-based survey in the set; the remaining thirteen were single-institution studies.

Crude prevalence of any refractive error varied more than eightfold across studies, from 10.8% (Ibrahim et al., Nigeria (13)) to 90.8% (Mvilongo et al., Cameroon (19)). Study-level characteristics and event counts are presented in Table 1.

Table 1. Characteristics and event counts of the 14 included studies (N = 5,431).

Author (year)	Country	Region	N	RE n (%)	My n	My %	Hyp n	Hyp %	Ast n	Ast %
Darko-Takyi et al. (2016) (6)	Ghana	Africa	105	62 (59.0)	18	17.1	20	19.0	24	22.9
Karki et al. (2018) (7)	Nepal	Asia	253	54 (21.3)	37	14.6	1	0.4	16	6.3
Al-Rashidi et al. (2018) (8)	Saudi Arabia	Middle East	162	95 (58.6)	87	53.7	6	3.7	2	1.2
Hashemi et al. (2020) (9)	Iran	Middle East	1,462	717 (49.0)	624	42.7	34	2.3	431	29.5
Abuallut et al. (2020) (10)	Saudi Arabia	Middle East	447	218 (48.8)	151	33.8	47	10.5	47	10.5
Satapathy et al. (2020) (11)	India	Asia	200	130 (65.0)	113	56.5	3	1.5	14	7.0
Torres Mazari et al. (2020) (12)	Paraguay	S. America	208	149 (71.6)	120	57.7	11	5.3	65	31.2
Ibrahim et al. (2022) (13)	Nigeria	Africa	157	17 (10.8)	12	7.6	3	1.9	2	1.3
Serenje et al. (2023) (14)	Zambia	Africa	210	141 (67.1)	44	21.0	18	8.6	79	37.6
Alqudah et al. (2023) (15)	Jordan	Middle East	700	525 (75.0)	434	62.0	47	6.7	44	6.3
Munoli et al. (2024) (16)	India	Asia	425	160 (37.6)	78	18.4	41	9.6	41	9.6
Kamara et al. (2024) (17)	Uganda	Africa	368	97 (26.4)	58	15.8	3	0.8	36	9.8
Arslan & Yasin (2024) (18)	Pakistan	Asia	603	179 (29.7)	152	25.2	9	1.5	18	3.0
Mvilongo et al. (2025) (19)	Cameroon	Africa	131	119 (90.8)	19	14.5	11	8.4	89	67.9
Total	**12 countries**	**4 regions**	**5,431**	**2,663 (49.0)**	**1,947**	**35.8**	**254**	**4.7**	**908**	**16.7**

N, total participants examined; RE, any refractive error; My, myopia; Hyp, hyperopia; Ast, astigmatism. Percentages are calculated against the total number of participants examined in each study. Subtype counts exceed the number of refractive error cases in three studies (Hashemi et al. (9), Abuallut et al. (10), Torres Mazari et al. (12)) because these studies permitted astigmatism to be recorded alongside a spherical diagnosis. For Mvilongo et al. (19), subtype counts were derived from the reported proportions of cases (astigmatism 74.8%, myopia 16.0%, hyperopia 9.2% of 119 cases) and are expressed here against the number examined.

Risk of bias within studies

Overall risk of bias, judged using the checklist described in Methods, was low in one study, moderate in eleven studies and high in two studies (Table 2). The single population-based study (Hashemi et al. (9)) was the only one rated low risk, reflecting its multi-stage cluster sampling frame, large sample size and objective clinical refraction. Eleven single-institution studies that used objective clinical refraction (autorefraction, retinoscopy or subjective refraction) were rated moderate risk; most sampled by convenience, and only one reported a response rate. Two studies were rated high risk, for different reasons. Alqudah et al. (15) ascertained refractive error status via an online, self-administered questionnaire rather than in-person clinical refraction, introducing potential recall and under-ascertainment bias not present in

the other thirteen studies. Mvilongo et al. (19) used cycloplegic refraction, the most rigorous ascertainment method in the set, but recruited only 131 of 240 eligible students (54.6%), the lowest participation rate reported by any included study, so selection bias cannot be excluded. No study reported a formal comparison of responders and non-responders, and a response rate was explicitly stated in only two studies (Arslan & Yasin (18): 603/623 eligible students, 96.8%; Mvilongo et al. (19): 131/240, 54.6%); this is flagged as a general limitation of the evidence base (see Discussion).

Table 2. Risk-of-bias assessment of the 14 included studies (adapted Newcastle–Ottawa Scale for cross-sectional studies).

Study	Sampling frame	Sample size	Random / systematic selection	Response rate reported	Objective refraction	Overall risk of bias
Darko-Takyi et al. (2016) (6)	Single institution	105	No (census of cohort)	No	Yes	Moderate
Karki et al. (2018) (7)	Single institution	253	No (convenience)	No	Yes	Moderate
Al-Rashidi et al. (2018) (8)	Single institution	162	No (convenience)	No	Yes	Moderate
Hashemi et al. (2020) (9)	Population-based, multi-stage cluster	1,462	Yes	Unclear	Yes	Low
Abuallut et al. (2020) (10)	Single institution	447	Yes (random sample)	No	Yes	Moderate
Satapathy et al. (2020) (11)	Single institution	200	No (convenience)	No	Yes	Moderate
Torres Mazari et al. (2020) (12)	Single institution	208	No (convenience)	No	Yes	Moderate
Ibrahim et al. (2022) (13)	Single institution	157	No (convenience)	No	Yes	Moderate
Serenje et al. (2023) (14)	Single institution	210	No (convenience)	No	Yes	Moderate
Alqudah et al. (2023) (15)	Single institution, online survey	700	Yes (random distribution)	No	No (self-report)	High
Munoli et al. (2024) (16)	Single institution	425	No (convenience)	No	Yes	Moderate
Kamara et al. (2024) (17)	Single institution	368	No (convenience)	No	Yes	Moderate
Arslan & Yasin (2024) (18)	Single institution	603	No (convenience)	Yes (96.8%)	Yes	Moderate
Mvilongo et al. (2025) (19)	Single institution	131	No (convenience)	Yes (54.6%)	Yes (cycloplegic)	High (low participation)

Pooled prevalence of any refractive error

Across the 14 included studies, 2,663 of the 5,431 students examined had refractive error of any type, a crude unweighted prevalence of 49.0%. Pooled analysis of all 14 studies using a random-effects model with restricted maximum likelihood estimation and the Knapp–Hartung adjustment yielded a logit-transformed estimate of 0.029 (SE 0.299; 95% CI −0.617 to 0.676), corresponding to a prevalence of any

refractive error of 50.7% (95% CI 35.0–66.3). Between-study heterogeneity was substantial ($\tau = 1.097$, $\tau^2 = 1.203$, 95% CI 0.622–3.274; $I^2 = 98.93\%$, 95% CI 97.95–99.60; $Q(13) = 634.36$, $p < .001$), and the 95% prediction interval was correspondingly wide at 8.0–92.5%. Because τ^2 substantially exceeded the within-study variances, random-effects weights were near-uniform across studies, ranging from 6.78% to 7.28%; the largest study therefore exerted no greater influence on the pooled estimate than the smallest. The forest plot is shown in Figure 2.

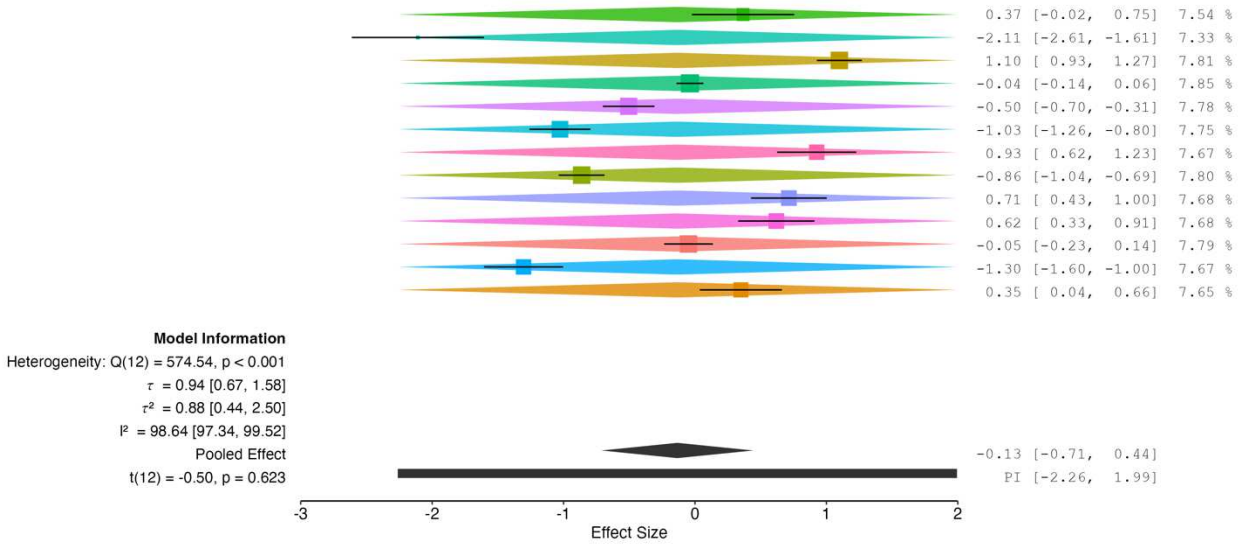


Figure 2. Forest plot of the pooled prevalence of any refractive error among college students in low- and middle-income countries (k = 14).

Effect sizes are logit-transformed proportions; squares denote study point estimates, scaled by random-effects weight, and horizontal lines the 95% confidence intervals. The diamond represents the pooled random-effects estimate and the horizontal bar below it the 95% prediction interval. The dashed vertical line marks the pooled estimate.

Patterns of refractive error

Across all 14 studies, 1,947 of the 5,431 students examined had myopia (crude prevalence 35.8%), 908 had astigmatism (16.7%) and 254 had hyperopia (4.7%). In the three studies that allowed a participant to carry more than one refractive diagnosis these subtype counts overlap, so they do not sum to the 2,663 students recorded with any refractive error. Each refractive error subtype was pooled separately against the total number of participants examined. Myopia was the predominant subtype, with a pooled prevalence of 28.7% (95% CI 18.9–41.1; logit −0.909, SE 0.255; $t(13) = -3.56$, $p = .004$). Astigmatism followed at 11.6% (95% CI 5.4–23.0; logit −2.031, SE 0.382; $t(13) = -5.32$, $p < .001$), and hyperopia was least frequent at 4.2% (95% CI 2.3–7.6; logit −3.122, SE 0.291; $t(13) = -10.72$, $p < .001$). Pooled estimates for all four outcomes are summarised in Table 3, and the corresponding forest plots are presented in Figures 3 to 5.

Myopia was the commonest refractive error in 11 of the 14 studies. All three exceptions were African: in Darko-Takyi et al. (Ghana (6)), Serenje et al. (Zambia (14)) and Mvilongo et al. (Cameroon (19)), astigmatism predominated, accounting for 22.9%, 37.6% and 67.9% of participants respectively against myopia prevalences of 17.1%, 21.0% and 14.5%.

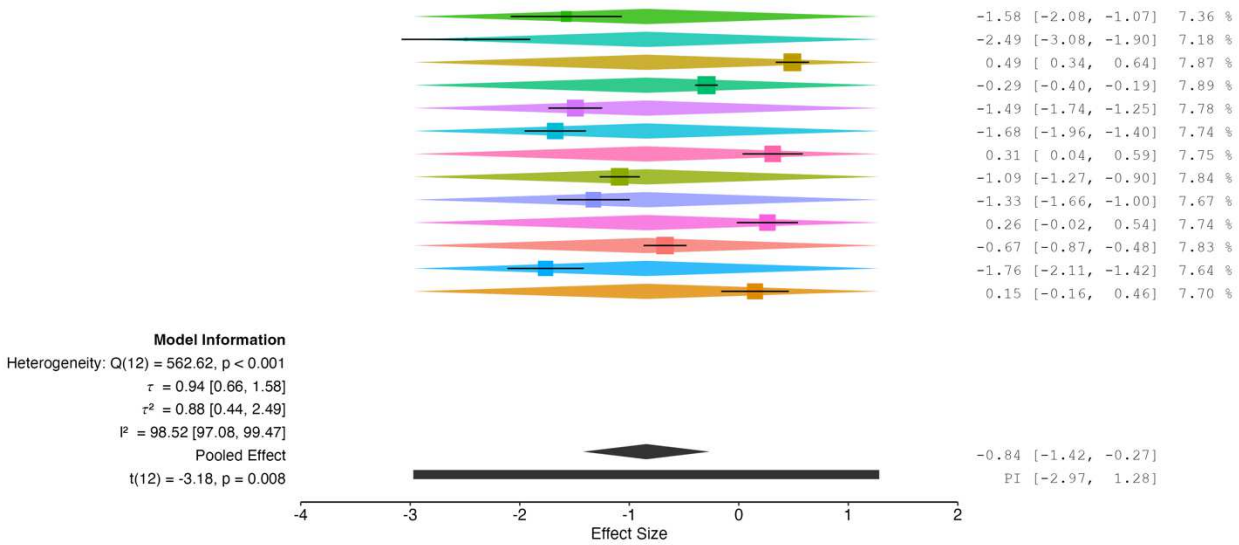


Figure 3. Forest plot of the pooled prevalence of myopia (k = 14).

Pooled estimate −0.91 (95% CI −1.46 to −0.36) on the logit scale, corresponding to 28.7% (95% CI 18.9–41.1).

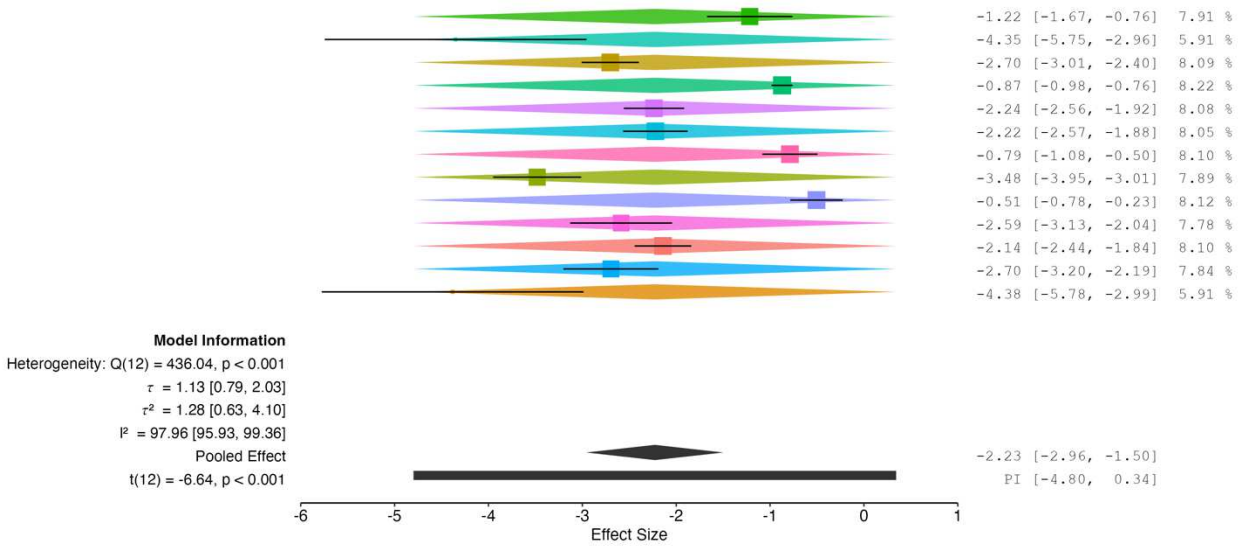


Figure 4. Forest plot of the pooled prevalence of astigmatism (k = 14).

Pooled estimate −2.03 (95% CI −2.86 to −1.21) on the logit scale, corresponding to 11.6% (95% CI 5.4–23.0).

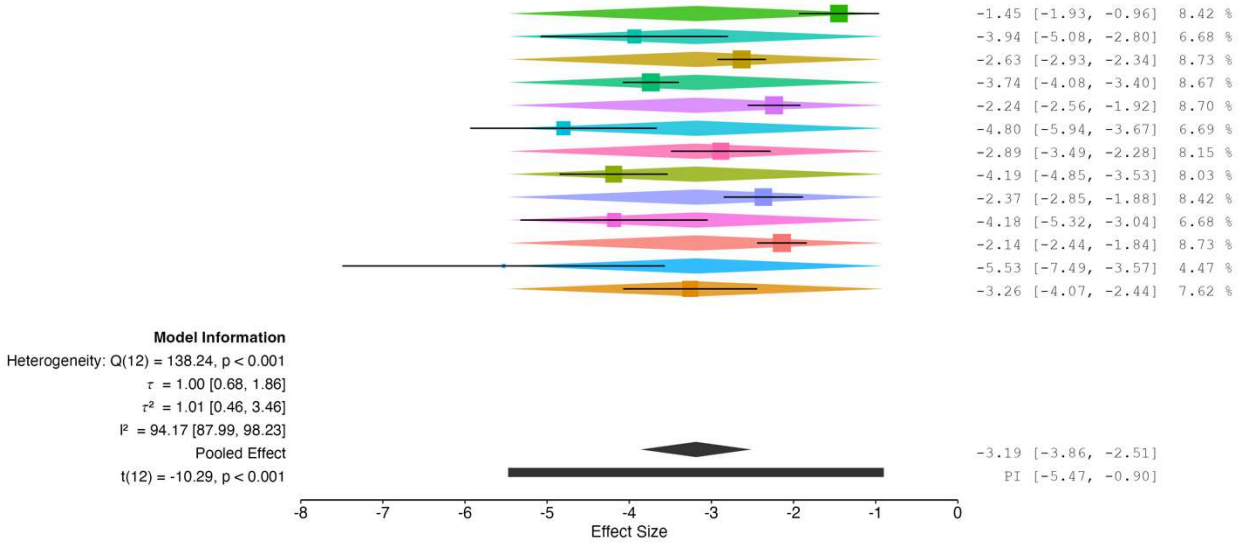


Figure 5. Forest plot of the pooled prevalence of hyperopia (k = 14).

Pooled estimate −3.12 (95% CI −3.75 to −2.49) on the logit scale, corresponding to 4.2% (95% CI 2.3–7.6).

Table 3. Pooled random-effects estimates for any refractive error and by subtype (k = 14; N = 5,431).

Outcome	k	N	Cases (n)	Pooled logit (SE)	Prevalence % (95% CI)	95% PI (%)	τ^2	I^2 (%)	Q(13)
Any refractive error	14	5,431	2,663	0.029 (0.299)	50.7 (35.0–66.3)	8.0–92.5	1.203	98.93	634.36
Myopia	14	5,431	1,947	−0.909 (0.255)	28.7 (18.9–41.1)	4.7–76.9	0.874	98.41	589.73
Astigmatism	14	5,431	908	−2.031 (0.382)	11.6 (5.4–23.0)	0.6–74.3	1.870	98.59	560.40
Hyperopia	14	5,431	254	−3.122 (0.291)	4.2 (2.3–7.6)	0.5–28.6	0.941	93.65	139.19

k, number of studies; N, pooled sample size; cases, total number of participants with the outcome across all studies; PI, prediction interval; τ^2, between-study variance; I^2, proportion of total variability attributable to heterogeneity. All models used restricted maximum likelihood estimation with the Knapp–Hartung adjustment on the logit scale. All Q statistics were significant at $p < .001$. Percentages are back-transformed from the logit scale.

Heterogeneity

Sources of clinical and methodological diversity identified a priori included the refraction protocol (all participants refracted versus refraction restricted to those failing a visual acuity threshold), the spherical equivalent and cylinder thresholds used to define each subtype, the sampling frame (population-based cluster sampling versus single-institution convenience sampling), the academic discipline of the sampled cohort and geographical region. Three studies (Hashemi et al. (9), Abuallut et al. (10) and Torres Mazari et al. (12)) classified astigmatism as a category that could coexist with a spherical diagnosis, whereas the remaining eleven assigned each participant to a single mutually exclusive category; in the former group, subtype counts consequently exceeded the number of participants with any refractive error.

Heterogeneity was extreme for every outcome and was not attributable to any single study. I^2 exceeded 98% for any refractive error, myopia and astigmatism, and was 93.65% (95% CI 87.36–98.02) for hyperopia, the most consistent of the four outcomes. Prediction intervals were correspondingly wide: for any refractive error, a future study conducted in a comparable setting would be expected to report a prevalence anywhere between 8.0% and 92.5%. The prediction intervals for astigmatism (0.6–74.3%) and hyperopia (0.5–28.6%) likewise spanned an order of magnitude or more. Subgroup analyses (Table 4) accounted for only part of this variation. These intervals indicate that the pooled point estimates should not be interpreted as generalisable single values, and that the observed variation reflects genuine differences between study populations and methods rather than sampling error alone.

Subgroup analyses

Pooled prevalence of any refractive error was higher in the four Middle Eastern studies (58.4%, 95% CI 37.2–76.9) than in the five African (51.1%, 95% CI 11.5–89.4) or four Asian studies (37.4%, 95% CI 14.0–68.8), but the between-group difference was not statistically significant ($Q = 3.03$, $df = 2$, $P = .220$) and heterogeneity remained extreme within every region (I^2 97.4–98.8%). The single South American study (71.6%) was described but not pooled. Restricting the analysis to the twelve studies of medical and health-science students gave a pooled prevalence of 51.9% (95% CI 33.7–69.6), close to the overall estimate; the two remaining studies were not pooled and differed markedly from one another (optometry 59.0%, engineering and information technology 29.7%).

The case-definition convention showed a potential exploratory difference that reached nominal significance. Among the eleven studies assigning each participant to a single mutually exclusive category, pooled myopia prevalence was 24.9% (95% CI 14.7–39.0); among the three permitting astigmatism to coexist with a spherical diagnosis it was 44.3% (95% CI 19.1–73.0), a difference that reached nominal significance in this exploratory, post-hoc analysis ($Q = 4.62$, $df = 1$, $P = .032$); however, this finding was not adjusted for multiple comparisons and should be interpreted cautiously. The same contrast was directionally present for astigmatism (9.4%, 95% CI 3.6–22.6, versus 22.1%, 95% CI 4.2–64.9; $Q = 2.51$, $df = 1$, $P = .113$) and absent for any refractive error (49.0% versus 56.6%, $P = .533$), as would be expected if the convention affects how cases are distributed between subtypes rather than how many cases are detected overall. The astigmatism contrast is attenuated relative to its direction because the one study using cycloplegic refraction (Mvilongo et al. (19)) applied mutually exclusive categories yet reported by far the highest astigmatism prevalence in the set, widening that subgroup. Subgroup estimates are presented in Table 4.

Table 4. Subgroup analyses of pooled prevalence by region, case-definition convention and academic discipline.

Subgroup	Outcome	k	N	Prevalence % (95% CI)	I^2 (%)	Between-group test
Africa	Any refractive error	5	971	51.1 (11.5–89.4)	98.8	Q = 3.03, df = 2, P = .220
Asia	Any refractive error	4	1,481	37.4 (14.0–68.8)	97.9	
Middle East	Any refractive error	4	2,771	58.4 (37.2–76.9)	97.4	
South America	Any refractive error	1	208	71.6 (not pooled)	n/a	
Mutually exclusive	Myopia	11	3,314	24.9 (14.7–39.0)	97.9	Q = 4.62, df = 1, P = .032
Overlapping diagnosis	Myopia	3	2,117	44.3 (19.1–73.0)	96.3	
Mutually exclusive	Astigmatism	11	3,314	9.4 (3.6–22.6)	98.0	Q = 2.51, df = 1, P = .113
Overlapping diagnosis	Astigmatism	3	2,117	22.1 (4.2–64.9)	97.5	
Mutually exclusive	Any refractive error	11	3,314	49.0 (29.4–69.0)	98.8	Q = 0.39, df = 1, P = .533
Overlapping diagnosis	Any refractive error	3	2,117	56.6 (24.8–83.8)	97.1	
Medical / health sciences	Any refractive error	12	4,723	51.9 (33.7–69.6)	99.0	not tested (k = 1 per other group)

k, number of studies; CI, confidence interval; Q, between-group heterogeneity statistic. Subgroups of a single study are reported descriptively and were not pooled.

Sensitivity analysis

One study (Mvilongo et al., Cameroon (19); N = 131) reported both the highest prevalence in the dataset (90.8%) and the lowest participation rate (54.6% of eligible students), and was rated at high risk of selection bias on that account. In the risk-of-bias sensitivity analysis, excluding this study lowered the pooled prevalence of any refractive error from 50.7% (95% CI 35.0–66.3) to 46.7% (95% CI 32.9–60.9) and reduced τ^2 by 27%, from 1.203 to 0.883. Heterogeneity was essentially unchanged (I^2 98.93% versus 98.64%), and the confidence intervals of the two estimates overlapped substantially. The pooled estimate was therefore robust to the exclusion of the most extreme study in the dataset, and the observed heterogeneity was not driven by any single result.

In a second sensitivity analysis, the one study that ascertained refractive error by self-report rather than clinical refraction (Alqudah et al. (15); N = 700) was excluded. The pooled prevalence of any refractive error fell from 50.7% (95% CI 35.0–66.3) to 48.6% (95% CI 32.5–65.1), with τ^2 essentially unchanged at

1.200 and heterogeneity likewise unchanged (I^2 98.9%); pooled subtype estimates moved by no more than 2.1 percentage points (myopia 26.6%, astigmatism 12.1%, hyperopia 4.0%). A leave-one-out analysis omitting each study in turn produced pooled estimates for any refractive error ranging from 46.7% to 54.6%; the two largest single influences were the study with the lowest participation rate (Mvilongo et al. (19)), whose omission lowered the pooled estimate to 46.7%, and the lowest-prevalence study (Ibrahim et al. (13)), whose omission raised it to 54.6%. The pooled estimates were therefore not dependent on the inclusion of any individual study, nor on the method by which refractive error was ascertained.

Publication bias and small-study effects

The funnel plot for the primary outcome, any refractive error, is presented in Figure 6, and the asymmetry statistics for all four outcomes in Table 5. Funnel plots for the three subtype outcomes (myopia, astigmatism and hyperopia) are provided in the supplementary file. For any refractive error, neither the meta-regression test ($z = 0.670$, $p = .503$) nor the weighted regression test ($t(12) = 0.215$, $p = .834$) indicated funnel plot asymmetry.

For the subtype outcomes, the two tests were partly discordant. The meta-regression test suggested asymmetry for myopia ($z = -2.345$, $p = .019$), astigmatism ($z = -2.557$, $p = .011$) and hyperopia ($z = -2.891$, $p = .004$), whereas the weighted regression test reached conventional significance only for astigmatism ($t(12) = -2.253$, $p = .044$), and was non-significant for myopia ($t(12) = -2.082$, $p = .059$) and hyperopia ($t(12) = -1.936$, $p = .077$).

These results require cautious interpretation. For proportion outcomes, the standard error of the logit is an arithmetic function of the observed proportion itself, so studies reporting lower prevalences necessarily have larger standard errors. Where the pooled prevalence is low, as for hyperopia (4.2%) and astigmatism (11.6%), this dependence can generate funnel-plot asymmetry even in the absence of selective publication. The absence of asymmetry for the primary outcome, where the pooled prevalence is close to 50% and the artefact is minimised, supports this interpretation. In addition, regression-based tests for funnel plot asymmetry are underpowered with fewer than ten studies per stratum and are of limited reliability at $k = 14$. Small-study effects can therefore not be excluded, but the present data do not provide persuasive evidence of publication bias.

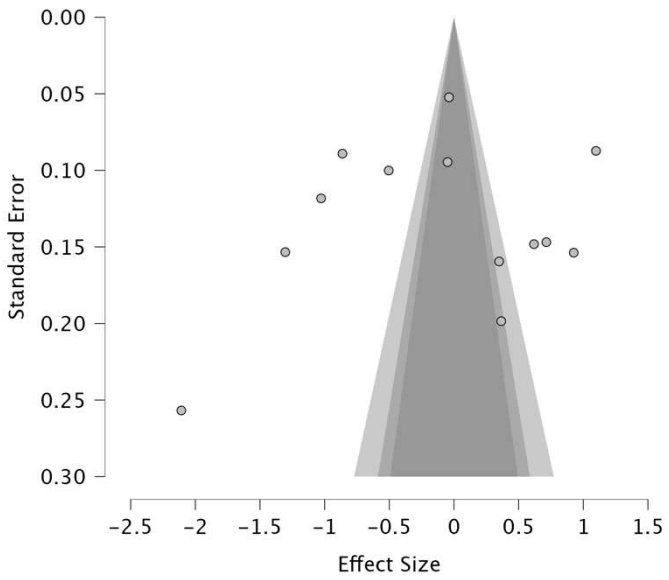


Figure 6. Funnel plot for any refractive error (k = 14).

Shaded regions denote the 90%, 95% and 99% pseudo-confidence contours around the pooled estimate (dashed vertical line).

Table 5. Tests for funnel plot asymmetry by outcome (k = 14).

Outcome	Egger z	p	Interpretation	Weighted t (df 12)	p	Interpretation
Any refractive error	0.670	.503	No asymmetry	0.215	.834	No asymmetry
Myopia	−2.345	.019	Asymmetry	−2.082	.059	No asymmetry
Astigmatism	−2.557	.011	Asymmetry	−2.253	.044	Asymmetry
Hyperopia	−2.891	.004	Asymmetry	−1.936	.077	No asymmetry

Meta-regression test corresponds to Egger's regression of effect size on standard error; the weighted regression test is its variance-weighted counterpart. Asymmetry indicated at $p < .05$. Given the arithmetic dependence of the standard error of a logit-transformed proportion on the proportion itself, asymmetry statistics for low-prevalence outcomes should not be interpreted as direct evidence of publication bias.

Sensitivity to model specification

Re-estimating each outcome under a Freeman–Tukey double-arcsine random-effects model and under a binomial-normal generalised linear mixed model produced estimates closely comparable with the primary logit-transformed analysis. For any refractive error the three specifications gave 50.7%, 50.7% and 50.8% respectively; for myopia 28.7%, 30.1% and 28.6%; for astigmatism 11.6%, 14.3% and 11.2%; and for hyperopia 4.2%, 4.7% and 3.9%. No estimate moved by more than 2.7 percentage points from the primary estimate and all confidence intervals overlapped substantially, indicating that the findings are not an artefact of the variance-stabilising transformation chosen. The estimated between-study standard deviation under the mixed model (0.91 to 1.36 on the logit scale) corroborated the extreme heterogeneity identified in the primary analysis. Results are given in Table 6.

Table 6. Pooled prevalence under three model specifications (k = 14; N = 5,431).

Outcome	Logit random effects (primary)	Freeman–Tukey double arcsine	GLMM (binomial-normal)	GLMM between-study SD
Any refractive error	50.7 (35.0–66.3)	50.7 (36.4–65.0)	50.8 (36.0–65.4)	1.07
Myopia	28.7 (18.9–41.1)	30.1 (19.6–41.8)	28.6 (19.2–40.1)	0.91
Astigmatism	11.6 (5.4–23.0)	14.3 (6.1–25.3)	11.2 (5.4–21.4)	1.36
Hyperopia	4.2 (2.3–7.6)	4.7 (2.3–7.7)	3.9 (2.1–6.8)	1.00

CI, confidence interval; GLMM, binomial-normal generalised linear mixed model with a random study intercept. Freeman–Tukey estimates are back-transformed using the harmonic mean sample size; GLMM intervals are profile-likelihood intervals. Values are percentages with 95% confidence intervals.

Discussion

This systematic review and meta-analysis pooled data from 14 cross-sectional studies and 5,431 college and university students across 12 low- and middle-income countries and found that around half of students (50.7%, 95% CI 35.0–66.3%) had some form of refractive error. Myopia was the predominant subtype, affecting an estimated 28.7% of students (95% CI 18.9–41.1%), roughly two and a half times the pooled prevalence of astigmatism (11.6%) and nearly seven times that of hyperopia (4.2%). The pooled estimate for any refractive error was robust to the exclusion, in a risk-of-bias sensitivity analysis, of the one study rated at high risk of selection bias, and no clear evidence of funnel-plot asymmetry was found for this primary outcome.

Our pooled myopia estimate of 28.7% (95% CI 18.9–41.1) lies below the pooled estimates reported in a recent international meta-analysis of myopia and near work, which found 35% (95% CI 30–41%) across all populations studied and 46% (95% CI 30–62%) among adults (3). The confidence intervals overlap substantially, and both analyses share the hallmark of very high between-study heterogeneity, suggesting that myopia prevalence in near-work-intensive populations is genuinely context-dependent rather than a fixed biological constant. Our astigmatism estimate (11.6%) is considerably lower than the pooled adult astigmatism prevalence reported in a broader, income-unrestricted synthesis of the general population (40.4%) (4). This divergence most plausibly reflects a measurement artefact rather than a true difference in underlying prevalence: eleven of the 14 included studies assigned each participant to a single, mutually exclusive refractive error category, so a student with coexisting myopic astigmatism would typically have been coded as “myopia”, not “astigmatism”, systematically deflating the astigmatism estimate relative to reviews that permit overlapping diagnoses. This exploratory, post-hoc subgroup analysis suggested a potential difference in myopia prevalence by case-definition convention (24.9% in the eleven studies using mutually exclusive categories versus 44.3% in the three permitting overlap; Q = 4.62, P = .032), with astigmatism showing a similar directional trend (9.4% versus 22.1%, P = .113) and any refractive error showing no difference (P = .533). Because the analysis was post hoc, based on unbalanced subgroups (11

versus 3 studies) and not adjusted for multiple comparisons, it should be interpreted cautiously and treated as hypothesis-generating rather than confirmatory. The directional pattern is nonetheless consistent with the case-definition convention redistributing cases between subtypes rather than altering overall detection. The astigmatism contrast falls short of significance largely because the single cycloplegic study (Mvilongo et al. (19)) used mutually exclusive categories yet reported the highest astigmatism prevalence in the set, so the direction of the effect should be read alongside the significant myopia contrast rather than in isolation. This is an important methodological caution for readers comparing prevalence figures across refractive error reviews that do not share a common case definition.

Heterogeneity was extreme for every outcome (I^2 93.7–98.9%), and several plausible, non-mutually-exclusive sources were identified a priori. First, refraction protocol varied: twelve of the 14 studies used non-cycloplegic autorefraction, retinoscopy or subjective refraction, one used self-report and only one (Mvilongo et al., Cameroon (19)) employed cycloplegic refraction; because accommodative spasm can inflate apparent myopia and mask latent hyperopia in young adults, uncontrolled accommodation is a recognised source of both over- and under-estimation in this age group. Second, diagnostic thresholds for spherical equivalent and cylinder power were not uniformly reported or applied across studies, so nominally identical categories (e.g., “myopia”) may correspond to different underlying cut-points. Regional subgroup analysis was consistent with this: pooled prevalence was higher in the Middle East (58.4%) than in Africa (51.1%) or Asia (37.4%), but the difference did not reach significance ($P = .220$) and heterogeneity remained above 97% within every region, so region alone does not account for the dispersion. Third, the sampling frame differed sharply: only one study (Hashemi et al., Iran (9)) employed population-based, multi-stage cluster sampling across all universities in a single city, while the remaining thirteen were single-institution convenience samples, limiting both internal comparability and external generalisability. Fourth, twelve of the 14 studies sampled medical or health-science students specifically, a group whose near-work-intensive training may not represent the broader college student population; the two exceptions did not behave uniformly: myopia remained the predominant subtype in the engineering and information-technology cohort, whereas astigmatism, not myopia, predominated in the optometry cohort. Finally, the wide prediction intervals observed here (8.0–92.5% for any refractive error) indicate that a comparable future study, conducted in a different LMIC setting, could plausibly report a prevalence anywhere across nearly the full possible range. This is not a flaw in the meta-analytic method so much as an accurate reflection of genuine population diversity, and it means the single pooled point estimate should always be read alongside its prediction interval, not in isolation.

The three studies in which astigmatism, rather than myopia, was the commonest refractive error were all from Sub-Saharan Africa (Darko-Takyi et al., Ghana (6); Serenje et al., Zambia (14); Mvilongo et al., Cameroon (19)), and the Cameroonian study, the only one to use cycloplegia, showed the pattern most strongly (astigmatism 67.9% against myopia 14.5%), which argues against uncontrolled accommodation as the sole explanation for it. Other African population-based studies have reported similarly elevated relative burdens of astigmatism; for example, a community-based study across three areas of Cape Town, South Africa, also found astigmatism among the more common refractive findings (20). Studies in other African settings and age groups have found the reverse pattern; a systematic review of school-age children in Ethiopia, for instance, found myopia far more common than astigmatism (21). Refractive error phenotype in Sub-Saharan African populations therefore appears heterogeneous across countries, settings and age groups rather than following a single continental pattern, and the present findings should be read as consistent with, rather than proof of, a distinct regional profile; differences in corneal curvature and axial length documented in some African populations are a plausible but unconfirmed explanation that would require dedicated ocular biometric studies to test directly.

Given that around half of the college students in this pooled sample had a refractive error that is, in the great majority of cases, fully correctable with spectacles, and that global data suggest only around one-third of people with refractive error have adequate access to correction (2), these findings support consideration of routine, low-cost vision screening at the point of tertiary-education entry in LMIC settings, integrated where possible into existing student health services rather than requiring new infrastructure. This is particularly salient for medical and health-science students, who made up the great majority of the evidence base synthesised here and for whom uncorrected vision may carry downstream implications for clinical training and, eventually, patient care.

To our knowledge, this is the first systematic review and meta-analysis to quantitatively pool refractive error prevalence specifically among college and university students within LMIC. Strengths of this review include a broad geographic scope spanning 12 countries across four regions, a methodologically appropriate logit-transformed random-effects model with the Knapp–Hartung small-sample adjustment, formal quantification of heterogeneity alongside prediction intervals, retention of every eligible study in the primary synthesis with risk of bias addressed by sensitivity analysis rather than by exclusion, and dual assessment of small-study effects using both funnel plots and two complementary regression-based tests.

Several limitations should temper interpretation of these findings. First, and most importantly, heterogeneity was extreme for every outcome, so the pooled point estimates are best regarded as a

weighted average across highly diverse settings rather than a single generalisable prevalence; the prediction intervals reported alongside each estimate should be given at least as much weight as the point estimate itself. Second, thirteen of the 14 studies were single-institution convenience samples, and a response rate was reported by only two of them, constraining formal risk-of-bias judgement on selection and raising the possibility of participation bias in either direction. Where a participation rate was reported it was as low as 54.6% (Mvilongo et al. (19)), and the sensitivity analysis excluding that study is the clearest available quantification of how much such bias could matter: it moved the pooled estimate by four percentage points, with fully overlapping confidence intervals. Third, one included study (Alqudah et al., Jordan (15)) relied on an online, self-administered survey rather than in-person clinical refraction; because self-reported refractive error status is subject to recall and under-diagnosis bias, particularly in settings with limited access to eye care, this study's inclusion alongside thirteen clinically examined cohorts introduces an additional layer of measurement heterogeneity. Its influence was quantified rather than adjusted for: excluding it lowered the pooled prevalence of any refractive error by 2.1 percentage points, to 48.6% (95% CI 32.5–65.1), with overlapping confidence intervals and essentially unchanged heterogeneity. Fourth, inconsistent case-definition conventions for astigmatism (mutually exclusive in eleven studies, overlapping with a spherical diagnosis in three) mean the pooled astigmatism and, to a lesser extent, myopia and hyperopia estimates are not fully comparable across studies at the level of underlying definition, a limitation discussed above in relation to comparisons with other reviews. Fifth, the predominance of medical and health-science student samples (12 of 14 studies) limits generalisability to college students in other disciplines. Sixth, subgroup analyses were conducted with between three and twelve studies per group and are correspondingly underpowered; they should be read as exploratory, and the absence of a significant regional difference does not establish that none exists. Seventh, regression-based tests for funnel plot asymmetry are acknowledged to be underpowered at $k = 14$ studies per outcome, so small-study effects and publication bias cannot be definitively excluded, particularly for the subtype outcomes where the arithmetic dependence of the logit standard error on prevalence itself complicates interpretation of the asymmetry statistics. Finally, we used only PubMed/MEDLINE as the primary indexed database, supplemented by regional and web-based sources. Although deliberate (see Methods), this deviates from standard multi-database recommendations and may have missed studies indexed exclusively elsewhere; the supplementary search and citation tracking mitigated but did not eliminate this risk.

Conclusion

Refractive error affects an estimated 50.7% of college and university students across the low- and middle-income countries sampled in this review, with myopia the predominant subtype. This represents a substantial burden of a condition that is, in principle, readily correctable with appropriate refractive services. However, extreme and multifactorial heterogeneity across the 14 studies synthesised here (spanning refraction protocol, diagnostic thresholds, sampling frame and academic discipline) means the pooled figure should be interpreted as an approximate central tendency across highly variable settings rather than a precise population parameter. Future primary research in this population would benefit from cycloplegic refraction, harmonised diagnostic thresholds and case definitions (particularly for astigmatism), population-based rather than single-institution sampling and broader representation of non-medical disciplines, while health policy in LMIC settings should consider routine, low-cost vision screening integrated into student health services at the point of tertiary-education entry.

Declarations

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Conflicts of interest: The authors declare no conflicts of interest.

Clinical Trial: Not applicable

Ethics approval: Not applicable. This study is a secondary quantitative synthesis of previously published, publicly available data and did not involve new data collection from human participants.

Data availability: The data extracted for this meta-analysis (Table 1) and the JASP analysis file are available from the corresponding author upon reasonable request.

Supplementary material: The full search strategies and information sources, the completed PRISMA 2020 checklist, the adapted risk-of-bias instrument and its decision rules, and funnel plots for myopia, astigmatism and hyperopia are supplied together in a single supplementary file accompanying this article.

Author contributions: ZOS conceived and designed the review, conducted the literature search and study selection, performed data extraction, risk-of-bias assessment and statistical analysis, and drafted and approved the final manuscript. MFI contributed to study screening, data verification, methodological review and manuscript revision. IK, CMA, TH and IMO contributed to literature screening, data extraction, quality assessment, interpretation of findings and critical revision of the manuscript. All

authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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