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REVIEW ARTICLE

Regional variations and temporal trends of childhood myopia prevalence in Africa: A systematic review and meta-analysis

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Abstract

Purpose: To provide contemporary and future estimates of childhood myopia prevalence in Africa.

Methods: A systematic online literature search was conducted for articles on childhood (≤18 years) myopia (spherical equivalent [SE] ≤ −0.50D; high myopia: SE ≤ −6.00D) in Africa. Population- or school-based cross-sectional studies published from 1 Jan 2000 to 30 May 2021 were included. Meta-analysis using Freeman–Tukey double arcsine transformation was performed to estimate the prevalence of childhood myopia and high myopia. Myopia prevalence from subgroup analyses for age groups and settings were used as baseline for generating a prediction model using linear regression.

Results: Forty-two studies from 19 (of 54) African countries were included in the meta-analysis (N = 737,859). Overall prevalence of childhood myopia and high myopia were 4.7% (95% CI: 3.3%–6.5%) and 0.6% (95% CI: 0.2%–1.1%), respectively. Estimated prevalence across the African regions was highest in the North (6.8% [95% CI: 4.0%–10.2%]), followed by Southern (6.3% [95% CI: 3.9%–9.1%]), East (4.7% [95% CI: 3.1%–6.7%]) and West (3.5% [95% CI: 1.9%–6.3%]) Africa. Prevalence from 2011 to 2021 was approximately double that from 2000 to 2010 for all studies combined, and between 1.5 and 2.5 times higher for ages 5–11 and 12–18 years, for boys and girls and for urban and rural settings, separately. Childhood myopia prevalence is projected to increase in urban settings and older children to 11.1% and 10.8% by 2030, 14.4% and 14.1% by 2040 and 17.7% and 17.4% by 2050, respectively; marginally higher than projected in the overall population (16.4% by 2050).

Conclusions: Childhood myopia prevalence has approximately doubled since 2010, with a further threefold increase predicted by 2050. Given this trajectory and the specific public health challenges in Africa, it is imperative to implement basic myopia prevention programmes, enhance spectacle coverage and ophthalmic services and generate more data to understand the changing myopia epidemiology to mitigate the expanding risk of the African population.

KEYWORDS
Africa, childhood, myopia, prevalence, systematic review and meta-analysis, time trends

INTRODUCTION

Myopia is a major contributor to vision impairment globally and is characterised primarily by poor uncorrected distance vision.[1] Although symptoms can easily be corrected with spectacles, contact lenses and laser refractive surgery, the availability of correction varies between countries. Thus, uncorrected refractive errors remain the commonest cause of vision impairment globally.[1] Myopia is also associated with an increased risk of ocular complications that can result in permanent vision loss, such as cataract, glaucoma, retinal detachment and myopic maculopathy (which remains without an effective treatment).[2–5] Myopia is a growing public health problem due to its association with these severe sight-threatening conditions.

Globally, myopia is expected to affect half of the world's population by the year 2050, unless current trends can be reversed.[6] There is a myopia epidemic in urban parts of East and Southeast Asia, with prevalence estimates reported to be as high as 96.5% in 19-year-old male conscripts in South Korea.[7–9] Myopia has also increased steadily in Western countries in recent decades, with the prevalence of myopia reported to have doubled in the United States and estimated to affect 50% of young persons in parts of Europe.[6,10,11,12] Considering the increase in the development, urbanisation and environmental/lifestyle changes in Africa, with a projected two-thirds of the African population (an additional 950 million people) expected to live in cities by the year 2050,[13,14] it is likely that the prevalence of myopia is also increasing in Africa. Other factors such as the recent increase in access to education[15,16] may also influence the risk of myopia development among African school children. Given that nearly 50% of the African population are under 18 years of age, with a projected 1 billion African child population by 2055,[17] an increase in myopia prevalence in this age group may portend a devastating cohort effect in future generations.

Generally, the prevalence of myopia in Africa is considered to be relatively low; however, estimates as high as 40% have been reported in some populations.[18–20] Previous systematic reviews, meta-analyses and future projections on myopia prevalence have been conducted for Asian and Western countries,[21,22] with very limited pooled estimates on myopia in Africa. Existing meta-analyses suggest that the prevalence of childhood myopia in Africa is relatively low, ranging from 4.7% to 6.2%.[23–25] However, these meta-analyses are based on a limited number of studies, with as few as six to eight included studies in some reviews (compared with China for example, where a recent meta-analysis included more than 40 studies).[21] In addition, no effort has been made previously to analyse pooled estimates for the different African subregions and for high myopia, or to analyse recent time trends or provide future projections on childhood myopia prevalence in Africa.

Although myopia prevalence is comparatively lower in Africa, it is important to note that it potentially has a greater short-term impact on individuals due to the problem of inadequate spectacle coverage (some communities have recorded spectacle coverage as low as 0 to 22%), and restricted access to eye care for those who may become myopic or develop ocular health complications.[26–29] These inequalities explain why uncorrected refractive error (primarily myopia) is the leading cause of vision impairment worldwide and second leading cause of blindness.[1] Consequently, there is a strong public health need to provide an analysis of the regional variations, changing trends and future prevalence estimates to inform future policy decisions on myopia in Africa. Therefore, the aim of this systematic review and meta-analysis was to appraise the currently available literature pertaining to myopia prevalence in Africa and to provide contemporary and future estimates of myopia prevalence in children across the different African countries and Global Burden of disease (GBD) African regions.

Key points

- For a long time, Africa has been left out of the global myopia conversation due to the comparatively low prevalence of this refractive error on the continent.
- Since 2010, childhood myopia has approximately doubled in the overall population and across different age groups, sex and study settings, and is projected to increase again threefold by the year 2050.
- The trend of increasing childhood myopia prevalence poses a significant public health threat to the continent, considering the challenges of lack of access to ophthalmic services and poor spectacle coverage.

METHODS

This systematic review and meta-analysis were reported following the preferred reporting items for systematic reviews and meta-analyses (PRISMA) and meta-analyses of observational studies in epidemiology (MOOSE) guidelines for reporting (Table S1). The meta-analysis follows the methodology described by Rudnicka and Owen.[30] The review was previously registered on PROSPERO (University of York, https://www.crd.york.ac.uk/prospero/) (ID: CRD42020200655).

Literature search strategy

The following online databases were searched between 15 May 2021 and 30 May 2021 for the literature on myopia prevalence in Africa: Medline via PubMed, Google Scholar, Cochrane Library, Africa Journals Online and Scopus.

Searches were restricted to studies published from 2000 onwards to reflect myopia prevalence in the 21st century. All unpublished studies were excluded from the review. No language restriction was applied to the search—studies in languages other than English were translated to English using Google Translate (google.com). The PICO (patient/population, intervention, comparison and outcomes) framework of the study was Population (children in Africa), Intervention (none), Comparison (none) and Outcome (prevalence of myopia and high myopia). This PICO was used to define the search strategy. Literature search terms were first generated in PubMed using the combination of search words or terms provided in Table 1 and then applied in other databases (Appendix 1). An ancestry literature search was also performed by perusing the references of eligible articles for any relevant article not captured on the initial database search. Two reviewers independently performed the primary and ancestry literature searches. Disagreements between the two reviewers were resolved by consensus involving a third reviewer.

Inclusion and exclusion criteria

Inclusion criteria for the systematic review and meta-analysis were (1) population- or school-based cross-sectional or longitudinal studies published from 1 Jan 2000 to 30 May 2021, inclusive. For longitudinal studies, information on myopia at the most recent follow-up was used; (2) studies with participants 18 years and younger; studies including participants older than 18 years were included if they provided age stratifications such that information for the age group of interest could be extracted; (3) studies that provided a clear definition of myopia (i.e., spherical equivalent ≤−0.50 D or visual acuity [VA] worse than 6/9.5 that can be corrected with minus lenses). Studies with VA cut-offs were included because an uncorrected VA of 6/9.5 which can be corrected with minus lenses has been shown to be reliable (sensitivity and specificity of 97.8% and 97.1%, respectively) in detecting myopia in children;[31] (4) studies that reported the prevalence of myopia and/or high myopia or provided information with which the prevalence could be calculated (i.e., proportion of the number of participants with myopia and/or high myopia and total number of participants in the study) and (5) studies that used a valid method for measuring refractive error (i.e., autorefraction, retinoscopy and subjective refraction) were allowed. Exclusion criteria were (1) clinic- or hospital-based studies; (2) unpublished studies; (3) studies specific to participants with ocular conditions such as amblyopia, strabismus, corneal abnormalities, glaucoma and other clinical diseases such as autism, cerebral palsy and dyslexia and (4) studies in isolated populations such as schools for the deaf/blind.

TABLE 1 Search strategy for PubMed

1	Prevalence [Text Word] OR Prevalence [MeSH Terms]
2	Epidemiology [Text Word] OR Epidemiology [MeSH Terms]
3	Incidence [Text Word] OR Incidence [MeSH Terms]
4	Myopia [Text Word] OR Myopia [MeSH Terms]
5	Nearsightedness [Text Word] OR Nearsightedness [MeSH Terms]
6	Shortsightedness [Text Word] OR Shortsightedness [MeSH Terms]
7	Refractive error [Text Word] OR Refractive error [MeSH Terms]
8	Children [Text Word] OR Children [MeSH Terms]
9	Paediatric [Text Word] OR Paediatric [MeSH Terms]
10	Africa [Text Word] OR Africa [MeSH Terms]
11	Name of each African country [Text Word] OR Name of each African country

Study screening and appraisal

Studies were initially screened using their titles and abstracts. All potentially relevant full-text articles were then assessed to ensure they satisfied the inclusion criteria. Two reviewers performed screening and eligibility assessment of articles; disagreements about article eligibility were resolved by discussions with a third reviewer. Information extracted from eligible articles included name of authors, article publication year, study location/country, period of study, study design, sample size, participants' mean age or range, method of diagnosis, myopia definition used, overall prevalence of myopia and age- and gender-specific prevalence of myopia. The quality of studies was assessed using the Joanna Briggs Institute Critical Appraisal Checklist for Prevalence Studies (JBI-CACPS)[32] (Appendix 2). Studies that used cycloplegia to measure myopia were considered as using standard, reliable methods based on the JBI-CACPS tool. Two reviewers also performed study quality assessment; disagreements were resolved by discussions with a third reviewer.

Data analysis

Statistical analysis was performed with R version 4.1.2 (The R Project for Statistical Computing, r-project.org, 2021) and OpenMeta (analyst) (Brown University, http://www.cebm.brown.edu/openmeta/), an open source software for meta-analysis.[33] Individual study proportions and pooled estimates were assessed and reported with a 95% confidence interval. The Freeman–Tukey double arcsine transformation was applied to study proportions to minimise the effects of studies with extremely high or low prevalence estimates on the overall pooled estimates.[34] Degree of inconsistency (I^2) and Cochran Q statistics were used to assess heterogeneity between studies. The Cochran Q statistic is based on the chi-square distribution. The I^2 statistic was chosen because it provides an estimate of

the percentage of heterogeneity across studies, not due to chance. Heterogeneity was considered meaningful when $I^2 > 50\%$, based on the recommendation by Higgins et al.[35,36] The random effect model was used to analyse pooled estimates due to expected heterogeneity between studies. Univariable meta-regression analysis was performed to investigate variables such as sex, age, study setting, region of study and period of publication as possible sources of heterogeneity across studies. In addition, a multiple meta-regression model including sex, age, study setting and region as co-variates was used to investigate the effect of publication year on myopia prevalence. Study regions were defined using the GBD regions;[1] however, only studies from North Africa were included from the North Africa and Middle East region. The leave-one-out analysis was performed to assess potential outliers and robustness of the pooled effects. Leave-one-out analysis provides an untransformed prevalence estimate and evaluates the effect each study has on the overall estimate by performing a series of meta-analyses, and each analysis performed without one study. This was conducted to show how each individual study affected the overall estimate.[36] Publication bias was evaluated using funnel plot, Egger's and Peter's test. In studies that presented myopia prevalence using both autorefraction and retinoscopy as diagnostic tests, and for unilateral and bilateral myopia separately, only data from autorefraction and unilateral myopia prevalence were extracted for the analysis. Due to the high variability in the age groupings used by the individual studies, categorising studies included in the review and meta-analysis into smaller age groups was not possible; hence, ages were grouped broadly into two categories: 5–11 years (younger children) and 12–18 years (older children). Data on rural and urban settings were extracted from studies that provided information for both rural and urban settings; however, for studies that did not provide information on rural and urban areas, the setting where the study was conducted was used. For analysis of year-specific prevalence, studies were classified into the following groups based on the year of publication: 2000–2005, 2006–2010, 2011–2015 and 2016–2021. Although data collection/study period reflects better on the prevalence within a given year, a sizable number of studies (18 studies) did not provide information on study period, so publication year was used as a proxy to represent the study period. The publication years were then stratified to reflect the prevalence of childhood myopia within the last two decades (2000–2010 and 2011–2021).

Using SPSS (IBM-SPSS, ibm.com) and GraphPad Prism Version 8.4.3 (GraphPad, graphpad.com), regression analyses were conducted to generate prediction models for myopia prevalence in the overall population, in 5–11 years and 12–18 years age groups, and in urban and rural settings over the next three decades. The myopia prevalence values obtained from the subgroup analyses based on year of publication for these subgroups were used as baseline for generating the prediction model. Given the lack of data in some years and the use of publication year as a proxy measure of study period, studies were grouped into 5-year bins by year of publication, and the mid-points for the various year groups (i.e., 2003 for year group 2000–2005; 2008 for 2006–2010; 2013 for 2011–2015; 2018 for 2016–2020) were used as an independent variable in the regression analysis. Linear regression models were generated, and a decision of the best prediction model was made based on the coefficient of determination (R^2), sum of squared residuals (SSR) and statistical significance of F-test as described in the study by Priscilla and Verkicharla.[37] For all statistical analyses, significance was set at $p < 0.05$.

RESULTS

Figure 1 shows the PRISMA flowchart detailing the steps in identifying articles included in this systematic review and meta-analysis. There were 3715 articles identified in the initial literature search, and 42 studies were included in the systematic review and meta-analysis.

A summary of the characteristics of studies included in the systematic review is presented in Table S2. Briefly, seven studies were conducted in Ghana,[38–44] six in Ethiopia,[45–50] five in Nigeria,[51–55] four in South Africa,[56–59] three from Egypt,[20,60,61] two each in Kenya,[62,63] Burkina Faso[64,65] and Sudan,[66,67] and one each in Rwanda,[68] Tunisia,[69] Libya,[70] Somalia,[71] Tanzania,[72] Togo,[73] Equatorial Guinea,[74] Morocco,[75] Uganda,[76] Malawi[77] and Benin[78] (Figure 2). Forty of the studies were school-based, and two were population-based. All included studies were cross-sectional. The pooled sample size from all studies was 737,859. Overall, most studies had good-quality ratings according to our assessment based on the JBI-CACPS, with all studies scoring 'Yes' in at least five of the nine checklists. Importantly, all studies scored 'Yes' to the questions: 'Were valid methods used for the identification of the condition?'; 'Was the sample frame appropriate to address the target population?'; and 'Was the sample size adequate?'; with 83% of the studies scoring a 'Yes' to the question 'Were study participants sampled in an appropriate way?'. A summary of the assessment of study quality is provided in Appendix 2.

The prevalence of childhood myopia in Africa was pooled from all 42 studies and was estimated to be 4.7% (95% CI: 3.3%–6.5%). There was high heterogeneity between studies (I^2 = 98.6%; Q = 2942.2 [df = 41], $p < 0.001$). The prevalence of high myopia (spherical equivalent ≤ −6.00D) was pooled from nine studies and was estimated to be 0.6% (95% CI: 0.2%–1.1%; I^2 = 89.6%; Q = 77.0 [df = 8], $p < 0.001$). Individual study prevalence ranged from 0.4% to 36.9% and 0.1% to 2.3% for myopia and high myopia, respectively. Forest plots for myopia and high myopia prevalence are presented in Figure 3. The study by Rushood et al.[66] (with a sample size of 671,119—approximately 91% of the total sample size) had the strongest impact on the

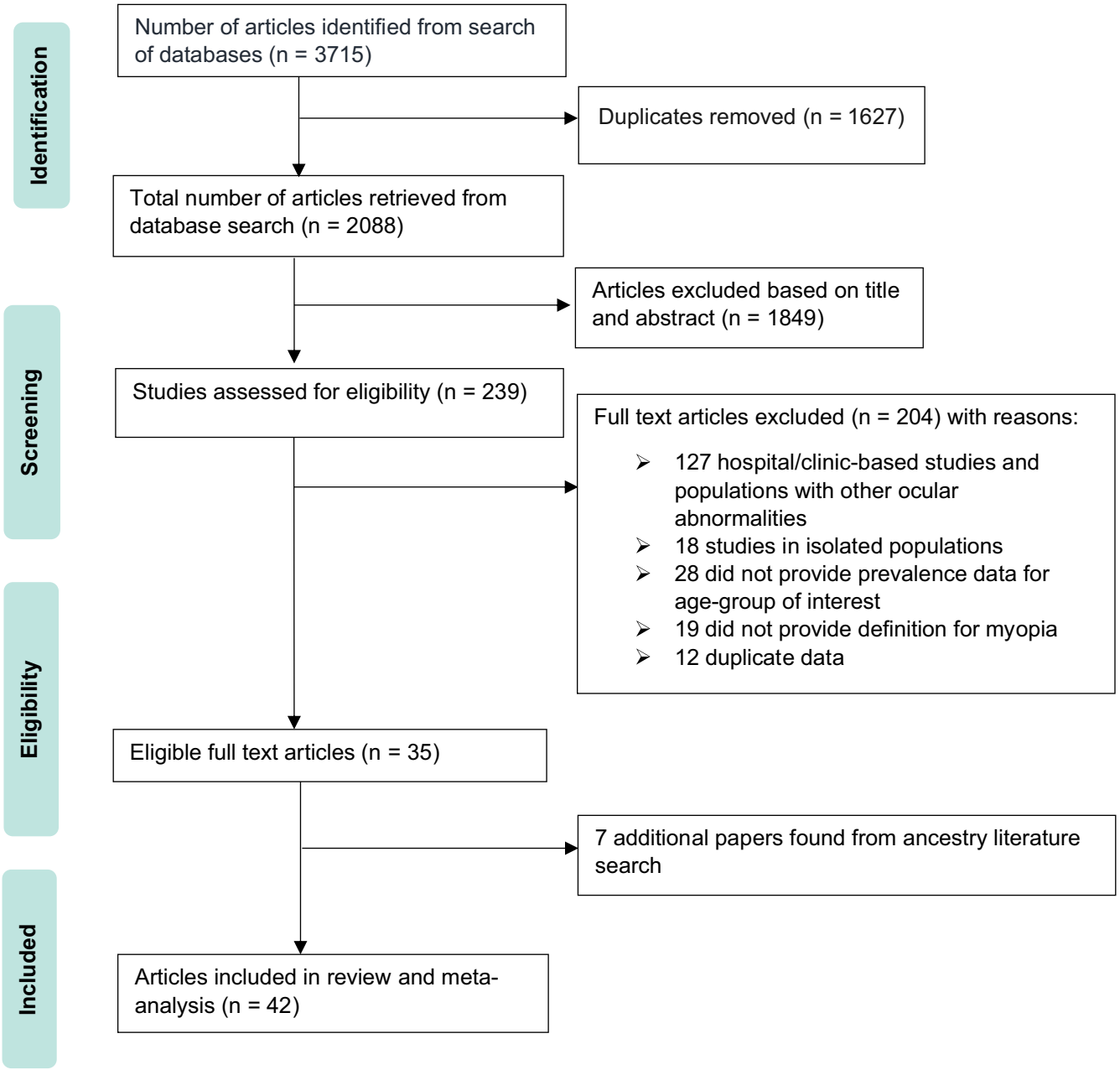

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flowchart of steps in identifying studies.

pooled estimate. Sensitivity analysis of the untransformed proportions revealed that the study by Rushood and colleagues had the most impact on the estimate of childhood myopia in Africa. When the Rushood et al.[66] study was excluded from the analysis, the overall untransformed prevalence of childhood myopia increased from 4.0% to 4.9% (Figure 4). However, when the Freeman–Tukey double arcsine transformation was applied to study proportion before conducting meta-analysis, the impact of the study by Rushood et al. was minimal—estimate of childhood myopia in Africa, with and without the study by Rushood et al., was 4.7% and 4.9%, respectively. More than twice as many studies were published from 2011 to 2021 compared with 2000–2010. As illustrated in Figure 5, there was asymmetry in the funnel plot [Egger's test ($p < 0.001$) and Peter's test ($p < 0.001$)]; however, the risk of potential publication bias is deemed to be low for meta-analysis of prevalence studies with low proportions like our study.[79]

The prevalence of childhood myopia in boys and girls were each pooled from 29 studies. Girls had similar prevalence rates [5.0% (95% CI: 3.2%–7.2)] to boys [4.9% (95% CI: 3.1%–7.1%)]. The prevalence of myopia in children aged 5–11 years and 12–18 years old was pooled from 17 and 23 studies, respectively; the pooled estimate was 4.6% (95% CI: 2.0%–8.1%) in children aged 5–11 years and 5.8% (95% CI: 4.0%–7.8%) in children aged 12–18 years, respectively. There was no significant association between myopia prevalence and age group ($p = 0.08$).

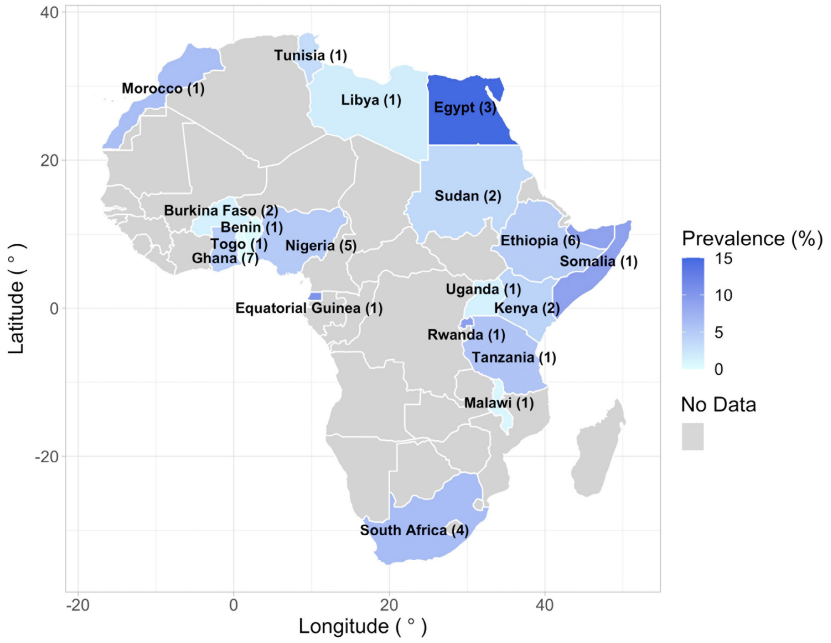

FIGURE 2 Map of Africa showing prevalence of childhood myopia in each country included in the meta-analysis. Number in parenthesis represents number of studies in each country.

Estimated prevalence across the African regions was highest in North Africa (6.8% [95% CI: 4.0%–10.2%]), followed by Southern Africa (6.3% [95% CI: 3.9%–9.1%]), East Africa (4.7 [95% CI: 3.1%–6.7%]) and West Africa (3.5% [95% CI: 1.9%–6.3%]) (Figure 6), but the differences were not significant on meta-regression ($p = 0.36$). The prevalence of childhood myopia in rural settings was 4.9% (95% CI: 2.5%–8.1%) and in urban settings was 6.0% (95% CI: 3.7%–8.8%), but there was no association between study setting and myopia prevalence ($p = 0.81$).

Estimated prevalence of myopia in studies with cycloplegia was approximately 30% lower than for studies without cycloplegia (4.0% vs. 5.7%, respectively), with studies using noncycloplegic refraction showing greater variability in their prevalence estimates (Figure S1). The estimated pooled prevalence from studies that performed retinoscopy with or without subjective refraction was lower (3.9% [95% CI: 2.3%–5.9%]) than from studies that performed autorefraction with or without subjective refraction (6.0% [95% CI: 3.1%–9.7%]). A summary of the various subgroup analyses conducted is presented in Table 2.

The prevalence of childhood myopia between 2000–2010 and 2011–2021 was pooled from 12 and 30 studies, respectively. The pooled prevalence of childhood myopia between 2000–2010 was 2.9% (95% CI: 1.6%–4.6%; $I^2 = 96.4$, Q[*df*] = 268.0 (11), $p < 0.001$) and 2011–2021 was 5.6% (95% CI: 3.6%–8.0%; $I^2 = 99.6$, Q(*df*) = 2453.5 (29), $p < 0.001$). There was no significant association between childhood myopia prevalence and publication year after adjusting for sex, age, study setting and region of study ($p = 0.72$). Estimated myopia prevalence from 2006 to 2010 (2.3%) was markedly lower than the prevalence from 2001 to 2005 (4.3%), implying a reducing trend in prevalence within these periods. However, qualitative review/analysis of the data suggests that the lower reported prevalence in this period could be due to the locations of studies included from 2006 to 2010, with six of eight studies conducted in West (four studies) and East (two studies) Africa, where the prevalence of myopia is generally lower. Childhood myopia prevalence in the last decade (2011–2021) was approximately double the prevalence in the decade of 2000–2010 for all studies combined, and 1.5 times higher for ages 5–11 years and 12–18 years, separately. In the last decade, childhood myopia prevalence was approximately 2.5 times higher than the prevalence in the decade of 2000–2010 for boys and girls, separately. A similar trend was observed in rural and urban settings; however, there was no significant difference in myopia prevalence between 2000–2010 and 2011–2021 for either urban or rural settings. A summary of the subgroup analyses of time trends for myopia prevalence for age, sex and study setting within the past two decades is presented in Table 3.

The authors have only presented pooled estimate predictions; however, it is worthwhile to acknowledge that our predictions using individual studies (Figure S2) were similar to the pooled estimate predictions. Based on the linear regression models, the prevalence of childhood myopia in urban settings in Africa is projected to increase to 11.1% by 2030, 14.4% by 2040 and 17.7% by the year 2050, which is marginally higher than expected in the overall population (10.3% by 2030, 13.4% by 2040 and 16.4% by 2050) and noticeably higher than in rural settings (7.0% by 2030, 7.7% by 2040 and 8.4% by 2050), respectively (Figure 7). Similarly, childhood myopia prevalence is projected to increase to 10.8% by 2030, 14.1%

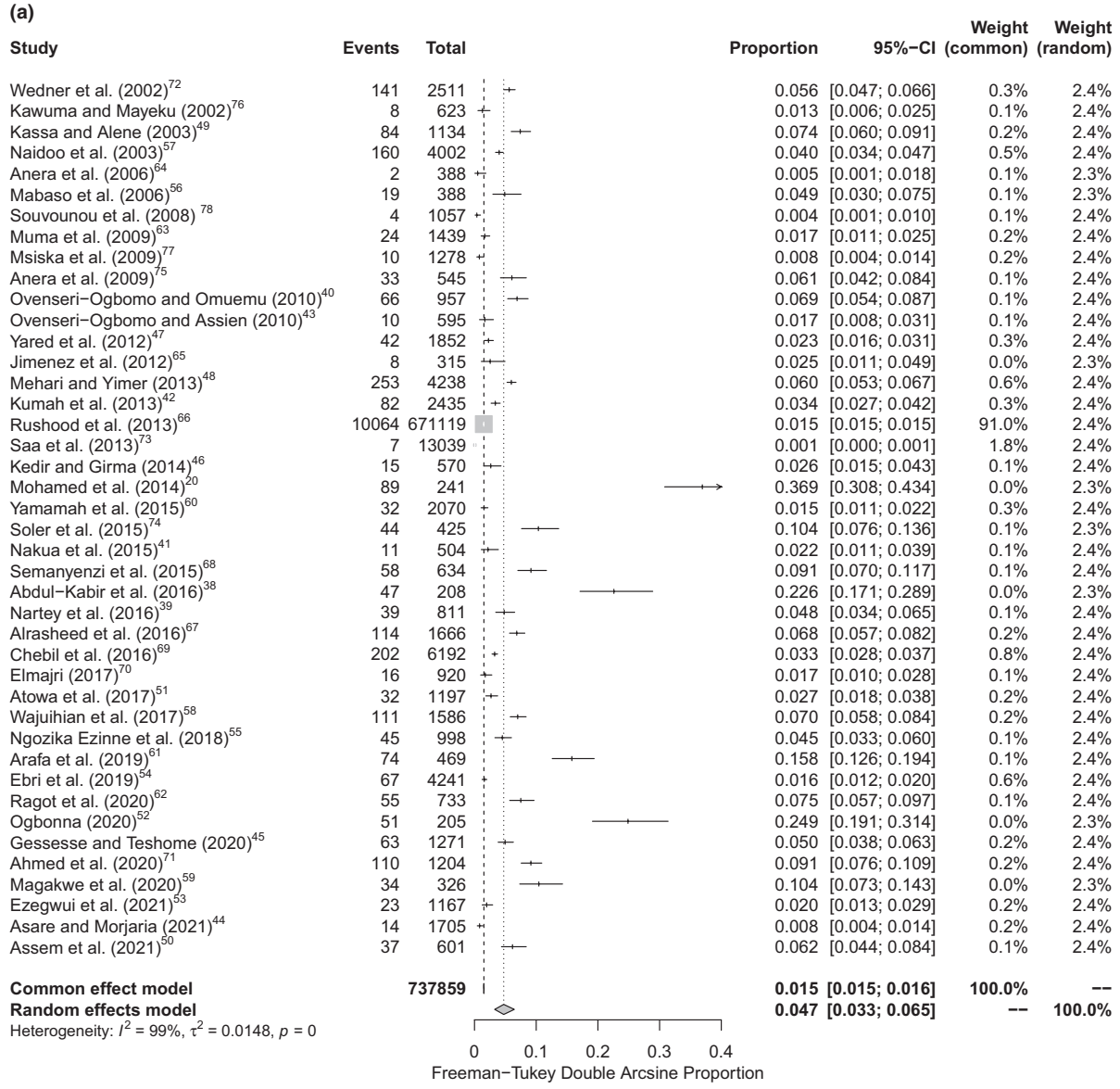

FIGURE 3 Forest plot of overall prevalence of childhood myopia in Africa. The prevalence of (a) childhood myopia in Africa was estimated to be 4.7% (95% CI: 3.3%–6.5%) and (b) high myopia was estimated to be 0.6% (95% CI: 0.2%–1.1%). The diamond represents the pooled estimate.

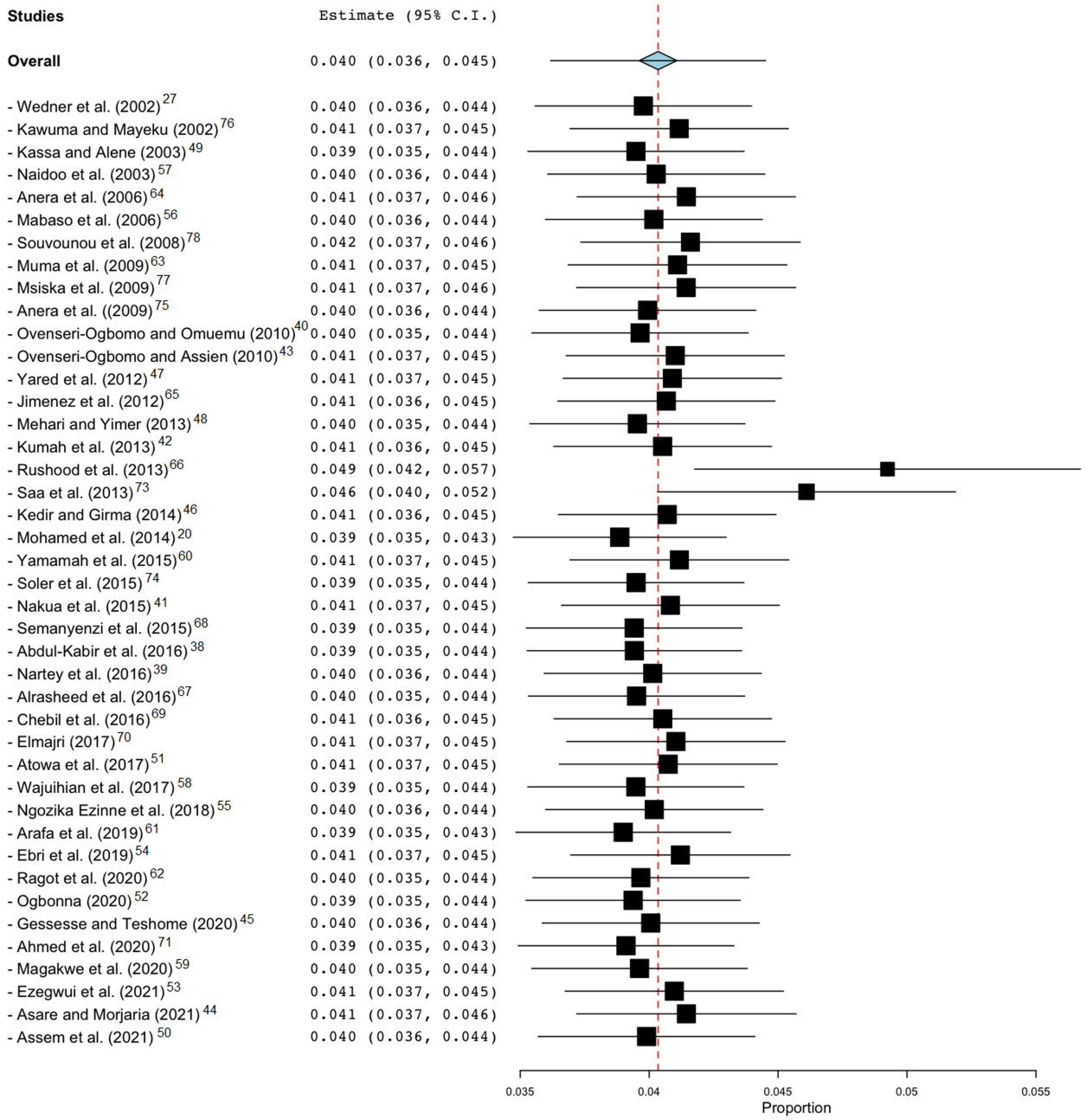

FIGURE 4 Leave-one-out sensitivity plot of all studies reporting the prevalence of childhood myopia in Africa. A leave-one-out sensitivity analysis provides an untransformed prevalence estimate and was performed to evaluate the contribution of each study to the overall estimate of childhood myopia in Africa. This revealed that the overall estimate of childhood myopia in Africa was most affected by the study by Rushood et al.,[66] followed by the Saa et al.[73] study.

by 2040 and 17.4% in ages 12–18 years, higher than projected for ages 5–11 years (8.5% by 2030, 11.0% by 2040 and 13.5% by 2050; Figure 8).

DISCUSSION

This meta-analysis suggests that the prevalence of myopia (4.7%) and high myopia (0.6%) in African children remains low but has approximately doubled over the past decade across different age groups, sex and study settings. More importantly, the prevalence of childhood myopia in Africa is predicted to more than treble again to reach 16.4% by the year 2050.

The estimated prevalence of childhood myopia in our study is considerably lower than reported in other locations outside Africa such as Taiwan[80] (36.4%), China[81] (63.1%), Norway[82] (13.4%), Germany[83] (11.4%), Ireland[84] (12–13 years; 19.9%), Northern Ireland[85] (12–13 years; 17.7%) and Australia[86] (18.9%). Our estimate is also lower than the childhood prevalence of myopia (37.7%) and high myopia (3.1%) reported in a meta-analysis of

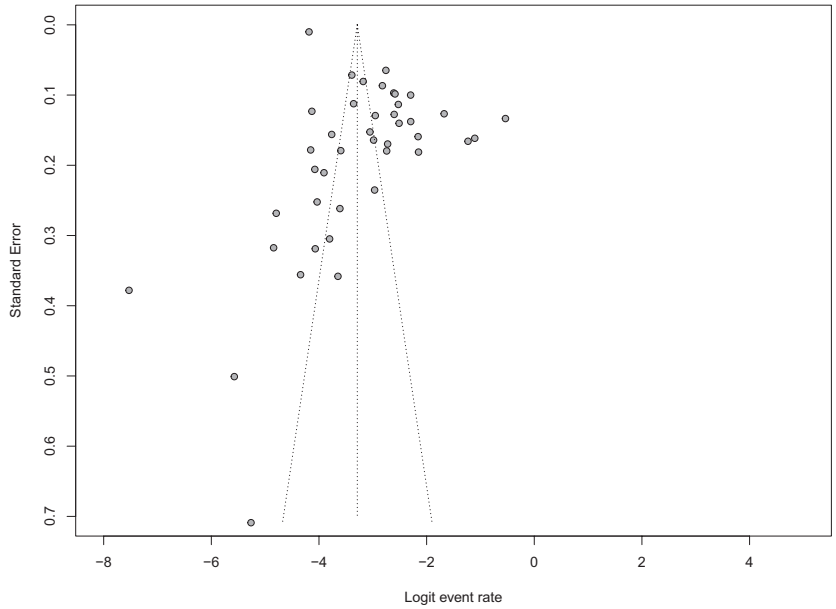

FIGURE 5 Funnel plot of studies reporting the prevalence of myopia in Africa.

Chinese studies.[87] The current estimate of childhood myopia is similar to a recent meta-analysis estimate in Africa,[23] despite differences in the number of studies included, which provides some reassurance as to the validity of the various estimates based on current data. This study addresses some of the key limitations of all previous reviews,[23–25] particularly the recent review by Ovenseri-Ogbomo et al.,[23] such as lack of time trend analysis and future projections of childhood myopia prevalence in Africa. Analysis of the temporal trends and projections of the trends could be useful in developing targeted policy measures in addressing the condition in future. Also, there has not been any previously pooled estimates across the different regions to highlight geographic variations of childhood myopia across the continent (given the development disparities,[88] myopia prevalence may vary across the different regions). Furthermore, the study by Ovenseri-Ogbomo et al.[23] did not provide an estimate for childhood high myopia prevalence in Africa. Our study therefore provides for the first-time pooled regional estimates of childhood myopia, childhood high myopia prevalence and changing trends in childhood myopia prevalence as well as projecting the prevalence in Africa by the year 2050.

The lower prevalence of childhood myopia reported in Africa may reflect a combination of genetic and behavioural influences. Historically, Africans have had lower exposure to known environmental risk factors for myopia development, including lower literacy rates, later time for primary school enrolment, lower average number of years spent in formal education and lower rate of urbanisation, compared with other Asian and Western countries.[89–91] The low prevalence estimates means that relatively little attention has been afforded to Africa when considering the public health implications of the global myopia epidemic. It is interesting, however, that our analyses suggest the condition has approximately doubled over the past decade in the overall population and across different age groups, sex and study settings, perhaps in response to an increasing level of exposure to myopiagenic risk factors. For instance, urbanisation in most capital cities and access to education have increased in many African countries in recent years.[13,92,93] According to data from the United Nations Educational, Scientific and Cultural Organisation (UNESCO), enrolment rates among primary school children in Sub-Saharan Africa have increased dramatically in the last decade.[15] In Ghana, for example, the introduction of a free Senior High School (SHS) educational policy has seen the enrolment of students in SHS double within the past few years.[16] An increase in access to education exposes children to an increase in near work activities such as reading, which is considered a significant contributory mechanism for myopia development. Mobile phone penetration in Africa has also increased rapidly, increasing from 1% in 2000 to 54% in 2012,[94] representing a new form of near work that has also been implicated as a potential risk of myopia.[95–97] Furthermore, many African countries have been identified as some of the fastest growing economies in the world.[98] This is typically associated with increased urbanisation[92,99] and other environmental and lifestyle changes, such as less time spent outdoors, known to increase risk of myopia development.[100–102] Regional variations in the prevalence rates in our study highlights this assertion and showed that the two most developed regions on the continent with average human development index (HDI) above 0.7—Northern and Southern Africa[88]—had the highest prevalence of childhood myopia, further supporting the known associations between myopia and socio-economic development.

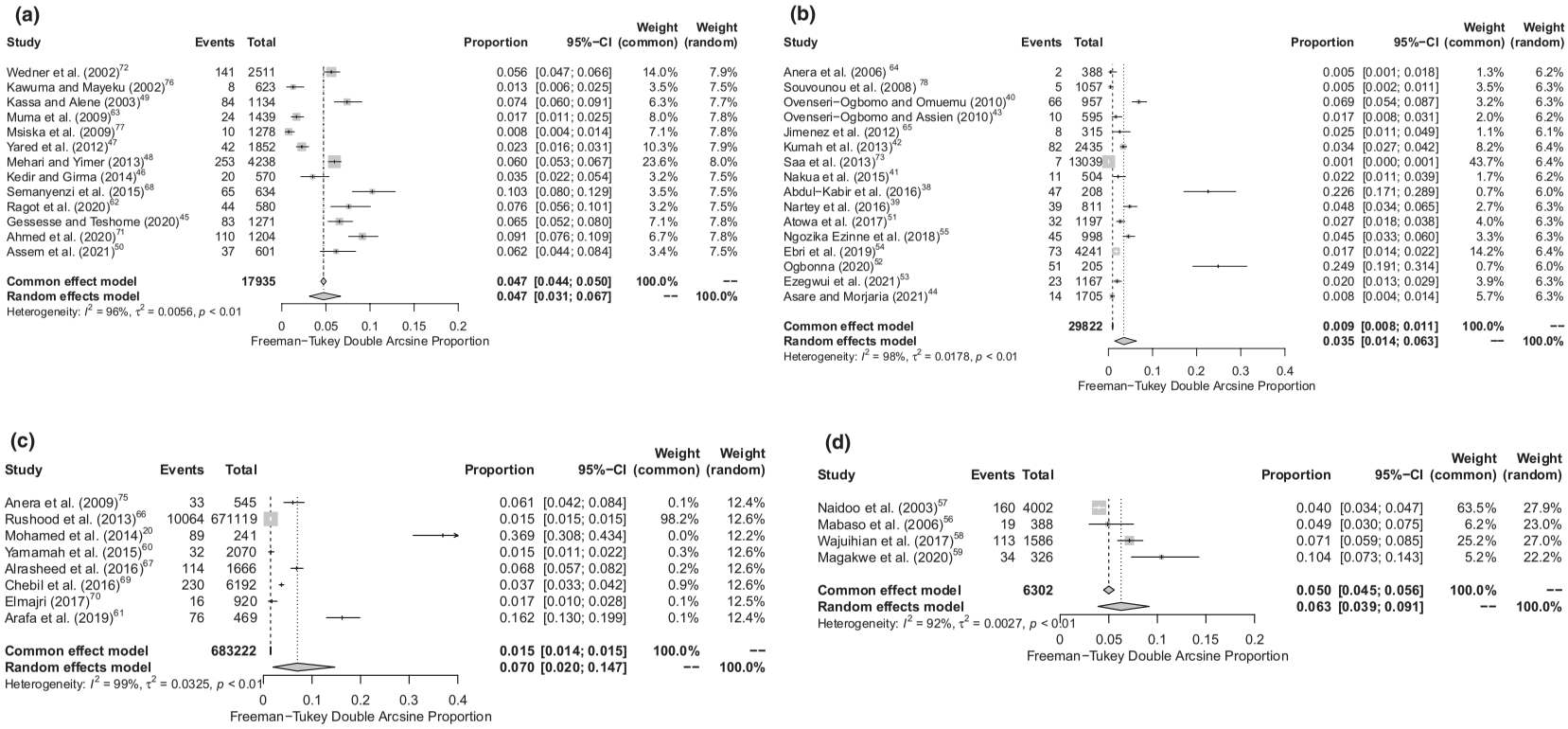

FIGURE 6 Forest plot showing prevalence of childhood myopia in (a) East Africa (b) West Africa (c) North Africa (d) Southern Africa. The diamond represents the pooled estimates.

TABLE 2 Summary of subgroup analysis of childhood myopia prevalence in Africa

Subgroup	Number of studies	Total participants	Prevalence (%) (95% CI)	Heterogeneity			*p*-value (subgroup)†
				I^2 statistics (%)	Q-statistic (*df*)	*p*-value*	
Sex							
Boys	29	397,947	4.9 (3.1–7.1)	98.6	754.4 (28)	<0.001	0.98
Girls	29	309,884	5.0 (3.2–7.2)	98.7	1096.2 (28)	<0.001	
Age (years)							
5–11	17	7503	4.6 (2.0–8.1)	97.5	432.4 (16)	<0.001	0.08
12–18	23	16,071	5.8 (4.0–7.8)	95.9	450.6 (22)	<0.001	
Setting							
Rural	17	19,009	4.9 (2.5–8.1)	98.7	549.9 (16)	<0.001	0.81
Urban	25	697,967	6.0 (3.7–8.8)	99.4	1460.1 (24)	<0.001	
Region							
East Africa	13	17,935	4.7 (3.1–6.7)	96.7	309.5 (12)	<0.001	0.36
West Africa	16	29,822	3.5 (1.9–6.3)	99.1	922.4 (15)	<0.001	
North Africa	8	683,222	6.8 (4.0–10.2)	99.0	724.2 (7)	<0.001	
Southern Africa	4	6257	6.3 (3.9–9.1)	91.8	36.5 (3)	<0.001	
Publication year							
2000–2005	4	8270	4.3 (2.6–6.5)	94.0	49.9 (3)	<0.001	0.17
2006–2010	8	6647	2.3 (0.9–4.3)	95.0	141.1 (7)	<0.001	
2011–2015	12	697,442	4.6 (2.8–6.5)	99.1	1255.3 (11)	<0.001	
2016–2021	18	25,347	6.3 (3.9–9.3)	98.6	621.6 (17)	<0.001	
Cycloplegia							
Yes	23	48,004	4.0 (2.3–6.2)	99.1	1560.3 (22)	<0.001	0.27
No	14	16,016	5.7 (3.2–8.9)	98.2	400.4 (13)	<0.001	
Type of refraction							
Retinoscopy	16	22,971	3.9 (2.3–5.9)	97.9	338.4 (15)	<0.001	0.73
Autorefraction	19	42,417	6.0 (3.1–9.7)	99.5	1833.8 (18)	<0.001	

*p-value represents test of the null hypothesis that heterogeneity is equal to zero.

†p-value represents test of the null hypothesis that the prevalence in all subgroups is the same—results displayed are from univariable meta-regression models.

TABLE 3 Prevalence of childhood myopia in the past two decades according to age, sex and setting

Subgroup	2000–2010			2011–2021			*p*-value
	Number of studies	Total participants	Prevalence (%) (95% CI)	Number of studies	Total participants	Prevalence (%) (95% CI)	
Age (years)							
5–11	3	1089	3.1 (0.9–6.5)	14	6414	4.9 (1.8–9.4)	0.62
12–18	5	3207	4.2 (1.4–8.3)	18	12,864	6.2 (4.2–8.7)	0.31
Sex							
Boys	9	4446	2.7 (1.3–4.4)	20	393,501	6.2 (3.6–9.4)	0.07
Girls	9	4722	2.6 (1.0–4.9)	20	305,162	6.4 (3.8–9.5)	0.05
Setting							
Rural	5	4627	2.5 (0.6–5.4)	12	14,382	6.2 (2.8–10.9)	0.16
Urban	7	10,290	3.3 (1.6–5.6)	18	6,87,677	7.3 (4.1–11.3)	0.13

These factors are likely to drive a continued rise in myopia prevalence in Africa. Our predictions suggest that the greatest increase in childhood myopia will occur in urban settings and older children, where prevalence is projected to reach 17.7% and 17.4% by 2050, noticeably higher than the 8.4% and 13.5% predicted in rural settings and younger

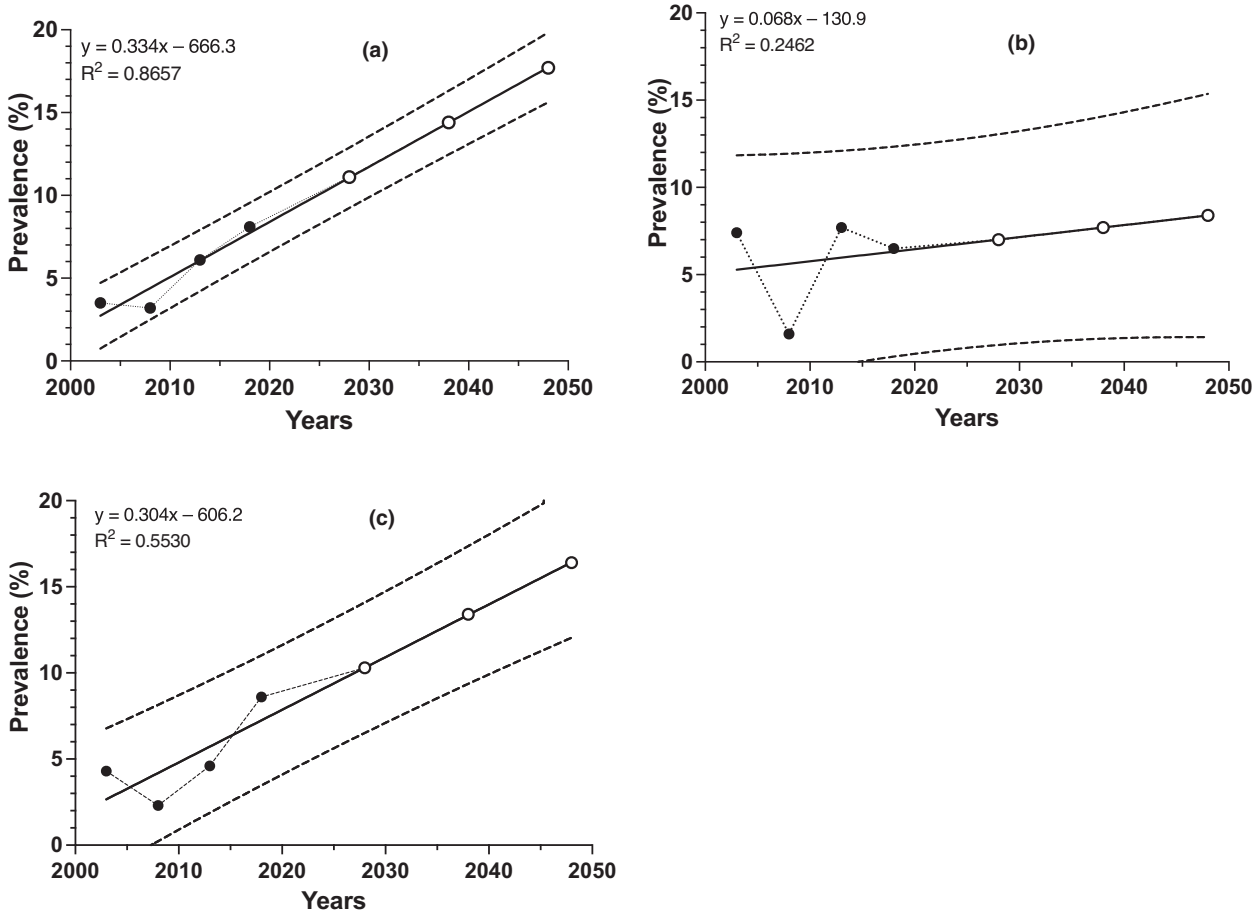

FIGURE 7 Prevalence of childhood myopia (%) in African children from the year 2000 to 2050. (a) Urban (b) rural (c) overall. The filled circles indicate the pooled prevalence estimate from the meta-analysis and the open circles indicate the predicted prevalence of myopia using a linear regression model. The dashed black lines running on either side of the linear fit/regression line represents the 95% prediction interval.

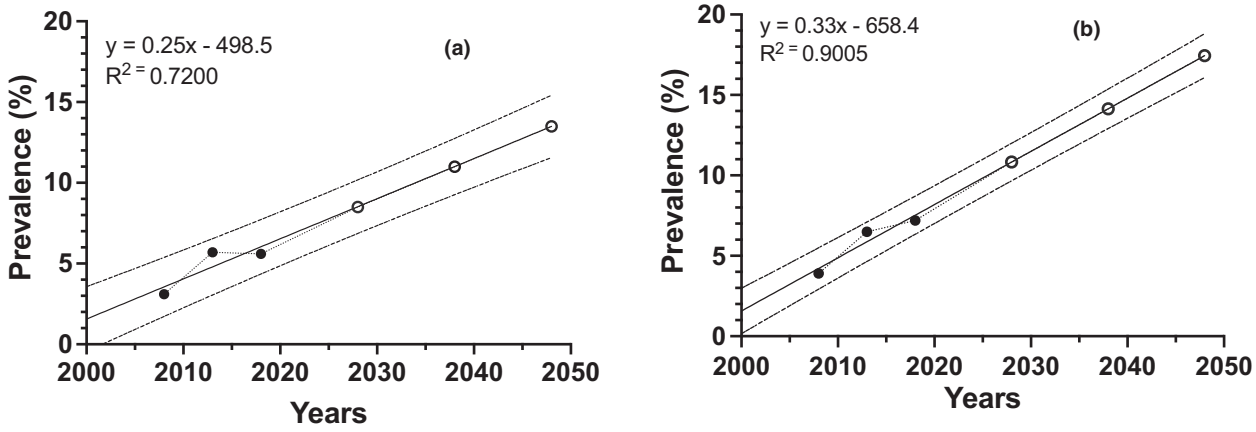

FIGURE 8 Prevalence of childhood myopia (%) in African children from the year 2000 to 2050. (a) 5–11 years (b) 12–18 years. The filled circles indicate the pooled prevalence estimate from the meta-analysis and the open circles indicate the predicted prevalence of myopia using a linear regression model. The dashed black lines running on either side of the linear fit/regression line represent the 95% prediction interval.

children, respectively. This finding is significant as it highlights the need for African countries to put in place measures to mitigate the predicted trend of increasing myopia prevalence in urban settings, especially due to the positive development trajectory of many African countries. It is, however, worth acknowledging that these predictions are susceptible to unpredictable social changes (such as was experienced during the COVID-19 pandemic) and must be

interpreted with caution. For example, in East Asia, there is evidence of a temporary acceleration of both the onset and the progression of myopia, particularly in societies that have shifted to home schooling.[103,104] In contrast, for Africa, despite the recent improvement in school enrolment rates, the generally weaker education systems have been overwhelmed by the COVID-19 pandemic[105] and may therefore potentially disrupt the predicted trends in our study, resulting in less myopia. The actual impact of COVID-19 on myopia in Africa may need to be explored further.

Given the recent and projected continued rise of myopia in Africa, it is important to consider the public health implications specific to the region. Despite the low estimated prevalence of childhood myopia in Africa, uncorrected refractive error is ranked as the leading cause of vision impairment in Africa because of the general lack of access to refractive error services and poor spectacle coverage in most parts of the continent.[26,29,106] Poor vision due to myopia in children can easily be remedied with timely cost-effective optical intervention; however, lack of access to these inexpensive services in Africa poses a significant burden on the education and vision-related quality of life of affected individuals, with the disease burden reflected as increased disability adjusted life years in myopic children.[107,108] Notwithstanding the recent drive to improve spectacle access, particularly in rural areas of Africa, some communities continue to report spectacle coverage as low as 0%–22.2%,[27,28] and myopia continues to exert a negative public health impact as a significant cause of disability.[107,108] Furthermore, myopic children have an increased risk of developing severe sight-threatening ocular disease later in life. The apparent absence of current myopia control therapies such as orthokeratology, myopia control spectacles and contact lenses in most African countries poses a significant additional challenge in the remediation of the condition on the continent.[109] Ophthalmology services are also not sufficiently established in most areas to deal with even the most routine ocular health complications associated with myopia, such as cataract and glaucoma.[110]

A major limitation of our investigation was that only one study[66] accounted for nearly 91% of the overall sample size. Given that this study reported a low prevalence of myopia, it affected the untransformed pooled estimate from the leave-one-out analysis and might have lowered the estimates found in the respective subgroup analysis for regions, settings and publication year. A Freeman–Tukey double arcsine transformation was applied, however, to mitigate the impact of large studies. Due to the difficulties in categorising children into smaller age groups, age was classified broadly into younger (5–11) and older (12–18) children, perhaps leading to nonsignificant differences between the two groups, as revealed by the meta-regression analysis, despite the noticeable differences in their prevalence estimates. Furthermore, only two of the 42 studies were population-based; however, school-based studies give an approximation to population-based studies in children, when the enrolment and completion rates are high, but this may not be the case in Africa, particularly for completion rates. Because of the substantial dropout rate (Sub-Saharan African ranks highest globally in out-of-school rate),[111] which primarily affects low-performing students, school-based studies may tend to inflate the prevalence of myopia in those remaining in school, particularly at the senior levels. Despite the high dropout rates among African school children, enrolment rates in Africa have also increased dramatically in recent years, with gross primary school enrolment rate in Sub-Saharan Africa averaging 100% in 2019.[15,111] Therefore, the estimated prevalence in our study probably provides the best possible representation of the current burden of childhood myopia among school children in those countries for which data are available in Africa to date.

Another potential limitation relates to the inclusion of studies that did not use cycloplegic refraction to confirm myopia status. This is particularly important in Africa where myopia prevalence is low, given that even low amounts of pseudomyopia and small errors in myopia estimation could considerably distort the overall estimate of myopia.[112] Almost half of the studies included in this review did not use cycloplegia ($n = 14$) or did not state whether it was used or not ($n = 5$). As expected, studies that used cycloplegia reported lower prevalence of myopia overall, likely reflecting the established influence of accommodation on myopia in children.[113,114] Use of cycloplegic refraction is considered the most reliable method for identifying refractive error in children due to errors associated with noncycloplegic refraction and is therefore the preferred method for epidemiological studies of refractive error.[112,115,116] In our meta-analysis, these errors are reflected in the wider confidence intervals and variability of the prevalence in studies that did not use cycloplegia (Figure S1), which is consistent with the study by Ovenseri-Ogbomo and colleagues.[23] Even though the difference between cycloplegic and noncycloplegic studies was not statistically significant, the inclusion of noncycloplegic data could have potentially contributed to a slight overestimation of the overall pooled estimate of myopia herein. Future epidemiological studies on childhood myopia prevalence in Africa should endeavour to use cycloplegic techniques in conformance with international guidelines[112,117] to provide more accurate and precise estimates of childhood myopia prevalence in Africa.

Lack of data primarily due to resource and logistical constraints remains problematic in terms of producing reliable estimates of myopia and high myopia in Africa—this was highlighted during our literature search and subsequent exclusion of nearly 100 hospital/clinic-based studies as researchers find these type of studies less resource-intensive to execute. Just 19 of the 54 countries in Africa are represented in this analysis, with 11 of those countries represented by just a single study. Furthermore, data on high myopia were only available from six

countries. The lack of myopia data has been identified as a global issue,[6] but this is particularly problematic in Africa. Africa is a very diverse continent; single studies, therefore, cannot be expected to adequately represent an entire country, and the 19 countries included cannot be reasonably expected to be representative of Africa as a whole. This can only be addressed with data that are more robust. Consideration should be given, therefore, to exploiting the improving school attendance statistics to implement proper school screening strategies that can inform public health planning specific to the African situation.

Lastly, despite the observation of asymmetry in the funnel plot, this may not directly imply the presence of publication bias. As discussed in the study by Hunter et al.,[79] funnel plot asymmetry in meta-analysis of prevalence studies may be due to scale artefacts, as the standard error of an effect is correlated with an effect such that studies with particularly low or high prevalence outcomes have a larger standard error.

There are also some notable strengths to this study. This is one of the most comprehensive estimates of childhood myopia prevalence in Africa to date, including nearly twice the number of studies relative to the earlier work. Our inclusion criteria and more comprehensive search strategy allowed us, for example, to source and include a reasonable mix of data from urban and rural settings. A key strength of this study was the analytical approach used in the meta-analysis. Even though the Rushood et al. study[38] accounted for nearly 91% of the study sample, when this was factored into our analyses, there was only a small increase (4.7% to 4.9%) in the transformed estimated prevalence of myopia, perhaps reinforcing the robustness of our analytical approach. Furthermore, the use of the JBI-CACPS ensured that all of the included studies fulfilled a minimum quality requirement considering the heterogenous nature of the different studies. It is reassuring to note that our findings are consistent with the recent investigation,[23] and other studies that explored urban–rural differences in myopic children.[21,81]

In conclusion, the current meta-analysis estimated the pooled prevalence of myopia and high myopia in African children aged ≤18 years as 4.7% and 0.6%, respectively. The prevalence of childhood myopia has approximately doubled since 2010 across different age groups, sex and study settings. This trend seems likely to continue as the African region becomes increasingly urbanised and as the lifestyle of African children continues to evolve in ways that increase exposure to known risks of myopia development and progression. Due to poorer access to eye care, myopia exerts a relatively greater public health burden in Africa because of vision impairment from uncorrected myopia. This reinforces the need to generate more data to better understand the changing epidemiology of myopia in Africa, and to inform an appropriate myopia control response to mitigate the expanding risk of myopia and its complications for the African population.

AUTHOR CONTRIBUTIONS

Emmanuel Kobia-Acquah: Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); methodology (equal); project administration (equal); resources (equal); software (equal); supervision (supporting); validation (supporting); visualization (equal); writing – original draft (lead); writing – review and editing (supporting). **Daniel Ian Flitcroft:** Formal analysis (supporting); methodology (equal); resources (equal); software (equal); supervision (lead); validation (lead); visualization (equal); writing – original draft (supporting); writing – review and editing (lead). **Prince Kwaku Akowuah:** Conceptualization (supporting); data curation (supporting); formal analysis (supporting); investigation (supporting); methodology (equal); project administration (supporting); resources (equal); software (equal); validation (supporting); visualization (equal); writing – original draft (supporting); writing – review and editing (supporting). **Gareth Lingham:** Data curation (supporting); formal analysis (supporting); methodology (equal); resources (equal); software (equal); supervision (lead); validation (supporting); visualization (equal); writing – original draft (supporting); writing – review and editing (lead). **James Loughman:** Formal analysis (supporting); methodology (equal); project administration (equal); resources (equal); software (equal); supervision (lead); validation (lead); visualization (equal); writing – original draft (supporting); writing – review and editing (lead).

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CONFLICT OF INTEREST

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX 1

Search terms

PUBMED

"myopia OR nearsightedness OR shortsightedness OR refractive error OR ametropia" AND "prevalence OR incidence OR epidemiology" AND "Children OR Paediatric" AND "Africa"

Google Scholar

"prevalence OR epidemiology" AND "myopia OR refractive errors" AND "Africa OR the name of each of the 54 countries in Africa"

Africa Journals Online

"prevalence OR epidemiology" AND "myopia OR refractive errors" AND "Africa"

Scopus

prevalence OR epidemiology AND myopia OR refractive error AND Africa

Cochrane Library

"prevalence OR epidemiology" AND "myopia OR refractive error" AND "Africa"

APPENDIX 2

Assessment of Study Quality - Joanna Briggs Institute Critical Appraisal Checklist for Prevalence Studies (JBI-CACPS)

Number	Study	Was the sample frame appropriate to address the target population?	Were study participants sampled in an appropriate way?	Was the sample size adequate?	Were the study subjects and the setting described in detail?	Was the data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?
	Benin									
1.	Souvounou et al. (2008)[78]	Y	U	Y	Y	N	Y	Y	Y	Y
	Burkina Faso									
2.	Anera et al. (2006)[64]	Y	U	Y	U	Y	Y	N	Y	U
3.	Jimenez et al (2012)[65]	Y	Y	Y	Y	Y	Y	N	Y	U
	Egypt									
4.	Yamamah et al. (2015)[60]	Y	Y	Y	Y	N	Y	Y	Y	U
5.	Mohamed et al. (2014)[20]	Y	Y	Y	Y	Y	Y	Y	Y	U
6.	Arafa et al. (2019)[61]	Y	Y	Y	Y	N	Y	Y	Y	U
	Equatorial Guinea									
7.	Soler et al. (2015)[74]	Y	Y	Y	Y	Y	Y	Y	Y	U
	Ethiopia									
8.	Gessesse and Teshome (2020)[45]	Y	Y	Y	Y	Y	Y	Y	Y	Y
9.	Kedir and Girma (2014)[46]	Y	Y	Y	Y	N	Y	N	Y	Y
10.	Yared et al. (2012)[47]	Y	Y	Y	Y	Y	Y	Y	Y	Y
11.	Mehari and Yimer (2013)[48]	Y	Y	Y	Y	N	Y	N	Y	Y
12.	Kassa and Alene (2003)[49]	Y	N	Y	Y	N	Y	N	Y	Y
13.	Assem et al. (2021)[50]	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Ghana									
14.	Abdul-Kabir et al. (2016)[38]	Y	Y	Y	Y	N	Y	N	Y	N
15.	Nartey et al. (2016)[39]	Y	Y	Y	Y	N	Y	N	Y	Y
16.	Ovenseri-Ogbomo and Omuemu (2010)[40]	Y	Y	Y	Y	Y	Y	Y	Y	Y
17.	Nakua et al. (2015)[41]	Y	Y	Y	Y	Y	Y	N	Y	Y
18.	Kumah et al. (2013)[42]	Y	Y	Y	Y	N	Y	Y	Y	Y
19.	Ovenseri-Ogbomo and Assien (2010)[43]	Y	N	Y	Y	N	Y	N	Y	Y
20.	Asare and Morjaria (2021)[44]	Y	Y	Y	Y	Y	Y	N	Y	Y

Continues

APPENDIX 2 continued

Number	Study	Was the sample frame appropriate to address the target population?	Were study participants sampled in an appropriate way?	Was the sample size adequate?	Were the study subjects and the setting described in detail?	Was the data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?
	Kenya									
21.	Ragot et al. (2020)[62]	Y	Y	Y	Y	Y	Y	Y	Y	U
22.	Muma et al. (2009)[63]	Y	N	Y	N	Y	Y	Y	N	Y
	Libya									
23.	Elmajri (2017)[70]	Y	N	Y	N	N	Y	Y	Y	Y
	Malawi									
24.	Msiska et al. (2009)[77]	Y	Y	Y	Y	N	Y	Y	Y	Y
	Morocco									
25.	Anera et al. (2009)[75]	Y	N	Y	Y	Y	Y	Y	Y	U
	Nigeria									
26.	Atowa et al. (2017)[51]	Y	Y	Y	Y	Y	Y	Y	Y	Y
27.	Ogbonna (2020)[52]	Y	Y	Y	Y	Y	Y	N	Y	Y
28.	Ezegwui et al. (2021)[53]	Y	Y	Y	Y	Y	Y	Y	Y	U
29.	Ebri et al. (2019)[54]	Y	Y	Y	Y	Y	Y	Y	Y	U
30.	Ngozika Ezinne et al. (2018)[55]	Y	Y	Y	Y	N	Y	Y	Y	Y
	Rwanda									
31.	Semanyenzi et al. (2015)[68]	Y	Y	Y	Y	Y	Y	N	Y	U
	Somalia									
32.	Ahmed et al. (2020)[71]	Y	Y	Y	N	Y	Y	N	Y	Y
	South Africa									
33.	Mabaso et al. (2006)[56]	Y	Y	Y	N	N	Y	N	Y	U
34.	Naidoo et al. (2003)[57]	Y	Y	Y	Y	N	Y	Y	Y	Y
35.	Wajuihian et al. (2017)[58]	Y	Y	Y	Y	Y	Y	N	Y	U
36.	Magakwe et al. (2020)[59]	Y	Y	Y	Y	Y	Y	Y	Y	Y
	Sudan									
37.	Rushood et al. (2013)[66]	Y	Y	Y	N	N	Y	N	Y	U
38.	Alrasheed et al. (2016)[67]	Y	Y	Y	N	Y	Y	Y	Y	Y

APPENDIX 2 continued

Number	Study	Was the sample frame appropriate to address the target population?	Were study participants sampled in an appropriate way?	Was the sample size adequate?	Were the study subjects and the setting described in detail?	Was the data analysis conducted with sufficient coverage of the identified sample?	Were valid methods used for the identification of the condition?	Was the condition measured in a standard, reliable way for all participants?	Was there appropriate statistical analysis?	Was the response rate adequate, and if not, was the low response rate managed appropriately?
	Tanzania									
39.	Wedner et al. (2002)[72]	Y	Y	Y	Y	Y	Y	N	Y	Y
	Togo									
40.	Saa et al. (2013)[73]	Y	Y	Y	N	N	Y	Y	Y	Y
	Tunisia									
41.	Chebil et al. (2016)[69]	Y	Y	Y	N	Y	Y	Y	Y	U
	Uganda									
42.	Kawuma and Mayeku (2002)[76]	Y	Y	Y	N	N	Y	Y	Y	Y

Y, Yes; N, No; U, Unclear; N/A, Not Applicable.