PLOS ONE

PLoS One. 2022; 17(2): e0263335. PMCID: PMC8812871
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335 PMID: 35113922

Systematic review and meta-analysis of myopia prevalence in African school children

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Aleksandra Barac, Editor

Abstract

Purpose

Increased prevalence of myopia is a major public health challenge worldwide, including in Africa. While previous studies have shown an increasing prevalence in Africa, there is no collective review of evidence on the magnitude of myopia in African school children. Hence, this study reviews the evidence and provides a meta-analysis of the prevalence of myopia in African school children.

Methods

This review was conducted using the 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Five computerized bibliographic databases, PUBMED, Scopus, Web of Science, ProQuest, and Africa Index Medicus were searched for published studies on the prevalence of myopia in Africa from 1 January 2000 to 18 August 2021. Studies were assessed for methodological quality. Data were gathered by gender, age and refraction technique and standardized to the definition of myopia as refractive error ≥ 0.50 diopter. A meta-analysis was

conducted to estimate the prevalence. Significant heterogeneity was detected among the various studies (I^2 >50%), hence a random effect model was used, and sensitivity analysis was performed to examine the effects of outliers.

Results

We included data from 24 quality assessed studies, covering 36,395 African children. The overall crude prevalence of myopia over the last two decades is 4.7% (95% CI, 3.9–5.7) in African children. Although the prevalence of myopia was slightly higher in females (5.3%, 95%CI: 4.1, 6.5) than in males (3.7%, 95% CI, 2.6–4.7; p = 0.297) and higher in older [12–18 years 5.1% (95% CI, 3.8–6.3) than younger children (aged 5–11 years, 3.4%, 95% CI, 2.5–4.4; p = 0.091), the differences were not significant. There was a significantly lower prevalence of myopia with cycloplegic compared with non-cycloplegic refraction [4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; p = 0.046].

Conclusions

Our results showed that myopia affects about one in twenty African schoolchildren, and it is overestimated in non-cycloplegic refraction. Clinical interventions to reduce the prevalence of myopia in the region should target females, and school children who are aged 12–18 years.

Introduction

Uncorrected refractive error is the most common cause of visual impairment affecting an estimated one billion people globally [1]. Myopia is the most common refractive error and an important cause of ocular morbidity, particularly among school-aged children and young adults. Worldwide, myopia is reaching epidemic proportions linked to changing lifestyles and modern technology, particularly mobile devices [2]. Globally, myopia affected 22.9% of the world's population in 2000, with projections of an increase to 49.8% by 2050 affecting 4.8 billion people [2], representing a 117% increase over 50 years. According to a 2015 report, it was estimated that globally, about 1.89 billion people are myopic and 170 million have high myopia [3].

The reported prevalence of myopia in children aged 5–17 years ranges from 1.2% in Mechi Zone, Nepal, to 73.0% in South Korea [4, 5]. Over 15 years, the prevalence of myopia increased from 79.5% to 87.7% in Chinese high school children with an average age of 18.5 ± 0.7 years [6]. In South African school children aged 5–15 years, the reported prevalence of myopia was only 2.9% with retinoscopy and 4.0% using autorefraction [7]. The authors reported that this prevalence increased to 9.6% at age 15 years.

The increase in myopia prevalence will have a significant economic impact because of associated ocular health problems and visual impairment. Uncorrected myopia of between– 1.50 D and– 4.00 D can significantly affect vision to be regarded as a cause of moderate visual impairment and blindness, respectively [8]. Apart from its direct impact on visual impairment, high myopia [usually defined as a spherical equivalent ≥ 5.00D [4, 9, 10] of myopia, although the definitions used to grade myopia are variable] increases the risk of potentially blinding ocular pathologies such as retinal holes; retinal tears; retinal degeneration; retinal detachment; and myopic macular degeneration [3, 11]. Uncorrected myopia has huge social, economic, psychological and developmental implications [12]. The economic cost of refractive errors, including myopia, has been estimated to be approximately US$ 202 billion per annum [13], far exceeding that of other eye diseases.

The increasing prevalence of myopia has led to research in the study of the possible mechanism for myopia development, which has generated two broad themes: the role of nature (genetic influences) and nurture (environmental influences including lifestyle). Understanding the mechanism for the development of myopia is also being explored in the control of myopia. Epidemiologic data from Southeast Asia has given credence to the association between near work and myopia, given the number of hours children from this region spend doing near work. Due to vast regional differences in culture, habits, socioeconomic status, educational levels and urbanization, there is uncertainty as to the exact magnitude of the myopia burden among African school–aged children and its trend over time [14].

In the last few decades, there has been a change in the lifestyle and behavior of people in Africa as a result of increasing urbanization [15]. Africa's urban population grew from 27 million in 1950 to 567 million in 2015 (a 2,000% increase), and now 50% of Africa's population live in one of the continent's 7,617 urban agglomerations of 10,000 or more inhabitants [16]. Consequently, more children and young adults in Africa are increasingly engaged in indoor and near work activities compared to earlier generations [17]. Children spend long hours doing schoolwork and, following the advent of technology, increasingly use mobile devices for gaming and other activities [18, 19]. These factors are thought to promote myopia development and/or progression [20–23].

Africa is the world's second largest and second most populous continent, after Asia, and it accounts for about 16% of the world's human population. While every global region will experience a decline in population by 2100, the African population is expected to triple. Africa's population is the youngest amongst all the continents, the median age in 2012 was 19.7 years compared to the global median of 30.4 years. This young population is an important asset for the continent's development. The challenges of the young population must be addressed in time as they constitute the bulk of the productive age of the economy. While rising myopia is a cause for global concern, it is not given due attention in Africa due to a lack of adequate prevalence data and prospective studies tracking the trend of myopia over decades [24]. Due to this, the representation of Africa is poor in studies predicting global trends of myopia [24]. The aim of this study was to systematically review the evidence and provide a meta–analysis of the prevalence of myopia in African school children which will address the knowledge gap and help understand the prevalence of myopia among this group in Africa.

Materials and methods

This systematic review followed the framework of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA. See Checklist in S1 File) [25]. The protocol for the review was registered with PROSPERO (#CRD42020187609).

Search strategy and quality assessment

Two review team members (GO and BE) performed an independent systematic search and review of myopia in Africa using published data spanning the last two decades. Refractive error came into reckoning as a cause of visual impairment in the last two decades, following the change in the definition of visual impairment which was based on presenting visual acuity [26]. The search was conducted on 25th May and 18th August 2021. A third reviewer, KO, adjudicated where there were disagreements. The quality of each selected article was assessed using the checklist developed by Downs and Black [27] and each included article was assessed and scored on a 10-item scale (scoring is shown in S1 Table). The search was restricted to articles available online, articles

mentioning prevalence of myopia in any region of Africa, and articles published in the English language. Searches included the following databases: Web of sciences, PubMed, ProQuest, MEDLINE, Scopus, and African Index Medicus from 1st of January 2000 to August 18, 2021.

We searched these databases using the following MeSH (Medical Subject Heading) terms and keywords: Refractive AND error AND Africa AND children AND prevalence. A number of iterations of these search terms were used, for example, "refractive error AND Africa AND children AND prevalence" or "refractive error AND Africa AND children". Further details about search strategy and MeSH terms are available in the (S2 File). A broader search also used terms such as epidemiology, myopia, and school children. We also identified and included relevant studies by manually searching through the reference lists of identified papers. The PRISMA flowchart presented in Fig 1 shows the process used for selecting articles.

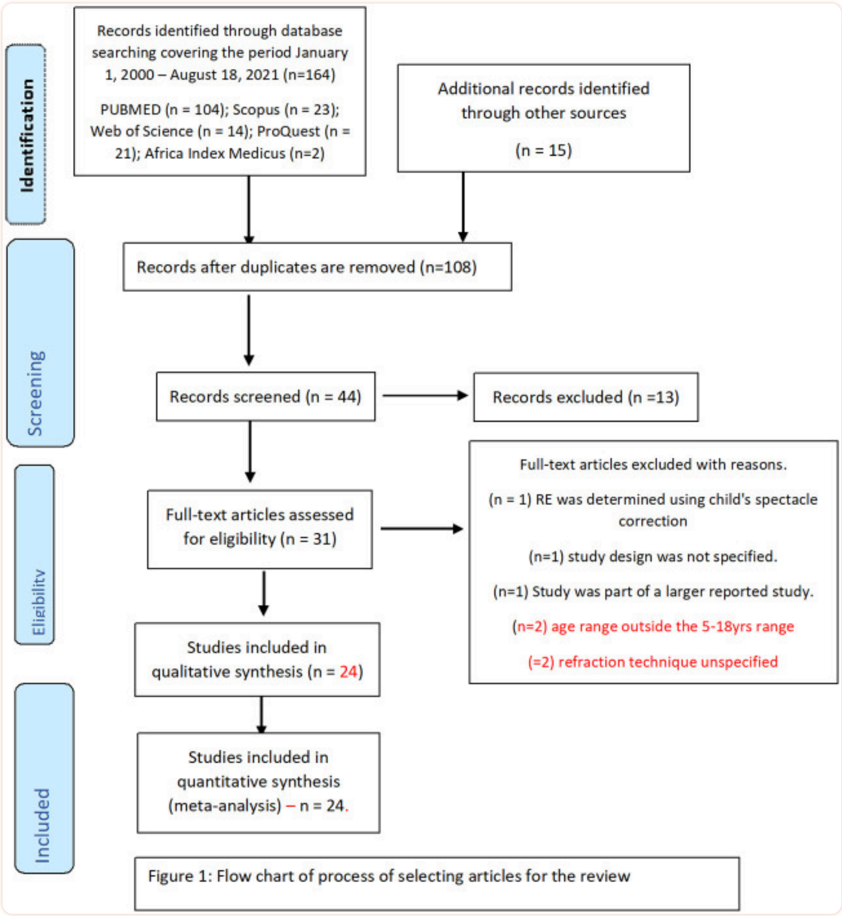


Fig 1

Flow chart of process of selecting articles for the review.

Inclusion and exclusion criteria

Studies published between 2000 and 2021, investigating the prevalence of refractive error in male and female school children aged 5 to 18 years of age were included in the review. Studies that employed an observational cross-sectional study design; had a clear description of the sampling technique; stated the method of measuring refractive error (cycloplegic or non-cycloplegic refraction), as well as objective or subjective refraction; stated the criteria for defining myopia (spherical equivalent ≥ 0.50 D of myopia [2, 28–30]; the study was either school–based or population–based; and were published in English language, were included in the review. The decision as to whether the articles met the inclusion criteria was made independently by the two reviewers (GO and BE) and where there was a disagreement, a third reviewer (KO) was consulted.

Studies where the criteria for defining myopia were not specified; the ages of the participants were either not specified or outside the age range specified for this review; or which reported findings from a hospital/clinic-based sample were excluded from the review.

Data extraction

The data extracted from each article included the following: Authors; year of publication; country of study; study design; sample size; sampling technique; the age of study participants; criteria for defining myopia; method of refractive error assessment (cycloplegic vs non-cycloplegic); method of refractive error assessment (objective vs subjective); prevalence of myopia; and the proportion of refractive error due to myopia. Where the reported prevalence was not clearly defined, the corresponding author in the published article was contacted for clarification.

Statistical methods

Meta–analysis was conducted using Stata version 14.0 (StataCorp, College Station, TX, USA). The syntax "metaprop" in Stata was used to generate forest plots and each forest plot showed the prevalence of myopia in school children, by gender, age and refraction technique in individual studies and its corresponding weight, as well as the pooled prevalence in each subset and its associated 95% confidence intervals (CI). A heterogeneity test obtained for the different studies showed a high level of inconsistency ($I^2 > 50\%$) thereby indicating the use of a random effect model in all the meta–analyses conducted. Sensitivity analysis was carried out by examining the effect of outliers, by employing similar method to that used by Patsopoulos et al. [31], which involves the process of comparing the pooled prevalence before and after eliminating one study at a time. The funnel plot was used to report the potential bias and small/large study effects and Begg's tests was used to assess asymmetry. The prevalence was subdivided into separate datasets based on overall prevalence, males or females, cycloplegic or non-cycloplegic refraction for a more detailed analysis of the prevalence of myopia. Also, to study a possible variation of the prevalence of myopia in terms of age, the age groups in the reported studies were divided into two categories: 5–11 years and 12–18 years. Their respective funnel plots are shown as (S3–S7 Files).

Results

Summary of included studies

From the described search strategy, a total of 164 potentially relevant titles/abstracts of articles were initially identified. Fig 1 presents the flowchart of the article screening and selection process. Following a quick inspection of identified studies and removal of duplicate articles, 44 relevant articles were assessed for eligibility. Using the pre–defined inclusion and exclusion criteria, 24 of 30 articles that underwent detailed review were eligible, and data from these studies were included in this study. A breakdown of the eligible studies as well as their quality assessment scores (maximum of 10) are presented in Table 1. S1 Table shows how the quality assessment scores were calculated.

Table 1

Characteristics of studies that reported the prevalence of myopia in school–aged children in Africa and were included in the meta–analysis.

First Author	Year of study	Study Country†	Age group (years)	Mean age (years)	Total Sample size	Cycloplegia	Objective refraction	Prevalence of myopia (%)	Comm refrac error
Atowa [32]	2017	Nigeria	8–15	11.5 ± 2.3	1197	Yes	Objective	2.7	
Wajuihian [33]	2017	South Africa	13–18	15.8 ± 1.6	1586	No	Objective	7	
Chebil [34]	2016	Tunisia	6–14	10.1 ± 1.8	6192	Yes	Objective	3.71	
Kedir [35]	2014	Ethiopia	7–15	Not reported	570	No	Subjective	2.6	
Soler [36]	2015	Equatorial Guinea	6–16	10.8 ± 3.1	425	Yes	Objective	10.4	
Kumah [37]	2013	Ghana	12–15	13.8	2435	Yes	Objective	3.2	
Mehari [38]	2013	Ethiopia	7–18	13.1 ± 2.5	4238	No	Objective	6	
Jimenez [39]	2012	Burkina Faso	6–16	11.2 ± 2.4	315	No	Objective	2.5	
Naidoo [7]	2003	South Africa	5–15	Not reported	4890	Yes	Objective	2.9	
Yamamah [40]	2015	Egypt	6–17	10.7 ± 3.1	2070	Yes	Objective	3.1	Astigm
Nartey [41]	2016	Ghana	6–16	10.6	811	No	Subjective	4.6	
Anera [42]	2006	Burkina Faso	5–16	10.2 ± 2.2	388	Yes	Objective	0.5	
Chukwuemeka [43]	2015	South Africa	7–14	9.9 ± 2.2	421	No	Objective	18.7	Astigm
Alrasheed [44]	2016	Sudan	6–15	10.8 ± 2.8	1678	Yes	Objective	6.8	Myopi
Abdul-Kabir [45]	2016	Ghana	10–15	Not reported	208	No	Objective	22.6	Myopi
Ebri [46]	2019	Nigeria	10–18	13.3 ± 1.9	4241	Yes	Objective	4.8	Astigm
Ezinne [47]	2018	Nigeria	5–15	9.0 ± 2.5	998	Yes	Objective	4.5	Myopi

† = country the study was conducted;

ǂ = authors provided data for only those aged 5–18 years.

The included studies comprised of the following: six (25.0%) studies from Ghana, four (16.7%) each from South Africa, and Nigeria, three from Ethiopia (12.5%), two (8.3%) from Burkina Faso, and one (4.2%) each from Sudan, Egypt, Equatorial Guinea, Somalia and Tunisia (Table 1). Of the reviewed articles, 84.2% (n = 21) were school–based, cross–sectional studies, two (8.3%) were population–based, cross–sectional studies, while one (4.2%) employed a cross–sectional study design but did not report whether it was school or population–based.

Method of measuring refractive error in African school–aged children

Of the reviewed studies, 13 (54.2%) performed cycloplegic refraction to determine the refractive error status of the children, while non-cycloplegic refraction was used in 11 (45.8%) of the studies. Regarding the technique used for refractive error measurement, over three–quarters of the studies (n = 20, 83.3%) performed objective refraction, with about one–sixth (n = 4, 16.7%) performing subjective refraction.

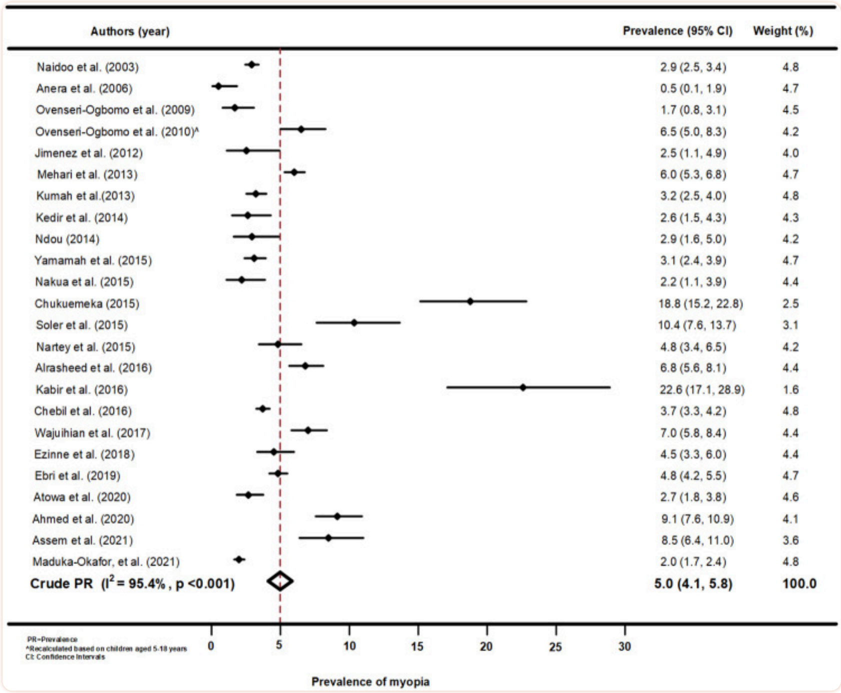
Prevalence of myopia in African school–aged children

The number of children aged 5–18 years included in the study ranged from 208 for a study conducted in Ghana [45] to 6192 for another study conducted in Tunisia [34, 55]. The prevalence of myopia reported in these studies ranged from 0.5% [42] to 10.4% [36, 52] with cycloplegic refraction. In studies where non–cycloplegic refraction was used to determine refractive error refraction in school children, the reported myopia prevalence ranged from 1.7% [51] to 22.6% [45].

Meta-analysis of myopia prevalence in children ag 5–18 years in Africa (2000–2021)

Myopia prevalence among school children in Africa

Fig 2 shows a forest plot of the prevalence of myopia among African school children aged 5–18 years. The pooled estimate of myopia in the African region was significant (5.0%, 95%CI: 4.1, 5.8; p<0.001) and about 37.5% of the studies (n = 9) reported significantly higher prevalence of myopia and 50% (n = 12) reporting significantly lower prevalence compared with the pooled estimate across Africa. The study by Abdul–Kabir found the highest prevalence (22.6%) of myopia among Ghanaian children (95%CI: 17.1, 28.9) [45], while Anera et al. found the lowest prevalence among children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9) [42]. The pooled prevalence estimates of myopia was similar to the study by Ebri [46] and Ezinne [47] (4.8%, 95%CI:4.2, 5.5), both involving children from Nigeria [46, 47]. Funnel plots and using Begg's test for Myopia in Africa indicated homogeneity (S3 File) and meta–regression analysis of myopia by year of publication indicated that publication of year increased as the proportion of myopia decreased but this relationship was not statistically significant (p = 0.423, S7 File).

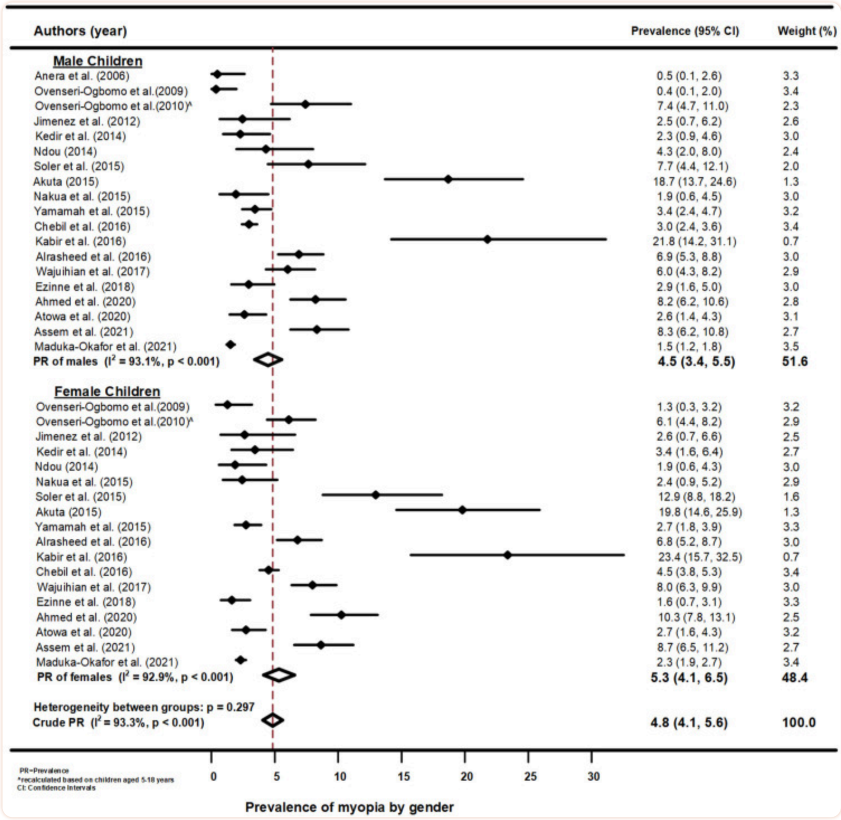


[Fig 2](#)

Forest plot of myopia prevalence from the meta–analysis of African studies.

Myopia prevalence by gender of the School children in Africa (2000–2021)

Fig 3 is a forest plot for prevalence of myopia by gender among school children aged 5–18 years in Africa. The prevalence estimates varied significantly between studies in both male and female children ($p<0.001$, per gender), and the overall pooled prevalence of myopia by gender was 4.8% (95%CI: 4.1, 5.6) and similar between male and female estimates ($p = 0.297$). Compared with the overall pooled estimate, the prevalence of myopia was slightly higher in male (4.5%, 95%CI: 3.4, 5.5) children than females (5.3%, 95%CI: 4.1, 6.5) but the difference was not significant as indicted by the overlapping of the CIs with that of the overall pooled estimate. Funnel plots and using Begg's test for Myopia by gender reported absence of publication biases (S4 File).



[Fig 3](#)

Forest plot of myopia prevalence by gender from the meta-analysis of African studies.

Myopia prevalence by age group of the school children in Africa (2000–2021)

The forest plot of the prevalence of myopia in children aged 5–11 years and 12–18 years is presented in [Fig 4](#). The pooled estimate of myopia in school children aged 5–11 years and 12–18 years was lower (3.7%, 95%CI 2.6, 4.7) and higher (5.8%, 95%CI 3.8, 6.3) respectively, than the pooled estimate but none was significant as they overlapped with the pooled estimate in Africa (4.4%, 95%CI 3.6, 5.2). The heterogeneity between the groups was approaching significant (p = 0.091) but older children had a higher prevalence of myopia than younger children. Among those aged 5–11 years, the highest significant prevalence was reported in a Ghanaian study (16.4%, 95%CI: 13.0, 20.3) and a study conducted in Equatorial Guinea (8.2%, 95%CI: 5.8, 11.3) while school children in Ethiopia (0.5%, 95%CI: 0.1, 1.5) had the lowest significant prevalence estimate of myopia. Among those aged 12–18 years, children in Ghana also showed the highest significant prevalence of myopia (20.2%, 95%CI: 16.5, 24.4), but the lowest prevalence was reported among School children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9). The heterogeneity of these studies by age as subgroups analysis were low ([S5 File](#)).

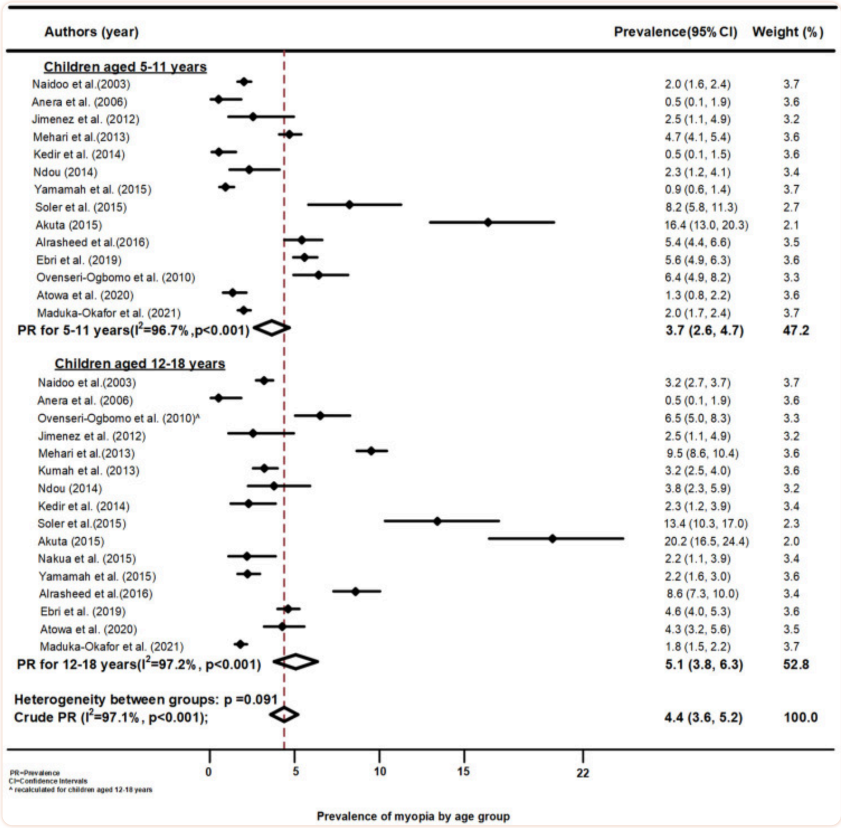
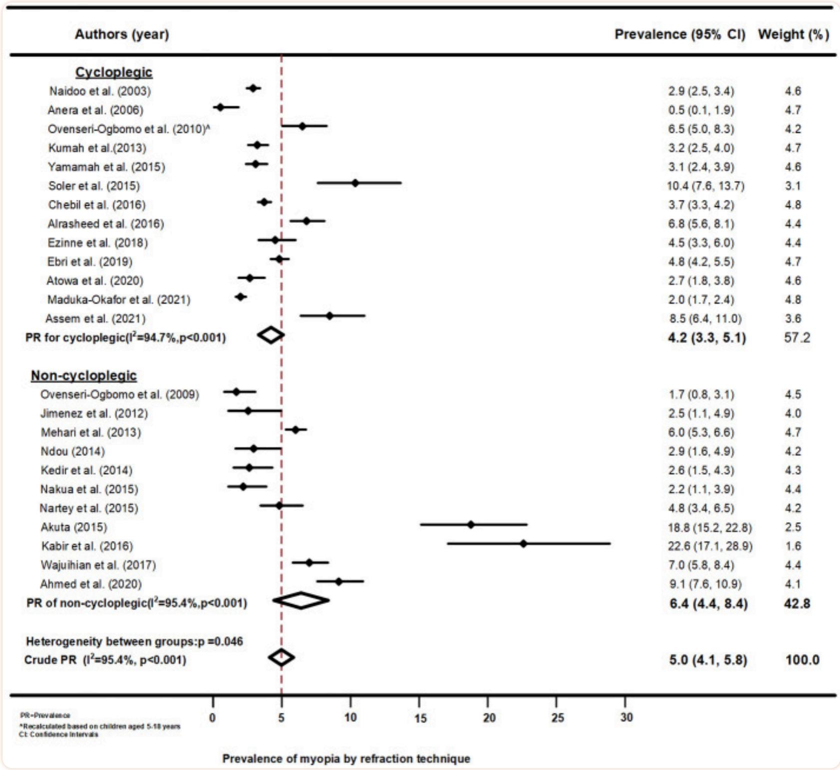


Fig 4

Forest plot of myopia prevalence by age group across African studies.

Myopia prevalence by mode of refraction among school children in Africa (2000–2021)

The forest plot displayed in Fig 5 shows the pooled estimate of myopia prevalence among school children in Africa. Using cycloplegic refraction, studies have reported significantly lower prevalence estimates of myopia among school children in Africa compared with those that used non–cycloplegic refraction (4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; p = 0.046). From the plot, it can be seen that studies that used non cycloplegic technique to determine refraction had greater variabilities in the reported myopia prevalence (ranging from 1.7 to 22.6%), but those that performed cycloplegic refraction had smaller between study variability in the reported prevalence of myopia (range from 0.5 to 10.4%). Funnel plots and the Begg's test for Myopia by refraction technique shown in S6 and S7 Files, respectively, found no publication biases.



[Fig 5](#)

Forest plot of myopia prevalence by refraction technique among school children in Africa.

Discussion

Prevalence of myopia

The present study provided recent estimates of the myopia prevalence in African children using data from twenty eight studies conducted over two decades. The prevalence of myopia defined as SER ≥ 0.50D of myopia in school children across African countries was 4.7% (95%CI, 3.9, 5.7%) and there were wide variations within and between African countries. A significantly higher prevalence rate was observed in Ghana [45] and South Africa [43], with significantly lower rates in Burkina Faso [42] and Ethiopia [56]. In some countries like Ghana, the variation in the reported prevalence of myopia between studies reached 21% [37, 41, 45, 48, 51, 52]. Although the regional variations in myopia prevalence found in this study are consistent with the statement of Foster and Jiang who remarked that "Considerable regional difference exists from country to country even within the same geographical area" [57], it remains unclear why these variations exist. While the criteria for defining refractive error is often cited as the reason for the variation in the prevalence of refractive errors, including myopia, between studies, this may not be the case in our study because only studies that defined myopia as spherical equivalent of ≥ 0.50 D were included.

The overall low prevalence of myopia found across Africa is consistent with other studies that reported lower myopia prevalence in African children compared with Asian children [5, 58]. It is instructive to note that in four of the studies that were included in the current review [36, 43, 45, 52], the reported prevalence of myopia was greater than 10%. Of these, two studies [36, 52] used cycloplegic refraction, which is thought to more accurately estimate the prevalence of myopia [59]. The lower prevalence of myopia in Africa compared with the other regions may be related to the differences in genetic predisposition to myopia development, and to culture [60–62]. Although the role of genetics in the development and progression of myopia is reported to be small [12], it is believed to have a role in an individual's susceptibility to environmental risk factors for myopia [63]. In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development [60, 63]. In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) [64]. We acknowledge that a recent investigation [65] has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

Notwithstanding the relatively low prevalence of myopia found among African children, there is a need to monitor myopia prevalence among children in this region given the increasing access to, and use of, mobile devices among African population [19], including children. This is important considering the reported higher increase in the prevalence of myopia in black children living in Africa (2.8% to 5.5%) compared with other black children not living in Africa (4.8% to 19.9%) after 10 years [58]. It is assumed that black children not in Africa may have more access and exposure to near work, including mobile devices, and less outdoor activities than their counterparts in Africa.

Age and gender-based differences in myopia prevalence

There was a 34.6% increase in the prevalence of myopia between the age groups with the older age group having a higher prevalence of 5.2%. The slightly higher prevalence of myopia between the two age groups shows there is a tendency for myopia prevalence to increase with age which is consistent with previous studies from elsewhere [58, 66, 67]. This increase in myopia prevalence is thought to be associated with the increasing growth of the eyeball. Although the pooled prevalence of myopia in female children was slightly higher than in male children (4.7 versus 3.7%), the difference did not reach statistical significance. The influence of gender on the prevalence of myopia has not been unequivocal in the literature [68–72] with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls [73]. Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys [74].

Prevalence of myopia by refraction technique (cycloplegic and non-cycloplegic)

The present study demonstrated that cycloplegic refraction resulted in significantly lower estimates of myopia prevalence than non-cycloplegic refraction, which was consistent with previous studies [75–78]. It has been reported that non-cycloplegic refraction overestimates the prevalence of myopia, yields a non-reliable measurement of association of myopia risk factors [59, 76], and hence cycloplegic refraction is regarded as the gold standard for measuring myopia [59]. Over half of the studies in this review utilised cycloplegic refraction, which is particularly important in this age group where the difference between the cycloplegic and non-cycloplegic refraction is quite high [77, 78]. The fact that non-cycloplegic refraction often results in overestimation of myopia may have, in part, accounted for the high prevalence reported in one study from Ghana [45]. Furthermore, we have demonstrated that cycloplegic refraction results in a lower variability of measured refractive error than non–cycloplegic refraction (see Fig 5), which may reflect the variable accommodative state during the refraction of children of different ages. This finding underscores the need to appropriately control accommodation when performing refraction especially in young children who have a higher amplitude of accommodation and in whom accommodation is more active.

Implications of the study

This is the first systematic review and meta-analysis to estimate the prevalence of myopia among school children in Africa and its variation with age, gender and refraction technique. As previously reported, the prevalence of myopia in Africa appears low compared to other regions such as South East Asia. This study also provides baseline data for comparison and future prevalence studies to establish a trend in myopia epidemiology in this population. A further remarkable finding in this review is the demonstration that non–cycloplegic refraction overestimated the prevalence of myopia and results in more variable estimates of refractive errors compared with cycloplegic refraction. The interpretation of myopia prevalence data obtained from non–cycloplegic refraction may be potentially misleading to researchers and policymakers. As a result, it is recommended that cycloplegic refraction be used in all studies investigating the prevalence of myopia in children.

Strengths and limitations of the review

This review has certain limitations. Firstly, this review did not investigate the trend in the prevalence of myopia among school children in Africa due to the limited number of studies. Secondly, the selection of English-only studies likely biased the results towards studies in Anglophone countries or countries where the findings were reported in English. Thirdly, the current review did not explore the various factors influencing the epidemiology of myopia in this population. Despite these limitations, a major strength of this study is the selection of studies that used a uniform definition of myopia (i.e. ≥ 0.50DS of myopia) which allowed for a better comparison in the reported prevalence of myopia. In addition, the study excluded studies that were conducted in unselected groups such as hospital-based studies and studies that did not report any evidence of sampling in the study. In addition, the selected studies were evaluated for robustness in the study designs employed in each study.

Conclusions

In summary, this systematic review and meta–analysis have shown that the prevalence of myopia among schoolchildren in Africa is lower than other regions of the world. The use of non–cycloplegic refraction for estimation of myopia prevalence can be misleading as it returns higher and more variable prevalence estimates. There is a need to monitor the trend of myopia as more children in this region are increasingly being exposed to identified risk factors for myopia development including access to mobile devices, increased near work, increased online or remote learning, and limited time outdoors. Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

Supporting information

S1 Table

Quality assessment of full-text articles included in review.

(DOCX)

Click here for additional data file.(23K, docx)

S1 File

PRISMA 2020 checklist.

(DOCX)

Click here for additional data file.(32K, docx)

S2 File

Search terms for refractive error Africa children prevalence filters (2000–2021).

(DOCX)

Click here for additional data file.(13K, docx)

S3 File

Funnel plots and 95% confidence intervals of Myopia.

(DOCX)

Click here for additional data file.(15K, docx)

S4 File

Funnel plots and 95% confidence intervals of Myopia by gender.

(DOCX)

Click here for additional data file.(15K, docx)

S5 File

Funnel plots and 95% confidence intervals of Myopia by age in categories.

(DOCX)

Click here for additional data file.(15K, docx)

S6 File

Funnel plots and 95% confidence intervals of Myopia by refraction technique.

(DOCX)

Click here for additional data file.(15K, docx)

S7 File

A meta-regression analysis of Myopia by year of publication.

The vertical axis is the log proportion of Myopia, and the horizontal axis represents year of publication. Each dark dot represented one selected study, and the size of each dark dots corresponds to the weight assigned to each study. Given the slope of the regression line has descending slightly in this figure, this could be interpreted as publication of year increased, the proportion of myopia decreased and, this relationship did not differ statistically ($p = 0.5512$).

(DOCX)

Click here for additional data file.(37K, docx)

S8 File

Data used in the analysis.

(XLSX)

Click here for additional data file.(46K, xlsx)

Acknowledgments

The authors acknowledge the guidance of late Prof Alabi, O Oduntan during data collection.

Funding Statement

The authors recieved no specific funding for this work.

Data Availability

All relevant data are within the paper and its Supporting information files.

References

1. World Health Organization. WHO launches first World report on vision [cited 2021 June 8]. https://www.who.int/news/item/08-10-2019-who-launches-first-world-report-on-vision.

2. Holden BA., Fricke TR., Wilson DA., Jong M., Naidoo KS., Sankaridurg P., et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–42. doi: 10.1016/j.ophtha.2016.01.006 [PubMed] [CrossRef] [Google Scholar]

3. Holden BA, Jong M, Davis S, Wilson D, Fricke T, Resnikoff S. Nearly 1 billion myopes at risk of myopia-related sight-threatening conditions by 2050—time to act now. *Clin Exp Optom*. 2015;98(6):491–3. doi: 10.1111/cxo.12339 [PubMed] [CrossRef] [Google Scholar]

4. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt*. 2012;32(1):3–16. doi: 10.1111/j.1475-1313.2011.00884.x [PubMed] [CrossRef] [Google Scholar]

5. Grzybowski A., Kanclerz P., Tsubota K., Lanca C., Saw S-M. A review on the epidemiology of myopia in school children worldwide. *BMC Ophthalmol*. 2020;20:27–38. doi: 10.1186/s12886-019-1220-0 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

6. Chen M., Wu A., Zhang L., Wang W., Chen X., Yu X., et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. *BMC Ophthalmol*. 2018;18:159. doi: 10.1186/s12886-018-0829-8 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

7. Naidoo KS, Raghunandan A, Mashige KP, Govender P, Holden BA, Pokharel GP, et al. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci*. 2003;44(9):3764–70. doi: 10.1167/iovs.03-0283 [PubMed] [CrossRef] [Google Scholar]

8. R. R. Bennett and Rabbetts' clinical visual optics. Oxford: Butterworth-Heinemann; 1998.

9. Kempen JH, Mitchell P, Lee KE, Tielsch JM, Broman AT, Taylor HR, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol*. 2004;122(4):495–505. doi: 10.1001/archopht.122.4.495 [PubMed] [CrossRef] [Google Scholar]

10. Williams K, Hammond C. High myopia and its risks. *Community eye health*. 2019;32(105):5–6. [PMC free article] [PubMed] [Google Scholar]

11. Holden BA., Mariotti SP., Kocur I., Resnikoff S., He M., Naidoo KS., et al. *The impact of myopia and high myopia: Report of the joint World Health Organization- Brien Holden Vision Institute Global Scientific Meeting on Myopia University of New South Wales, Sydney, Australia, 16–18 March 2015*. Geneva: World Health Organization; 2017. [Google Scholar]

12. Congdon N, Burnett A, Frick K. The impact of uncorrected myopia on individuals and society. *Community eye health*. 2019;32(105):7–8. [PMC free article] [PubMed] [Google Scholar]

13. Fricke TR., Holden BA., Wilson DA., Schlenther G., Naidoo KS., Resnikoff S., et al. Global cost of correcting vision impairment from uncorrected refractive error. *Bull World Health Organ*. 2012;90:728–38. doi: 10.2471/BLT.12.104034 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

14. Rudnicka AR, Owen CG, Nightingale CM, Cook DG, Whincup PH. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: the Child Heart and Health Study in England (CHASE). *Invest Ophthalmol Vis Sci*. 2010;51(12):6270–6. doi: 10.1167/iovs.10-5528 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

15. Wachira L-J. Lifestyle Transition towards Sedentary Behavior among Children and Youth in Sub-Saharan Africa: A narrative review: IntechOpen; 2021.

16. OECD/SWAC. *Africa's Urbanisation Dynamics 2020: Africapolis, Mapping a New Urban Geography, West African Studies*. Paris: OECD Publishing; 2020. [Google Scholar]

17. Juma K, Juma PA, Shumba C, Otieno P, Asiki G. Non-Communicable Diseases and Urbanization in African Cities: A Narrative Review. In: Anugwom EE, Awofeso N, editors. Public Health in Developing Countries—Challenges and Opportunities: IntechOpen.

18. Porter G, Hampshire K, Abane A, Munthali A, Robson E, Mashiri M, et al. Youth, mobility and mobile phones in Africa: findings from a three-country study. *Information Technology for Development*. 2012;18(2):145–62. [Google Scholar]

19. Porter G, Hampshire K, Milner J, Munthali A, Robson E, de Lannoy A, et al. Mobile Phones and Education in Sub-Saharan Africa: From Youth Practice to Public Policy. *Journal of International Development*. 2016;28(1):22–39. [Google Scholar]

20. Hepsen IF, Evereklioglu C, Bayramlar H. The effect of reading and near-work on the development of myopia in emmetropic boys: a prospective, controlled, three-year follow-up study. *Vision Res*. 2001;41(19):2511–20. doi: 10.1016/s0042-6989(01)00135-3 [PubMed] [CrossRef] [Google Scholar]

21. Ip JM, Saw S-M, Rose KA, Morgan IG, Kifley A, Wang JJ, et al. Role of Near Work in Myopia: Findings in a Sample of Australian School Children. *Investigative Ophthalmology & Visual Science*. 2008;49(7):2903–10. [PubMed] [Google Scholar]

22. Huang HM, Chang DS, Wu PC. The Association between Near Work Activities and Myopia in Children-A Systematic Review and Meta-Analysis. *PLoS One*. 2015;10(10):e0140419. doi: 10.1371/journal.pone.0140419 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

23. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology*. 2012;119(10):2141–51. doi: 10.1016/j.ophtha.2012.04.020 [PubMed] [CrossRef] [Google Scholar]

24. Wolffsohn JS, Calossi A, Cho P, Gifford K, Jones L, Li M, et al. Global trends in myopia management attitudes and strategies in clinical practice. *Cont Lens Anterior Eye*. 2016;39(2):106–16. doi: 10.1016/j.clae.2016.02.005 [PubMed] [CrossRef] [Google Scholar]

25. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi: 10.1136/bmj.n71 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

26. Dandona L, Dandona R. Revision of visual impairment definitions in the International Statistical Classification of Diseases. *BMC medicine*. 2006;4:7-. doi: 10.1186/1741-7015-4-7 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

27. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377–84. doi: 10.1136/jech.52.6.377 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

28. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Gupta V, et al. Incidence and progression of myopia and associated factors in urban school children in Delhi: The North India Myopia Study (NIM Study). *PLoS One*. 2017;12(12):e0189774. doi: 10.1371/journal.pone.0189774 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

29. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Menon V, et al. Prevalence of myopia and its risk factors in urban school children in Delhi: the North India Myopia Study (NIM Study). *PLoS One*. 2015;10(2):e0117349. doi: 10.1371/journal.pone.0117349 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

30. Luo HD, Gazzard G, Liang Y, Shankar A, Tan DT, Saw SM. Defining myopia using refractive error and uncorrected logMAR visual acuity >0.3 from 1334 Singapore school children ages 7–9 years. *Br J Ophthalmol*. 2006;90(3):362–6. doi: 10.1136/bjo.2005.079657 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

31. Patsopoulos NA, Evangelou E, Ioannidis JP. Sensitivity of between-study heterogeneity in meta-analysis: proposed metrics and empirical evaluation. *International Journal of Epidemiology*. 2008;37(5):1148–57. doi: 10.1093/ije/dyn065 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

32. Atowa UC, Munsamy AJ, Wajuihian SO. Prevalence and risk factors for myopia among school children in Aba, Nigeria. *African Vision and Eye Health*; Vol 76, No 1 (2017). [Google Scholar]

33. Wajuihian SO, Hansraj R. Refractive Error in a Sample of Black High School Children in South Africa. *Optom Vis Sci*. 2017;94(12):1145–52. doi: 10.1097/OPX.0000000000001145 [PubMed] [CrossRef] [Google Scholar]

34. Chebil A, Jedidi L, Chaker N, Kort F, Largueche L, El Matri L. Epidemiologic study of myopia in a population of schoolchildren in Tunisia. *Tunis Med*. 2016;94(3):216–20. [PubMed] [Google Scholar]

35. Kedir J, Girma A. Prevalence of refractive error and visual impairment among rural school-age children of Goro District, Gurage Zone, Ethiopia. *Ethiop J Health Sci*. 2014;24(4):353–8. doi: 10.4314/ejhs.v24i4.11 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

36. Soler M, Anera RG, Castro JJ, Jiménez R, Jiménez JR. Prevalence of Refractive Errors in Children in Equatorial Guinea. *Optometry and Vision Science*. 2015;92(1). doi: 10.1097/OPX.0000000000000448 [PubMed] [CrossRef] [Google Scholar]

37. Kumah BD, Ebri A, Abdul-Kabir M, Ahmed AS, Koomson NY, Aikins S, et al. Refractive error and visual impairment in private school children in Ghana. *Optom Vis Sci*. 2013;90(12):1456–61. doi: 10.1097/OPX.0000000000000099 [PubMed] [CrossRef] [Google Scholar]

38. Mehari ZA, Yimer AW. Prevalence of refractive errors among schoolchildren in rural central Ethiopia. *Clin Exp Optom*. 2013;96(1):65–9. doi: 10.1111/j.1444-0938.2012.00762.x [PubMed] [CrossRef] [Google Scholar]

39. Jimenez R, Soler M, Anera RG, Castro JJ, Perez MA, Salas C. Ametropias in school-age children in Fada N'Gourma (Burkina Faso, Africa). *Optom Vis Sci*. 2012;89(1):33–7. doi: 10.1097/OPX.0b013e318238b3dd [PubMed] [CrossRef] [Google Scholar]

40. Yamamah GA, Talaat Abdel Alim AA, Mostafa YS, Ahmed RA, Mohammed AM. Prevalence of Visual Impairment and Refractive Errors in Children of South Sinai, Egypt. *Ophthalmic Epidemiol*. 2015;22(4):246–52. doi: 10.3109/09286586.2015.1056811 [PubMed] [CrossRef] [Google Scholar]

41. Nartey ET, van Staden DB, Amedo AO. Prevalence of Ocular Anomalies among Schoolchildren in Ashaiman, Ghana. *Optometry and Vision Science*. 2016;93(6). doi: 10.1097/OPX.0000000000000836 [PubMed] [CrossRef] [Google Scholar]

42. Anera RG, Jiménez JR, Soler M, Pérez MA, Jiménez R, Cardona JC. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol*. 50. Japan2006. p. 483–4. doi: 10.1007/s10384-006-0354-9 [PubMed] [CrossRef] [Google Scholar]

43. Chukwuemeka AG. *Prevalence of refractive errors among primary school children (7–14 years) in Motherwell Township, Eastern Cape, South Africa*. Eastern Cape, South Africa: University of Limpopo; 2015. [Google Scholar]

44. Alrasheed SH, Naidoo KS, Clarke-Farr PC. Prevalence of visual impairment and refractive error in school-aged children in South Darfur State of Sudan. *African Vision and Eye Health*; Vol 75, No 1 (2016). [Google Scholar]

45. Abdul-Kabir M, Bortey DNK, Onoikhua EE, Asare-Badiako B, Kumah DB. Ametropia among school children—a cross-sectional study in a sub-urban municipality in Ghana. *Pediatr Dimensions*. 2016;1(3):65–8. [Google Scholar]

46. Ebri AE, Govender P, Naidoo KS. Prevalence of vision impairment and refractive error in school learners in Calabar, Nigeria. *African Vision and Eye Health*; Vol 78, No 1 (2019) [Google Scholar]

47. Ezinne NE, Mashige KP. Refractive error and visual impairment in primary school children in Onitsha, Anambra State, Nigeria. *African Vision and Eye Health*; Vol 77, No 1 (2018). [Google Scholar]

48. Nakua EK, Otupiri E, Owusu-Dabo E, Dzomeku VM, Otu-Danquah K, Anderson M. Prevalence of refractive errors among junior high school students in the Ejisu Juaben Municipality of Ghana. *J Sci Tech*. 2015;35(1):52–62. [Google Scholar]

49. Ndou NP. *Uncorrected refractive errors among primary school children of Moretele sub-distric in North-west Province*, South Africa: University of Limpopo; 2014. doi: 10.5713/ajas.2013.13774 [CrossRef] [Google Scholar]

50. Abdi Ahmed Z, Alrasheed SH, Alghamdi W. Prevalence of refractive error and visual impairment among school-age children of Hargesia, Somaliland, Somalia. *East Mediterr Health J*. 2020;26(11):1362–70. doi: 10.26719/emhj.20.077 [PubMed] [CrossRef] [Google Scholar]

51. Ovenseri-Ogbomo GO, Assien R. Refractive error in school children in Agona Swedru, Ghana. *African Vision and Eye Health; South African Optometrist*: Vol 69, No 2 (2010). [Google Scholar]

52. Ovenseri-Ogbomo G, Omuemu DV. Prevalence of refractive error among school children in the Cape Coast Municipality, Ghana. *{Opto}*. 2010:59. [Google Scholar]

53. Assem AS, Tegegne MM, Fekadu SA. Prevalence and associated factors of myopia among school children in Bahir Dar city, Northwest Ethiopia, 2019. *PLoS One*. 2021;16(3):e0248936. doi: 10.1371/journal.pone.0248936 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

54. Maduka-Okafor FC, Okoye O, Ezegwui I, Oguego NC, Okoye OI, Udeh N, et al. Refractive Error and Visual Impairment Among School Children: Result of a South-Eastern Nigerian Regional Survey. *Clin Ophthalmol*. 2021;15:2345–53. doi: 10.2147/OPTH.S298929 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

55. Rushood AA, Azmat S, Shariq M, Khamis A, Lakho KA, Jadoon MZ, et al. Ocular disorders among schoolchildren in Khartoum State, Sudan. *East Mediterr Health J*. 2013;19(3):282–8. [PubMed] [Google Scholar]

56. Woldeamanuel GG, Biru MD, Geta TG, Areru BA. Visual impairment and associated factors among primary school children in Gurage Zone, Southern Ethiopia. *Afr Health Sci*. 2020;20(1):533–42. doi: 10.4314/ahs.v20i1.60 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

57. Foster PJ, Jiang Y. Epidemiology of myopia. *Eye*. 2014;28(2):202–8. doi: 10.1038/eye.2013.280 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

58. Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. *Br J Ophthalmol*. 2016;100(7):882–90. doi: 10.1136/bjophthalmol-2015-307724 [PMC free article] [PubMed]

[CrossRef] [Google Scholar]

59. Morgan IG, Iribarren R, Fotouhi A, Grzybowski A. Cycloplegic refraction is the gold standard for epidemiological studies. *Acta Ophthalmol*. 2015;93(6):581–5. doi: 10.1111/aos.12642 [PubMed] [CrossRef] [Google Scholar]

60. Ip JM, Huynh SC, Robaei D, Rose KA, Morgan IG, Smith W, et al. Ethnic Differences in the Impact of Parental Myopia: Findings from a Population-Based Study of 12-Year-Old Australian Children. *Investigative Ophthalmology & Visual Science*. 2007;48(6):2520–8. doi: 10.1167/iovs.06-0716 [PubMed] [CrossRef] [Google Scholar]

61. Goldschmidt E, Jacobsen N. Genetic and environmental effects on myopia development and progression. *Eye*. 2014;28(2):126–33. doi: 10.1038/eye.2013.254 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

62. Armarnik S, Lavid M, Blum S, Wygnanski-Jaffe T, Granet DB, Kinori M. The relationship between education levels, lifestyle, and religion regarding the prevalence of myopia in Israel. *BMC Ophthalmology*. 2021;21(1):136. doi: 10.1186/s12886-021-01891-w [PMC free article] [PubMed] [CrossRef] [Google Scholar]

63. Lim LT, Gong Y, Ah-Kee EY, Xiao G, Zhang X, Yu S. Impact of parental history of myopia on the development of myopia in mainland china school-aged children. *Ophthalmology and eye diseases*. 2014;6:31–5. doi: 10.4137/OED.S16031 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

64. The Global Economy. Business and economic data for 200 countries [cited 2021 August 12]. https://www.theglobaleconomy.com/.

65. Gajjar S, Ostrin LA. A systematic review of near work and myopia: measurement, relationships, mechanisms and clinical corollaries. *Acta Ophthalmologica*. 2021. doi: 10.1111/aos.15043 [PubMed] [CrossRef] [Google Scholar]

66. French AN, Morgan IG, Burlutsky G, Mitchell P, Rose KA. Prevalence and 5- to 6-year incidence and progression of myopia and hyperopia in Australian schoolchildren. *Ophthalmology*. 2013;120(7):1482–91. doi: 10.1016/j.ophtha.2012.12.018 [PubMed] [CrossRef] [Google Scholar]

67. Hashemi H, Fotouhi A, Mohammad K. The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic Epidemiol*. 2004;11(3):213–25. doi: 10.1080/09286580490514513 [PubMed] [CrossRef] [Google Scholar]

68. Lam CSY, Goh WSH. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. *Clinical and Experimental Optometry*. 1991;74(3):97–103. [Google Scholar]

69. Maul E, Barroso S, Munoz SR, Sperduto RD, Ellwein LB. Refractive Error Study in Children: results from La Florida, Chile. *Am J Ophthalmol*. 2000;129(4):445–54. doi: 10.1016/s0002-9394(99)00454-7 [PubMed] [CrossRef] [Google Scholar]

70. Czepita D, Mojsa A, Ustianowska M, Czepita M, Lachowicz E. Role of gender in the occurrence of refractive errors. *Ann Acad Med Stetin*. 2007;53(2):5–7. [PubMed] [Google Scholar]

71. Quek TP, Chua CG, Chong CS, Chong JH, Hey HW, Lee J, et al. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt*. 2004;24(1):47–55. doi: 10.1046/j.1475-1313.2003.00166.x [PubMed] [CrossRef] [Google Scholar]

72. Zhao J, Mao J, Luo R, Li F, Munoz SR, Ellwein LB. The progression of refractive error in school-age children: Shunyi district, China. *Am J Ophthalmol*. 2002;134(5):735–43. doi: 10.1016/s0002-9394(02)01689-6 [PubMed] [CrossRef] [Google Scholar]

73. Vision. NRCUCo. *Myopia: Prevalence and Progression*. Washington (DC): National Academies Press (US); 1989. [PubMed] [Google Scholar]

74. Gong J-F, Xie H-L, Mao X-J, Zhu X-B, Xie Z-K, Yang H-H, et al. Relevant factors of estrogen changes of myopia in adolescent females. *Chinese medical journal*. 2015;128(5):659. doi: 10.4103/0366-6999.151669 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

75. Lundberg K, Suhr Thykjaer A, Søgaard Hansen R, Vestergaard AH, Jacobsen N, Goldschmidt E, et al. Physical activity and myopia in Danish children-The CHAMPS Eye Study. *Acta Ophthalmol*. 2018;96(2):134–41. doi: 10.1111/aos.13513 [PubMed] [CrossRef] [Google Scholar]

76. Fotouhi A, Morgan IG, Iribarren R, Khabazkhoob M, Hashemi H. Validity of noncycloplegic refraction in the assessment of refractive errors: the Tehran Eye Study. *Acta Ophthalmol*. 2012;90(4):380–6. doi: 10.1111/j.1755-3768.2010.01983.x [PubMed] [CrossRef] [Google Scholar]

77. Fotedar R, Rochtchina E, Morgan I, Wang JJ, Mitchell P, Rose KA. Necessity of cycloplegia for assessing refractive error in 12-year-old children: a population-based study. *Am J Ophthalmol*. 2007;144(2):307–9. doi: 10.1016/j.ajo.2007.03.041 [PubMed] [CrossRef] [Google Scholar]

78. Hu YY, Wu JF, Lu TL, Wu H, Sun W, Wang XR, et al. Effect of cycloplegia on the refractive status of children: the Shandong children eye study. *PLoS One*. 2015;10(2):e0117482. doi: 10.1371/journal.pone.0117482 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r001

Decision Letter 0

Aleksandra Barac, Academic Editor

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13 Dec 2021

PONE-D-21-28841Systematic Review and Meta-analysis of Myopia prevalence in African School children.PLOS ONE

Dear Dr. Osuagwu,

Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit but does not fully meet PLOS ONE's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

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We look forward to receiving your revised manuscript.

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Reviewer's Responses to Questions

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

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3. Have the authors made all data underlying the findings in their manuscript fully available?

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4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level

- They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

I think we should exclude these articles or change the inclusion criteria

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

In a meta-analysis, Gajjar (Acta ophtahlmol 2021) show that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) shows the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Reviewer #2: This is a good Meta-analysis regarding the myopia prevalence in Africa

it is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

****

6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose "no", your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

[NOTE: If reviewer comments were submitted as an attachment file, they will be attached to this email and accessible via the submission site. Please log into your account, locate the manuscript record, and check for the action link "View Attachments". If this link does not appear, there are no attachment files.]

While revising your submission, please upload your figure files to the Preflight Analysis and Conversion Engine (PACE) digital diagnostic tool, https://pacev2.apexcovantage.com/. PACE helps ensure that figures meet PLOS requirements. To use PACE, you must first register as a user. Registration is free. Then, login and navigate to the UPLOAD tab, where you will find detailed instructions on how to use the tool. If you encounter any issues or have any questions when using PACE, please email PLOS at figures@plos.org. Please note that Supporting Information files do not need this step.

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r002

Author response to Decision Letter 0

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13 Jan 2022

Response to Reviewers comments

Dear Aleksandra Barac

Thanks for the very useful comments which has strengthened our manuscript. We have revised the article according to the suggested comments. We have provided a point-by-point response to all reviewers comments for clarity.

The changes made in the revised manuscript and supplementary files were highlighted using red font for easy identification.

Journal Requirements:

When submitting your revision, we need you to address these additional requirements.

1. Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. The PLOS ONE style templates can be found at

https://journals.plos.org/plosone/s/file?id=wjVg/PLOSOne_formatting_sample_main_body.pdf and

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Response: Done

2. Please include captions for your Supporting Information files at the end of your manuscript, and update any in-text citations to match accordingly. Please see our Supporting Information guidelines for more information: http://journals.plos.org/plosone/s/supporting-information.

Response: Done

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

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3. Have the authors made all data underlying the findings in their manuscript fully available?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception (please refer to the Data Availability Statement in the manuscript PDF file). The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: No

Response: We have included the study data used in the analysis as a spread sheet inline with PlosOne policy

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4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1:

The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

Response: Agreed and we have excluded the 4–24year-old range study (Yareed et al) and the 5-19 year study (Ovenseri-Ogbomo et al) as they do not meet our stipulated inclusion criteria of 5-18 year.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level. They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

Response: The inclusion and exclusion criteria were made clearer and as suggested, we excluded these studies as the two stipulated criteria are not specified [Rushood (39) and Woldeamanuel (47)]

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

Response: We have included the mean age in Table 1 and the study with age range 4-24years was excluded based on the exclusion criteria.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

Response: In a meta-analysis, Gajjar (Acta ophthalmol 2021) showed that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) showed the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside. However, we agree with the reviewer and have made the following revision in the discussion section:

In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development(62, 65). In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) (66). We acknowledge that a recent investigation(67) has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Response: Zadnik et al study was referring to a specific context in their study, where they found that girls tended to have steeper corneas, stronger crystalline lenses, and shorter eyes/axial length than boys. These findings are specific to their study and cannot be used to explain any result where a higher prevalence of myopia in girls is found. For example, we know that shorter axial length is generally associated with hyperopia and not myopia.

However, the new analysis after removing the 4 studies, showed no statistically significant difference in myopia prevalence between gender. Therefore, we have removed this statement and the revised section now reads:

The influence of gender on the prevalence of myopia has not been unequivocal in the literature (70-74) with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls (75). Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys (76).

Reviewer #2

This is a good Meta-analysis regarding the myopia prevalence in Africa. It is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

Response: Thanks for the suggestion. Although the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about the differences in the prevalence of myopia between ethnic groups in Africa, studies that have been conducted in Africa did not specify the different ethnicities. However, we think there is need for such comparison between black vs white vs Asian and this could be another research interest with a different research aim for another manuscript. We have suggested this in the conclusion for future study direction. The section now reads:

Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

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6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose “no”, your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

Response. Thanks for your comments

Attachment

Submitted filename: *Response to Reviewers comments.docx*

Click here for additional data file. (31K, docx)

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r003

Decision Letter 1

Aleksandra Barac, Academic Editor

17 Jan 2022

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

PONE-D-21-28841R1

Dear Dr. Osuagwu,

We're pleased to inform you that your manuscript has been judged scientifically suitable for publication and will be formally accepted for publication once it meets all outstanding technical requirements.

Within one week, you'll receive an e-mail detailing the required amendments. When these have been addressed, you'll receive a formal acceptance letter and your manuscript will be scheduled for publication.

An invoice for payment will follow shortly after the formal acceptance. To ensure an efficient process, please log into Editorial Manager at http://www.editorialmanager.com/pone/, click the 'Update My Information' link at the top of the page, and double check that your user information is up-to-date. If you have any billing related questions, please contact our Author Billing department directly at authorbilling@plos.org.

If your institution or institutions have a press office, please notify them about your upcoming paper to help maximize its impact. If they'll be preparing press materials, please inform our press team as soon as possible -- no later than 48 hours after receiving the formal acceptance. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information, please contact onepress@plos.org.

Kind regards,

Aleksandra Barac

Academic Editor

PLOS ONE

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r004

Acceptance letter

Aleksandra Barac, Academic Editor

24 Jan 2022

PONE-D-21-28841R1

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

Dear Dr. Osuagwu:

I'm pleased to inform you that your manuscript has been deemed suitable for publication in PLOS ONE. Congratulations! Your manuscript is now with our production department.

If your institution or institutions have a press office, please let them know about your upcoming paper now to help maximize its impact. If they'll be preparing press materials, please inform our press team within the next 48 hours. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information please contact onepress@plos.org.

If we can help with anything else, please email us at plosone@plos.org.

Thank you for submitting your work to PLOS ONE and supporting open access.

Kind regards,

PLOS ONE Editorial Office Staff

on behalf of

Dr. Aleksandra Barac

Academic Editor

PLOS ONE

Br J Ophthalmol. 2016 Jul; 100(7): 882–890.
Published online 2016 Jan 22. doi: 10.1136/bjophthalmol-2015-307724
PMCID: PMC4941141
PMID: 26802174

Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention

Alicja R Rudnicka,[1] Venediktos V Kapetanakis,[1] Andrea K Wathern,[1] Nicola S Logan,[2] Bernard Gilmartin,[2] Peter H Whincup,[1] Derek G Cook,[1] and Christopher G Owen[1]

Abstract

The aim of this review was to quantify the global variation in childhood myopia prevalence over time taking account of demographic and study design factors. A systematic review identified population-based surveys with estimates of childhood myopia prevalence published by February 2015. Multilevel binomial logistic regression of log odds of myopia was used to examine the association with age, gender, urban versus rural setting and survey year, among populations of different ethnic origins, adjusting for study design factors. 143 published articles (42 countries, 374 349 subjects aged 1–18 years, 74 847 myopia cases) were included. Increase in myopia prevalence with age varied by ethnicity. East Asians showed the highest prevalence, reaching 69% (95% credible intervals (CrI) 61% to 77%) at 15 years of age (86% among Singaporean-Chinese). Blacks in Africa had the lowest prevalence; 5.5% at 15 years (95% CrI 3% to 9%). Time trends in myopia prevalence over the last decade were small in whites, increased by 23% in East Asians, with a weaker increase among South Asians. Children from urban environments have 2.6 times the odds of myopia compared with those from rural environments. In whites and East Asians sex differences emerge at about 9 years of age; by late adolescence girls are twice as likely as boys to be myopic. Marked ethnic differences in age-specific prevalence of myopia exist. Rapid increases in myopia prevalence over time, particularly in East Asians, combined with a universally higher risk of myopia in urban settings, suggest that environmental factors play an important role in myopia development, which may offer scope for prevention.

Keywords: Epidemiology, Child health (paediatrics), Optics and Refraction, Public health

Feedback

Introduction

Myopia is the most common cause of correctable visual impairment in the developed world in adults and children1–5 and is a leading cause of preventable blindness in developing countries.6 Approximately one in six of the world's population is myopic.7 This represents a substantial burden worldwide with an appreciable unmet need for visual correction especially in poorer countries.[8] Myopia begins in early life and increases in frequency and severity through childhood and adolescence into adulthood. High myopia affects up to 20% of secondary school children in East Asia, and is associated with sight-threatening pathologies that are irreversible.[9] In white European populations the prevalence of myopia is relatively low affecting approximately 3–5% of 10-year olds[10–12] and up to 20% aged 12–13 years.[2] [13–15] In contrast, studies from Asian populations suggest rapid increases in the prevalence of childhood myopia (in terms of prevalence and absolute levels of myopia), affecting 80–90% of school-leavers in East Asia.[9] [16–19] However, not all Asian populations appear to be undergoing this myopic transition.[12] [20–23] There are marked ethnic and geographical differences in myopia prevalence, which seem to have changed over time. There is a need to bring together the evidence to quantify population differences in myopia prevalence over time. However, quantifying the degree of ethnic differences in myopia is often hampered by interstudy differences in methodology, where different age groups, sampling methods and definitions of myopia are used. Hence, we undertook a systematic review of geographical and ethnic variations in myopia prevalence in childhood over an extended time period using a quantitative Bayesian meta-regression of studies that reported myopia prevalence. We provide estimates of myopia prevalence by age, ethnicity and sex, and examine trends over time. The influence of interstudy differences in study design on estimates of myopia prevalence was investigated as well as gender differences, and living in urban versus rural environments.

Methods

The systematic review followed the Meta-analysis Of Observational Studies in Epidemiology guidelines for the conduct of systematic reviews and meta-analysis of observational studies.[24] A combination of text words for myopia (short$sight*/myopi?/myope$/refractive error$/ocular refraction), childhood (child/childhood/children/adolescent/adolescence/teenage) and epidemiological terms (incident/incidence/prevalen*/population$/survey$) were combined with the related medical subject headings in MEDLINE (1950 to February 2015), and subject headings EMBASE (1980 to February 2015) and Web of Science (1970 to February 2015) databases (full search strategy is available in the online supplementary material). Validity of the search strategy was verified by its ability to identify all studies known to the investigators and those identified in recent qualitative reviews of myopia.[7] [9] [25] [26]

Inclusion and exclusion criteria

Studies were included if they provided quantitative estimates of myopia prevalence in populations with a clearly defined sampling strategy. Surveys or audits of hospital eye departments or clinics were excluded. Studies that did not report ethnicity of the participants were excluded. Review articles were excluded to avoid duplication of data from individual studies, but were used to check that relevant studies were identified. Studies inviting non-specific volunteers, that relied on self-reported myopia or carried out refractive assessment in a subset, that is, only in those with reduced vision, were excluded.

Studies identified and data extraction

All data extraction was carried out independently by three reviewers (ARR, VVK and CGO), with independent extraction in a subset. Disagreements in data extraction were resolved by discussion.

Data were extracted on a number of key indicators of study quality, identified a priori. These included methods of assessment (including subjective refraction/retinoscopy and open or closed field autorefraction and use of cycloplegia) and case definition of myopia. In the presence of multiple definitions for myopia within a study, the definition with spherical equivalent refraction/sphere refraction closest to '−0.5 D or less' was used. Some studies reported prevalence based on subjective refraction separately from those on autorefraction. In these situations we included only data from the autorefractor measurements to avoid double counting data from the same study. When prevalence was reported with and without the use of cycloplegia, estimates obtained after the use of cycloplegia were used preferentially.

Data were also extracted on study response rates, habitation type (urban, rural or mixed) and year of survey (midpoint when a study period was reported), geographical location (region/city and country), number of children examined, number with myopia, estimates of myopia prevalence by gender and ethnic/racial group where available. For longitudinal studies, prevalence estimates from follow-up visits were not included in the analyses as our analyses are based on myopia prevalence not incidence.

Among studies that reported ethnicity, most studies were conducted on indigenous population groups (migrant populations were classified according to the reported ethnicity). Ethnicity was classified into the groups listed below, broadly following definitions of the United Nations (UN) and WHO:

I. Whites: individuals of white European ancestry residing in Europe, America, Australia and New Zealand
II. East Asian (eg, Chinese, Japanese, Mongolian, Taiwanese, and Chinese children in Hong Kong and Singapore)
III. South Asian (eg, Indian, Pakistani, Bangladeshi and Nepalese)
IV. South-East Asian (eg, Malaysian, Thai, Cambodian, Lao)
V. Blacks in Africa (eg, children from Burkina Faso, Madagascar, South Africa and Tanganyika)
VI. Blacks not in Africa (eg, blacks in UK or America)
VII. Middle Eastern or North African (eg, Iranian, Israeli, North African and Tunisian)
VIII. Hispanic or Latino (eg, Chilean, Colombian, Mexican, Puerto Rican and Ecuadorian)
IX. Native Hawaiian or other Pacific Islander (eg, Aborigines and children from Vanuatu)
X. American Indian or Alaska native

Ethnic specific estimates of prevalence were extracted if available; otherwise the reported prevalence of myopia was linked to the predominant ethnicity of the study population.

Statistical analysis

All statistical analyses were carried out using OpenBUGS (V.3.2.2)[27] and R (V.3.1.1).[28] We used Bayesian multilevel binomial logistic regression to investigate the associations between the log odds of myopia in either eye and potentially modifying factors, including age, gender, ethnicity, year of survey, and study design factors such as methods of assessment and habitation type.

Associations with age were non-linear and varied by ethnicity therefore the model allowed for a quadratic association with age that differed by ethnic group by including an interaction term in the models. Note, quadratic associations on the log odds scale translate into flexible non-linear associations on the prevalence scale, which encompass exponential associations with an asymptote. Ethnic specific time trends in reported myopia prevalence were investigated using year of survey.

Missing data on survey year were imputed for studies by subtracting 3 years from the year that the article was published (based on the median time to publication, in studies with available data). There were sufficient data to analyse time trends in whites, East Asians and South Asians only. We estimate ORs for rural versus urban and rural versus mixed habitation settings assuming a common OR across ethnicity; however we present sensitivity analyses by ethnicity.

We allowed for potential systematic differences between studies using different methods of refractive assessment by including study level covariates for the use of cycloplegia or not and whether refraction was based on (1) subjective refraction/retinoscopy (this included studies that performed autorefraction and subjective refraction/retinoscopy) or (2) open field autorefraction or (3) closed field autorefraction. This investigation was performed on a subset of studies with available data adjusting for ethnic specific associations with age and survey year, as well as habitation type. Additional analyses investigated an interaction between age and use of cycloplegia.

The difference in myopia prevalence between boys and girls was estimated from a separate model using the subset of studies that reported data separately for boys and girls, adjusting for study design factors and ethnic specific associations with age. All analyses took into account the hierarchical data structure arising from repeated measures of prevalence within the same study population by fitting 'study population' as a 'level' in all our models. A study population was defined as the same ethnicity examined at the same point in time in the same geographical location. A full description of the model appears in the online supplementary statistical appendix. We present median prevalence estimates and ORs with 95% credible intervals (95% CrI), which represent the range of values within which the true value of an estimate is expected to lie with 95% probability.

Modelled age and ethnic specific prevalence estimates were standardised to urban populations and applied to UN demographic data for 2015 and 2025.[29] We selected the dominant ethnic group for the following UN defined regions (1) Black—Africa and the Caribbean, (2) White—Europe, North America, Western Asia, Australia and New Zealand, (3) Hispanic—Central and Southern America, (4) Other/mixed—Melanesia, Micronesia and Polynesia. More detailed ethnic division was possible for Asia where (5) East Asian was used to represent Eastern and Central Asia, (6) South Asian—Southern Asia, and (7) South-East Asian—South-Eastern Asia. Using UN population data by 5-year intervals (from 0 year to 19 years) the mid age band prevalence estimates at ages 2 years, 7 years, 12 years and 17 years were applied to the corresponding population data, to obtain population numbers with myopia, overall and by region, with associated 95% CrIs as described previously.[30] A description of the statistical model is available online (see online supplementary statistical appendix).

Results

The article selection process is outlined in figure 1. In total 143 articles reported age-specific prevalence of myopia in 164 separate study populations (374 349 participants, 74 847 cases of myopia) from cross-sectional surveys published between 1958 and 2015 in 42 different countries. Online supplementary table S1 summarises the key features of the articles contributing to this review along with the citation. Table 1 summarises the numbers of subjects and cases of myopia by ethnicity contributing to the analysis. Data extracted on myopia prevalence by ethnicity showed stark differences overall (figure 2) and a non-linear increase in myopia prevalence with age. We therefore modelled ethnic specific quadratic associations with age. There were sufficient data to estimate trends over time in myopia prevalence in whites, East Asians and South Asians only. Estimated over an extended time period there appears to have been a marginal decline in the odds of myopia in white children and adolescents after adjustment for age and environmental setting (estimates per decade in table 2). However, the 95% CrI for this result is wide and compatible with stable myopia prevalence over time. In contrast, evidence suggests a 23% increase per decade in East Asians (95% CrI 1.00 to 1.55), with weak evidence of an increase in myopia prevalence over time in South Asians (table 2). There was no evidence to suggest that time trends were not linear. In addition, among East Asians time trends did not appear to vary by geographical location.

Table 1

Summary of the number of study populations with data on myopia prevalence by ethnic group

Ethnicity	No. study populations	Published articles	K	N	x	Survey years Range	Survey years Mean*
White	34	34	87	54 324	3444	1958 to 2011	1994
East Asian	65	55	310	157 879	60895	1983 to 2013	2000
South Asian	23	20	72	46 012	2648	1992 to 2014	2002
South-East Asian	9	7	18	19 134	2076	1987 to 2010	2006
Black in Africa	10	5	24	8491	262	1961 to 2009	1993
Black not in Africa	5	5	15	5038	371	1997 to 2008	2006
Middle Eastern or North African	16	16	67	41 812	2679	1990 to 2011	2008
Hispanic or Latino	10	10	26	33 408	1503	1976 to 2007	1995
Native Hawaiian or other Pacific Islander	6	6	15	5794	529	1967 to 2008	1987
American Indian or Alaska native	4	4	9	2457	440	1967 to 2002	1985
Unknown/other/mixed	3	3	3	323	42	2001 to 2008	2004

K, total number of available estimates of prevalence.

N, total number of participants (published or estimated).

X, total number of cases of myopia using definition closest to 'spherical equivalent refraction/sphere refraction of −0.50 D or more myopia'

*Mean survey year weighted by study population size.

Table 2

ORs for trends over time, environmental setting and methods of refractive assessment

Factor	Number of study populations	Adjusted odds ratio* (95% credible interval)
Calendar Time		
Per decade in whites	34	0.85 (0.69, 1.05)
Per decade in East Asians	65	1.23 (1.00, 1.55)
Per decade in South Asians	23	1.05 (0.45, 2.63)
Environmental setting		
Rural	37	1.00
Urban	115	2.61 (1.79, 3.86)
Mixed†	12	2.71 (1.63, 4.68)
Study design characteristics		
Cycloplegia—yes	109	1.00
Cycloplegia—no	43	2.12 (1.76, 2.52)
Subjective refraction/retinoscopy	85	1.00
Closed field autorefraction	54	2.18 (1.79, 2.73)
Open field autorefraction	12	1.30 (0.89, 1.85)

*ORs are the medians (95% credible intervals in parenthesis) of the posterior distributions from the Bayesian multilevel binomial logistic regression of the log odds of myopia adjusting for ethnic specific associations with age, ethnic specific associations with survey year (for white, East Asian and South Asian children, only) and environmental setting. The multilevel model took into account that some study populations provide only one age-specific estimate whereas others contribute data for several age groups. ORs for the study design characteristics are based on a subset of studies that specifically reported whether cycloplegia was used. ORs for environmental setting and study design characteristics were assumed to be common across ethnicities.

†Mixed refers to studies that reported myopia prevalence for urban and rural groups combined.

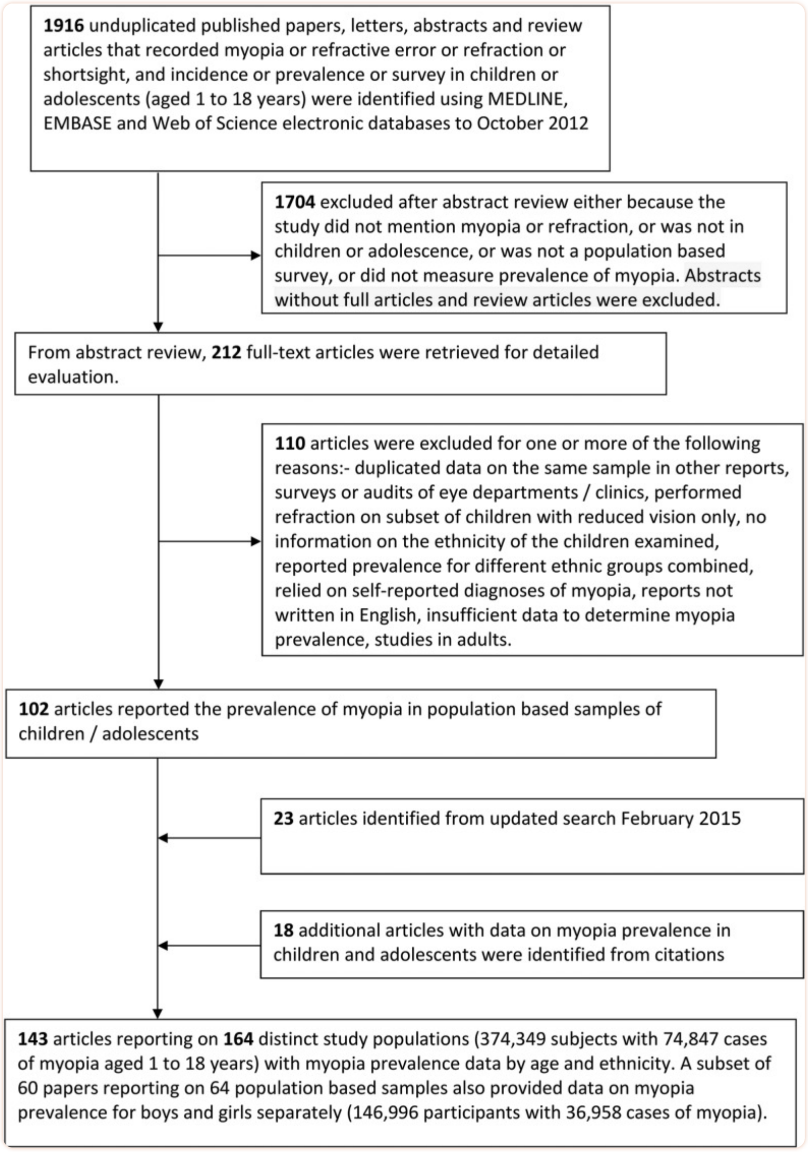
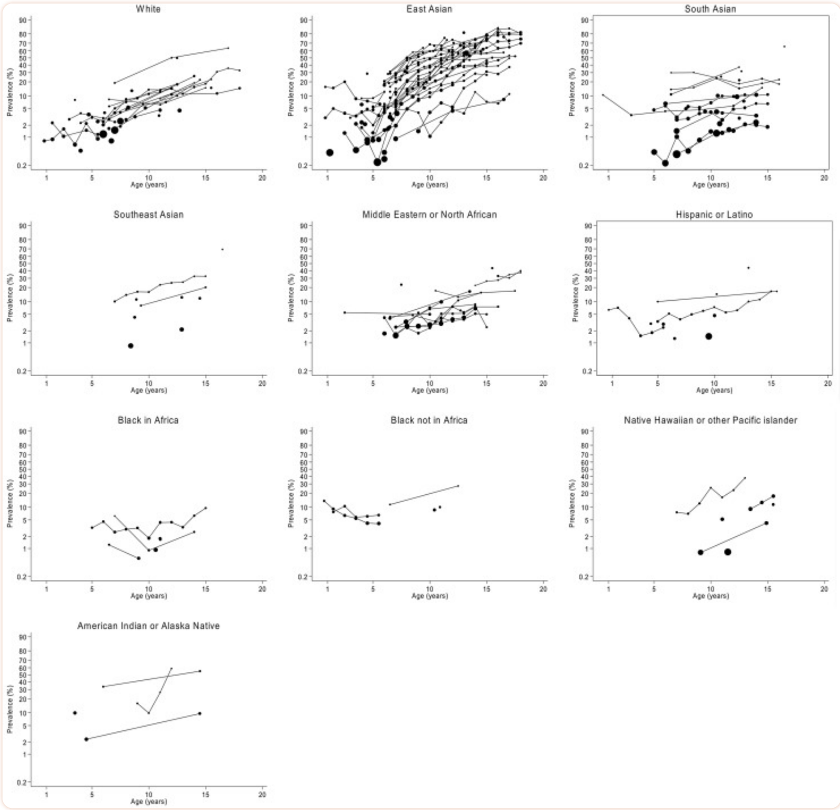


Figure 1

Summary of article selection process from MEDLINE, EMBASE and Web of Science.



[Figure 2](#)

Prevalence (%) of myopia for boys and girls combined by age and ethnic group. Data extracted on the age-specific prevalence (as a percentage) of myopia for all study populations are plotted against age for girls and boys combined, by ethnic group. The vertical axis is plotted on the logit scale. Data points from the same study population are joined by a straight line. The size of each symbol is inversely proportional to the SE of the estimate of prevalence.

[Table 3](#) provides estimates of myopia prevalence by age and ethnicity standardised to children residing in urban environments. For whites, East Asians and South Asians estimates are also standardised to 2005. For other ethnic groups there were insufficient data to model time trends and therefore estimates are indicative of data available for the 'average' survey year given in [tables 1](#). East Asians have the highest prevalence of myopia reaching 80% by 18 years of age. In contrast, the lowest myopia prevalence in late adolescence is in black children in Africa (5.5% of 15 year olds).

Table 3

Estimated prevalence of myopia by age and ethnicity in boys and girls combined

	Prevalence (%) of myopia by age				Year
Ethnicity	5 years	10 years	15 years	18 years	
White	1.6 (1.0, 2.5)	6.7 (4.1, 10.3)	16.7 (10.6, 24.5)	22.8 (14.6, 32.7)	2005*
East Asian	6.3 (4.4, 9.2)	34.5 (26.7, 44.0)	69.0 (60.6, 76.8)	79.6 (73.0, 85.4)	2005*
South Asian	5.3 (2.9, 9.6)	9.2 (5.2, 15.7)	13.0 (7.4, 21.6)	13.9 (7.7, 23.5)†	2005*
South-East Asian	6.7 (2.9, 14.4)‡	11.5 (5.3, 23.3)	23.7 (11.7, 41.8)	28.0 (13.8, 48.2)†	2006§
Black in Africa	2.8 (1.5, 5.0)	1.8 (1.1, 2.7)	5.5 (3.1, 9.0)		1993§
Black not in Africa	4.8 (4.0, 5.7)	8.2 (6.8, 9.8)	19.9 (14.3, 26.5)¶		2006§
Middle Eastern or North African	3.5 (2.0, 5.7)	5.5 (3.4, 8.8)	19.6 (12.8, 28.6)	47.1 (34.2, 60.4)	2008§
Hispanic or Latino	5.0 (1.9, 11.6)	4.7 (1.8, 11.0)	14.3 (5.8, 29.8)		1995§
Native Hawaiian or other Pacific Islander	2.6 (0.5, 11.6)‡	5.5 (1.4, 20.3)	23.0 (6.9, 57.6)		1987§
American Indian or Alaska native**	11.3 (3.3, 31.4)	20.2 (6.0, 49.9)	29.8 (10.7, 59.7)††		1985§

Prevalence estimates are medians (95% credible intervals in parenthesis) of the posterior distributions for predicted prevalence from the Bayesian multilevel binomial logistic regression of the log odds of myopia adjusting for ethnic specific associations with age, ethnic specific associations with survey year (for white, East Asian and South Asian children, only) and environmental setting. The multilevel model takes into account that some study populations provide only one age-specific estimate whereas others contribute data for several age groups.

Estimates correspond to urban populations.

*Survey year fitted in the model.

†Estimate at age 16.5 years (upper limit of available data).

‡Estimate at age 7 years (lower limit of available data).

§Mean survey year weighted by study population size.

¶Estimate at age 12.5 years (upper limit of available data).

**Estimates correspond to rural populations as there were no data in an urban setting for this ethnic group.

††Estimate at age 14.5 years (upper limit of available data).

Children living in predominantly urban environments have 2.6 times the risk of myopia compared with children living in rural environments (table 2, OR 2.61, 95% CrI 1.79 to 3.86). Studies that reported prevalence for a mixed (urban+rural) population are a very heterogeneous group and the estimate should be interpreted with caution. There was no evidence of heterogeneity in the OR of urban versus rural environment by ethnicity. For all ethnic groups, except whites, an urban environment is associated with an increased risk of myopia, especially in blacks in Africa, South Asians and South-East Asians (figure 3). However, exclusion of one outlying study in western Newfoundland whites31 residing in a rural community weakened the OR for urban versus rural in whites to 0.99 (95% CrI 0.26 to 5.01).

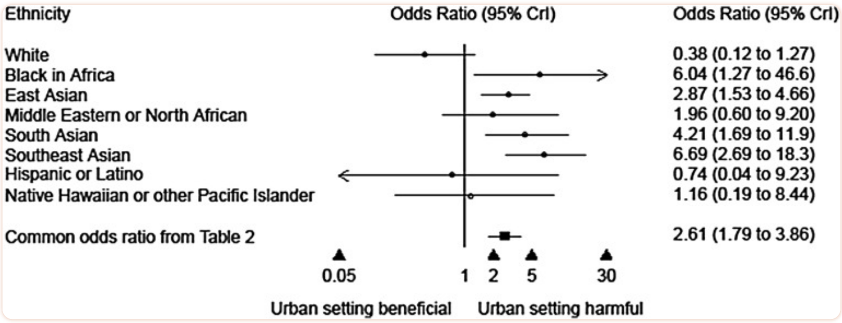


Figure 3

ORs for urban versus rural setting are from a Bayesian multilevel binomial logistic regression stratified by ethnicity, adjusting for the quadratic association with age and year of survey (for white, East Asian and South Asian children, only). The common OR is from a Bayesian multilevel binomial logistic regression model using all the data from all ethnic groups combined that adjusts for the ethnic specific quadratic association with age, ethnic specific associations with survey year (for white, East Asian and South Asian children, only) and environmental setting, assuming common OR for urban versus rural settings across ethnicities (as presented in table 2).

Studies that did not use cycloplegia reported double the odds of myopia than those that did use cycloplegia (after allowing for age, ethnicity, survey year and environmental setting, table 2). We examined an interaction between use of cycloplegia and age and found that the OR for 'no cycloplegia' versus cycloplegia was stronger at younger ages than at older ages (see online supplementary table S2). Method of measurement of refraction was also associated with myopia prevalence. Studies defining myopia based on autorefraction reported a higher prevalence of myopia (especially closed autorefraction) than studies using retinsocopy or subjective refraction (either exclusively or in addition to autorefraction).

The meta-regression comparing boys and girls is based on 64 study populations with 146 996 participants and 36 958 cases of myopia. We examined differences between boys and girls for each ethnic group separately. At about age 9 years gender differences begin to emerge in whites and East Asians and become more pronounced with age showing a higher prevalence of myopia in girls than in boys (see online supplementary table S3). By 18 years of age white girls are approximately twice as likely as white boys to be myopic (OR 2.03 95% CrI 1.40 to 2.93). A similar picture emerged for East Asians (OR 2.30 95% CrI 2.01 to 2.61). There was no clear evidence of gender differences in South Asians or in Hispanic/Latinos and there was insufficient data in the other ethnic groups to estimate gender differences by age.

There were sufficient data to investigate geographical variations in age-specific myopia prevalence in whites, East Asians and South Asians. In whites there was no clear evidence of differences in myopia prevalence in studies from Europe, USA and Oceania. Among East Asians the highest prevalence of myopia is among those residing in Singapore (86% of 15 year olds, table 4). Rates are very similar in Hong Kong and Taiwan (~80% of 15 year olds), lower in China (~59% of 15 year olds) and Australia (41% of 15 year olds). Rates are lowest in a rural population of Mongolia (table 4).

Estimates in Japan are based on data from the 1990s and may not be representative of contemporary Japanese children. South Asian children residing in Australia, England or Singapore are approximately five times more likely to be myopic than their counterparts living in Nepal or India (table 4). At 15 years of age approximately 40% of migrant South Asians are myopic compared with 9% of indigenous South Asians.

Table 4

Estimated prevalence of myopia by age in boys and girls combined (1) stratified by country for East Asians, and (2) stratified by continent for South Asians

	Prevalence (%) of myopia by age				
	5 years	**10 years**	**15 years**	**18 years**	**Year**
East Asians by country					
Australia	1.9 (0.8, 4.2)*	13.6 (6.2, 26.5)	40.6 (22.3, 60.9)*	–	2005†
China	3.9 (2.9, 5.9)	24.9 (19.8, 34.3)	59.0 (51.7, 69.3)	71.9 (65.4, 80.0)*	2005†
Hong Kong	9.2 (5.4, 15.7)	45.3 (31.8, 60.7)	78.2 (66.8, 87.1)	86.4 (78.2, 92.2)*	2005†
Japan	1.7 (0.7, 3.8)	12.2 (5.8, 24.3)	37.6 (21.1, 58.2)	51.7 (32.1, 71.2)*	1990‡
Malaysia	4.6 (1.4, 14.5)*	28.4 (10.4, 58.1)	63.2 (33.5, 85.7)	75.3 (47.2, 91.4)	1990‡
Mongolia	0.3 (0.1, 0.9) *§	2.7 (0.8, 7.2)§	10.8 (3.5, 25.0)§	17.7 (5.9, 37.2)*§	2003‡
Singapore	14.9 (9.9, 22.4)	59.0 (47.2, 70.2)	86.2 (79.4, 91.1)	91.7 (87.2, 94.8)*	2005†
Taiwan	10.1 (5.9, 19.8)¶	48.0 (34.0, 67.4) ¶	80.0 (69.0, 90.0)¶	87.6 (79.9, 94.0)¶	2005†
USA	4.9 (1.9, 12.0)	–	–	–	2005†
South Asians by continent					
Living in South Asia	3.6 (2.2, 5.7)	6.4 (4.0, 9.7)	9.1 (5.7, 13.7)	10.3 (5.8, 17.0)*	2005†
Not living in South Asia	20.4 (10.6, 36.0)*	31.6 (17.8, 50.1)	40.5 (24.1, 59.5)	43.8 (25.2, 63.9)*	2005†

Numbers express medians and 95% credible intervals in parenthesis.

Estimates correspond to urban populations standardised where possible to 2005. For Japan and Malaysia, estimates are indicative of 1990 and for Mongolia estimates are for a rural population in 2003.

Cells without estimates of prevalence indicate insufficient data to obtain estimates.

*Estimate obtained by extrapolation.

†Survey year as fitted in the model.

‡Mean survey year weighted by study population size.

§Estimates correspond to rural populations.

¶Estimates correspond to mixed populations in terms of urban/rural environmental setting.

Estimates of the global myopia prevalence and number of cases by region were attained by applying modelled age and ethnic specific prevalence estimates to UN defined population data for calendar years 2015 and 2025 and ages 0 year to <19 years (see online supplementary table S4). Global estimates suggest a burden of 312 million myopic cases in 2015 (95% CrI 265 million to 369 million), rising to 324 million (95% CrI 276 million to 382 million) in 2025. Population prevalence of myopia in childhood (0 year to <19 years) is highest in East Asia (35%) with nearly 80% of cases in Asia. The global share of myopia cases will remain high in Asia in 2025 with a marginal increase in Africa due to more rapid expansion of this age group in Africa than in other regions.

Discussion

This is the first systematic review and quantitative meta-analysis of the worldwide prevalence of myopia in childhood and adolescence. We have quantified the striking ethnic differences in myopia prevalence that become more marked with age. In particular, East Asians show the highest prevalence with over 90% of East Asians living in Singapore and 72% of East Asians living in China aged 18 years exhibiting myopia (defined as at least −0.5 D of myopia). Overall South Asians had much lower rates with limited evidence of trends over time. However, there were marked differences between those living in South Asia compared with migrant South Asian populations. There was no strong evidence of time trends in myopia prevalence among white populations. Non-linear associations between age and the log odds of myopia captured a large proportion of the ethnic variation in myopia prevalence. Some ethnic groups show a rapid increase with age in the early years that flattens (East Asians, whites, South Asians), suggesting that levels of myopia may have plateaued, reaching saturated levels.[32] In others the increase in myopia prevalence was almost linear with age (South-East Asian, American Indian or Alaska Native, Native Hawaiian Pacific Islanders). In other groups the increase with age did not emerge until after about 8 years of age (Hispanics, blacks (in and outside of African) and Middle Eastern or North Africans). We have shown that living in an urban rather than rural environment is associated with almost a tripling in the risk of myopia and this pattern is seen among all ethnic groups. As expected, studies that did not use cycloplegia reported higher myopia prevalence (especially at younger ages) as did studies that relied on autorefractor findings, particularly closed field instruments. We also showed that sex difference in the age-specific prevalence of myopia exist in whites and East Asians, emerge at about 9 years of age and become more marked through adolescence showing double the odds of myopia in girls compared with boys.

The increase in myopia prevalence seen in urban compared with rural populations agrees with others that have explicitly examined this in children with the same ethnic ancestry.[20] [21] [33–46]

Although there was no formal evidence of a difference in urban-rural differences across ethnic groups, some populations showed marginally larger ORs compared with others. Stronger urban-rural differences in South Asians and South-East Asians may reflect greater disparity in living conditions compared with high-income countries. These findings are consistent with the results of studies in population groups that migrate from rural to urban settings, which tend to adopt myopia rates of the host population, for example, Pacific Islanders that migrated to Taiwan;[47] South Asian children living in the UK have higher rates of myopia[12] than South Asian children residing in predominantly rural communities in India;[21] [39] Indians in Singapore have prevalence rates more similar to Singaporean Chinese than to Indians in India.[48] [49] The apparent decreased risk of myopia associated with urban environment in whites was explained by inclusion of western Newfoundland whites residing in a rural community with shared genetic ancestry, who showed an unusually high prevalence of myopia.[31] Removal of this single population reduced the OR for urban versus rural in whites towards the null.

Potential explanations have been suggested for the higher rates of myopia in children residing in urban settings compared with children from the same ethnic groups living in more rural settings including a more congested environment[33] [44] and greater emphasis on education and hence near vision activities.[50–53] Several studies have shown a link between increased near vision activities and myopia,[19 38 54 55] but this is not a universal finding.[11 56 57] Years of education have also been related to myopia[25] and introduction of formal education at younger ages in some East Asian countries[57 58] may be a contributing factor. In Singapore[59] children from as young as 3 years and as young as 2 years in Hong Kong[32] actively participate in additional education classes before formal schooling education begins. In contrast, the prevalence of myopia is low in African populations where literacy rates are low, and formal education does not start for most children until the ages of 6–8 years.[60 61] It is possible that the younger age of initial exposure to formal education patterns levels of myopia through childhood.

Further evidence is provided by the reported independent associations of population density on myopia prevalence,[33 44] which may suggest a contribution from a collection of risk factors associated with urban living environment. Time spent outdoors will differ between urban and rural communities and has been examined in relation to myopia.[56 58 62–67] Children who become myopic are less likely to participate in sports/outdoor activities.[68] In a 2-year prospective study there was a suggestion that longer durations spent outdoors were associated with slower axial elongation in non-myopic teenagers but not in pre-existing myopes.[69] A recent systematic review and meta-analysis showed a 2% reduction in the odds of myopia for every additional hour per week spent outdoors.[70] Biological mechanisms for an association include low accommodative demand outdoors coupled with increased depth of focus.[25] Time spent outdoors is also culturally patterned, and might be related to sibship; teasing out the independent, potentially causal, effects of time spent outdoors requires further study.[62 65 71 72]

Despite the association between myopia prevalence and an urban environment, ethnic differences in myopia prevalence exist among populations drawn from the same living environment.[12 14 54] Whether these ethnic differences reflect genetic susceptibility to environmental factors or are due to ethnic differences in other factors is unclear. A previous meta-analysis of three British birth cohort studies including over 15 000 white children showed that various familial factors were related to the odds of reduced vision (a proxy for myopia) in childhood including social class, parental education, maternal age and birth order (with higher risk among first-born children).[10] All of these familial factors are likely to differ with level of urbanisation and ethnic group. It is also likely that intensity of near vision and emphasis on academic achievements are related to sibship and birth order.

Higher rates of myopia prevalence in girls compared with boys have been found in some individual studies,[10 18 57 73–78] but not in others.[12 21 23 79–81] The reason for disagreements between studies examining the association between myopia and sex is likely to be due to two factors (1) age of children studied, and (2) statistical power of a study which is influenced by the size of the study and the age-specific prevalence of myopia. The sex differences seem to emerge at about 9 years of age and become more pronounced with age, hence comparisons at younger ages are unlikely to show gender differences. Differences observed beyond the first decade of life have been attributed to a stronger emphasis on education/near distance related activities in girls compared with boys.[18] This gender difference may persist in adulthood.[5 53 82 83] It is well established that differences between cycloplegic and non-cycloplegic refractions are more marked at younger ages,[84–86] especially with closed field autorefraction.[87]

This review has a number of strengths and limitations. By adopting a more inclusive approach, we were able to include more studies in the meta-analysis thereby increasing the sample size and representativeness. Adopting a more exclusive approach, that is, omitting studies with imperfect study methods, would result in loss of power and would not allow study design differences to be quantified. We took account of study level factors including environmental setting, year of survey and survey methods used to define cases of myopia, particularly use of cycloplegia. The increased numbers allowed us to quantify the marked differences in the age-specific prevalence of myopia between ethnic groups, between urban and rural environments as well as gender differences. Limitations of this study include the omission of study response rates in the analysis as reliable data were not routinely reported. Our analysis is based on summaries from published data rather than data from individuals, which may lack the granularity to determine associations. A meta-analysis based on individual data would have yielded more precise results for the age-specific prevalence and could adjust for individual factors. Such an approach would be preferable if these data could be obtained for all relevant studies. However, the difficulty with an individual data meta-analysis is that it may represent a subset, biased towards well resourced studies, which are not representative of studies as a whole. Future work could examine trends in myopia incidence over time by meta-analysing estimates of incidence from longitudinal studies. This review did not examine within-person changes in spherical refraction over time which is likely to show different myopic refraction progression rates by ethnicity over time.

In summary, this meta-analysis provides the most comprehensive and current evidence on myopia prevalence in childhood and adolescence. It seems that populations that have experienced rapid economic transition (East and South Asians) have undergone the most rapid myopic transition. It will be important to monitor trends in myopia over time especially in relation to populations undergoing rapid transitions in myopia and to identify factors of the urban environment that are responsible. Understanding the aetiology of childhood myopia will give clues to prevention, potentially offering strategies to limit the economic impact of refractive error.

Supplementary Material

Web supplement:

Click here to view. (255K, pdf)

Footnotes

Collaborators: All authors contributed substantially to the conception and design of this paper. ARR, VVK, AKW and CGO conducted the literature searches and extracted the data from published papers. ARR, VVK and CGO drafted the paper and carried out statistical analysis. All authors contributed to revising the manuscript and all authors approved the final version. ARR and CGO will act as guarantors. The guarantors accept full responsibility for the integrity of the work as a whole. All authors had access to the data, and approved the final version to be published.

Funding: This work was supported by a grant from the BUPA Foundation (TBF-M10-034).

Disclaimer: All researchers acted independently of study funders. The study funders played no role in study design and the collection, analysis, and interpretation of data and the writing of the article and the decision to submit it for publication. None of the funders influenced data analysis or interpretation of results. The comments made in this paper are those of the authors and not necessarily those of any funders.

Competing interests: None declared.

References

1. Junghans B, Kiely PM, Crewther DP, et al.. Referral rates for a functional vision screening among a large cosmopolitan sample of Australian children. *Ophthalmic Physiol Opt* 2002;22:10–25. 10.1046/j.1475-1313.2002.00010.x [PubMed] [CrossRef] [Google Scholar]

2. Kleinstein RN, Jones LA, Hullett S, et al.. Refractive error and ethnicity in children. *Arch Ophthalmol* 2003;121:1141–7. 10.1001/archopht.121.8.1141 [PubMed] [CrossRef] [Google Scholar]

3. Lam CS, Goldschmidt E, Edwards MH. Prevalence of myopia in local and international schools in Hong Kong. *Optom Vis Sci* 2004;81:317–22. 10.1097/01.opx.0000134905.98403.18 [PubMed] [CrossRef] [Google Scholar]

4. Cumberland PM, Peckham CS, Rahi JS. Inferring myopia over the lifecourse from uncorrected distance visual acuity in childhood. *Br J Ophthalmol* 2007;91:151–3. 10.1136/bjo.2006.102277 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

5. Foster PJ, Jiang Y. Epidemiology of myopia. *Eye (Lond)* 2014;28:202–8. 10.1038/eye.2013.280 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

6. Congdon NG, Friedman DS, Lietman T. Important causes of visual impairment in the world today. *JAMA* 2003;290:2057–60. 10.1001/jama.290.15.2057 [PubMed] [CrossRef] [Google Scholar]

7. Gilmartin B. Myopia: precedents for research in the twenty-first century. *Clin Experiment Ophthalmol* 2004;32:305–24. 10.1111/j.1442-9071.2004.00831.x [PubMed] [CrossRef] [Google Scholar]

8. Kempen JH, Mitchell P, Lee KE, et al.. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol* 2004;122:495–505. 10.1001/archopht.122.4.495 [PubMed] [CrossRef] [Google Scholar]

9. Morgan IG, Ohno-Matsui K, Saw SM. Myopia. *Lancet* 2012;379:1739–48. 10.1016/S0140-6736(12)60272-4 [PubMed] [CrossRef] [Google Scholar]

10. Rudnicka AR, Owen CG, Richards M, et al.. Effect of breastfeeding and sociodemographic factors on visual outcome in childhood and adolescence. *Am J Clin Nutr* 2008;87:1392–9. [PubMed] [Google Scholar]

11. Williams C, Miller LL, Gazzard G, et al.. A comparison of measures of reading and intelligence as risk factors for the development of myopia in a UK cohort of children. *Br J Ophthalmol* 2008;92:1117–21. 10.1136/bjo.2007.128256 [PubMed] [CrossRef] [Google Scholar]

12. Rudnicka AR, Owen CG, Nightingale CM, et al.. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: The child heart and health study in england (CHASE). *Invest Ophthalmol Vis Sci* 2010;51:6270–6. 10.1167/iovs.10-5528 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

13. O'Donoghue L, McClelland JF, Logan NS, et al.. Refractive error and visual impairment in school children in Northern Ireland. *Br J Ophthalmol* 2010;94:1155–9. 10.1136/bjo.2009.176040 [PubMed] [CrossRef] [Google Scholar]

14. Ip JM, Huynh SC, Robaei D, et al.. Ethnic differences in refraction and ocular biometry in a population-based sample of 11–15-year-old Australian children. *Eye* 2008;22:649–56. 10.1038/sj.eye.6702701 [PubMed] [CrossRef] [Google Scholar]

15. Logan NS, Shah P, Rudnicka AR, et al.. Childhood ethnic differences in ametropia and ocular biometry: the Aston Eye Study. *Ophthalmic Physiol Opt* 2011;31:550–8. 10.1111/j.1475-1313.2011.00862.x [PubMed] [CrossRef] [Google Scholar]

16. Saw SM. A synopsis of the prevalence rates and environmental risk factors for myopia. *Clin Exp Optom* 2003;86:289–94. 10.1111/j.1444-0938.2003.tb03124.x [PubMed] [CrossRef] [Google Scholar]

17. Saw SM, Goh PP, Cheng A, et al.. Ethnicity-specific prevalences of refractive errors vary in Asian children in neighbouring Malaysia and Singapore. *Br J Ophthalmol* 2006;90:1230–5. 10.1136/bjo.2006.093450 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

18. Fan DSP, Lam DSC, Lam RF, et al.. Prevalence, incidence, and progression of myopia of school children in Hong Kong. *Invest Ophthalmol Vis Sci* 2004;45:1071–5. 10.1167/iovs.03-1151 [PubMed] [CrossRef] [Google Scholar]

19. Quek TPL, Chua CG, Chong CS, et al.. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt* 2004;24:47–55. 10.1046/j.1475-1313.2003.00166.x [PubMed] [CrossRef] [Google Scholar]

20. Dandona R, Dandona L, Naduvilath TJ, et al.. Refractive errors in an urban population in southern India: The Andhra Pradesh Eye Disease Study. *Invest Ophthalmol Vis Sci* 1999;40:2810–8. [PubMed] [Google Scholar]

21. Dandona R, Dandona L, Srinivas M, et al.. Refractive error in children in a rural population in India. *Invest Ophthalmol Vis Sci* 2002;43:615–22. [PubMed] [Google Scholar]

22. Kalikivayi V, Naduvilath TJ, Bansal AK, et al.. Visual impairment in school children in Southern India. *Indian J Ophthalmol* 1997;45:129–34. [PubMed] [Google Scholar]

23. Murthy GVS, Gupta SK, Ellwein LB, et al.. Refractive error in children in an urban population in New Delhi. *Invest Ophthalmol Vis Sci* 2002;43:623–31. [PubMed] [Google Scholar]

24. Stroup DF, Berlin JA, Morton SC, et al.. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. *JAMA* 2000;283:2008–12. [PubMed] [Google Scholar]

25. Morgan I, Rose K. How genetic is school myopia? *Prog Retin Eye Res* 2005;24:1–38. 10.1016/j.preteyeres.2004.06.004 [PubMed] [CrossRef] [Google Scholar]

26. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt* 2012;32:3–16. 10.1111/j.1475-1313.2011.00884.x [PubMed] [CrossRef] [Google Scholar]

27. Lunn D, Spiegelhalter D, Thomas A, et al.. The BUGS project: evolution, critique and future directions. *Stat Med* 2009;28:3049–67. 10.1002/sim.3680 [PubMed] [CrossRef] [Google Scholar]

28. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. 2014. 21-4-2015.

29. United Nations. World Population Prospects: The 2012 Revision.[2012. http://esa.un.org/wpp/unpp/panel_indicators.htm (accessed Sep 2014). [Google Scholar]

30. Kapetanakis VV, Chan MP, Foster PJ, et al.. Global variations and time trends in the prevalence of primary open angle glaucoma (POAG): a systematic review and meta-analysis. *Br J Ophthalmol* 2016. 10.1136/bjophthalmol-2015-307223 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

31. Richler A, Bear JC. The distribution of refraction in 3 isolated communities in Western Newfoundland. *Am J Optom Physiol Opt* 1980;57:861–71. 10.1097/00006324-198011000-00012 [PubMed] [CrossRef] [Google Scholar]

32. Lam CS, Lam CH, Cheng SC, et al.. Prevalence of myopia among Hong Kong Chinese schoolchildren: changes over two decades. *Ophthalmic Physiol Opt* 2012;32:17–24. 10.1111/j.1475-1313.2011.00886.x [PubMed] [CrossRef] [Google Scholar]

33. Ip JM, Rose KA, Morgan IG, et al.. Myopia and the urban environment: findings in a sample of 12-year-old Australian school children. *Invest Ophthalmol Vis Sci* 2008;49:3858–63. 10.1167/iovs.07-1451 [PubMed] [CrossRef] [Google Scholar]

34. Yingyong P. Refractive errors survey in primary school children (6–12 year old) in 2 provinces: Bangkok and Nakhonpathom (one year result). *J Med Assoc Thai* 2010;93:1205–10. [PubMed] [Google Scholar]

35. Garner LF, Owens H, Kinnear RF, et al.. Prevalence of myopia in Sherpa and Tibetan children in Nepal. *Optom Vis Sci* 1999;76:282–5. 10.1097/00006324-199905000-00014 [PubMed] [CrossRef] [Google Scholar]

36. Zhang MZ, Saw SM, Hong RZ, et al.. Refractive errors in Singapore and Xiamen, China: a comparative study in school children aged 6 to 7 years. *Optom Vis Sci* 2000;77:302–8. 10.1097/00006324-200006000-00010 [PubMed] [CrossRef] [Google Scholar]

37. Lin LLK, Shih YF, Hsiao CK, et al.. Epidemiologic study of the prevalence and severity of myopia among school children in Taiwan in 2000. *J Formos Med Assoc* 2001;100:684–91. [PubMed] [Google Scholar]

38. Saw SM, Hong RZ, Zhang MZ, et al.. Near-work activity and myopia in rural and urban schoolchildren in China. *J Pediatr Ophthalmol Strabismus* 2001;38:149–55. [PubMed] [Google Scholar]

39. Khan AA, Nasti AR, Ayoub DM, et al.. Prevalence of refractive errors in school children. *JK Practitioner* 2005;12:156–9. [Google Scholar]

40. Fotouhi A, Hashemi H, Khabazkhoob M, et al.. The prevalence of refractive errors among schoolchildren in Dezful, Iran. *Br J Ophthalmol* 2007;91:287–92. 10.1136/bjo.2006.099937 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

41. Czepita D, Zejmo M, Mojsa A. Prevalence of myopia and hyperopia in a population of Polish schoolchildren. *Ophthalmic Physiol Opt* 2007;27:60–5. 10.1111/j.1475-1313.2006.00419.x [PubMed] [CrossRef] [Google Scholar]

42. Uzma N, Kumar BS, Khaja Mohinuddin Salar BM, et al.. A comparative clinical survey of the prevalence of refractive errors and eye diseases in urban and rural school children. *Can J Ophthalmol* 2009;44:328–33. 10.3129/i09-030 [PubMed] [CrossRef] [Google Scholar]

43. Padhye AS, Khandekar R, Dharmadhikari S, et al.. Prevalence of uncorrected refractive error and other eye problems among urban and rural school children. *Middle East Afr J Ophthalmol* 2009;16:69–74. 10.4103/0974-9233.53864 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

44. Zhang M, Li L, Chen L, et al.. Population density and refractive error among Chinese children. *Invest Ophthalmol Vis Sci* 2010;51:4969–76. 10.1167/iovs.10-5424 [PubMed] [CrossRef] [Google Scholar]

45. Gao Z, Meng N, Muecke J, et al.. Refractive error in school children in an urban and rural setting in Cambodia. *Ophthalmic Epidemiol* 2012;19:16–22. 10.3109/09286586.2011.632703 [PubMed] [CrossRef] [Google Scholar]

46. Wu JF, Bi HS, Wang SM, et al.. Refractive error, visual acuity and causes of vision loss in children in Shandong, China. The Shandong children eye study. *PLoS ONE* 2013;8:e82763. [PMC free article] [PubMed] [Google Scholar]

47. Lin LLJ, Hung P-T, Ko L-S, et al.. Study of myopia among aboriginal school children in Taiwan. *Acta Ophthalmologica* 1988;66(Suppl 185):34–6. 10.1111/j.1755-3768.1988.tb02658.x [PubMed] [CrossRef] [Google Scholar]

48. Au Eong KG, Tay TH, Lim MK. Race, culture and Myopia in 110,236 young Singaporean males. *Singapore Med J* 1993;34:29–32. [PubMed] [Google Scholar]

49. Wu HM, Seet B, Yap EP, et al.. Does education explain ethnic differences in myopia prevalence? A population-based study of young adult males in Singapore. *Optom Vis Sci* 2001;78:234–9. 10.1097/00006324-200104000-00012 [PubMed] [CrossRef] [Google Scholar]

50. He MG, Zeng JW, Liu YZ, et al.. Refractive error and visual impairment in urban children in southern China. *Invest Ophthalmol Vis Sci* 2004;45:793–9. 10.1167/iovs.03-1051 [PubMed] [CrossRef] [Google Scholar]

51. Shih YF, Chiang TH, Hsiao CK, et al.. Comparing myopic progression of urban and rural Taiwanese schoolchildren. *Jpn J Ophthalmol* 2010;54:446–51. 10.1007/s10384-010-0860-7 [PubMed] [CrossRef] [Google Scholar]

52. Tay MT, Au Eong KG, Ng CY, et al.. Myopia and educational attainment in 421,116 young Singaporean males. *Ann Acad Med Singap* 1992;21:785–91. [PubMed] [Google Scholar]

53. Williams KM, Bertelsen G, Cumberland P, et al.. Increasing Prevalence of Myopia in Europe and the Impact of Education. *Ophthalmology* 2015;122:1489–97. 10.1016/j.ophtha.2015.03.018 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

54. Saw SM, Chua WH, Hong CY, et al.. Nearwork in early-onset myopia. *Invest Ophthalmol Vis Sci* 2002;43:332–9. [PubMed] [Google Scholar]

55. Mutti DO, Mitchell GL, Moeschberger ML, et al.. Parental myopia, near work, school achievement, and children's refractive error. *Invest Ophthalmol Vis Sci* 2002;43:3633–40. [PubMed] [Google Scholar]

56. Ip JM, Saw SM, Rose KA, et al.. Role of near work in myopia: findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci* 2008;49:2903–10. 10.1167/iovs.07-0804 [PubMed] [CrossRef] [Google Scholar]

57. Lu B, Congdon N, Liu XJ, et al.. Associations Between Near Work, Outdoor Activity, and Myopia Among Adolescent Students in Rural China The Xichang Pediatric Refractive Error Study Report No. 2. *Archives of Ophthalmology* 2009;127:769–75. 10.1001/archophthalmol.2009.105 [PubMed] [CrossRef] [Google Scholar]

58. Rose KA, Morgan IG, Smith W, et al.. Myopia, lifestyle, and schooling in students of Chinese ethnicity in Singapore and Sydney. *Arch Ophthalmol* 2008;126:527–30. 10.1001/archopht.126.4.527 [PubMed] [CrossRef] [Google Scholar]

59. Dirani M, Chan Y-H, Gazzard G, et al.. Prevalence of refractive error in Singaporean Chinese children: The Strabismus, Amblyopia, and Refractive Error in young Singaporean Children (STARS) study. *Invest Ophthalmol Vis Sci* 2010;51:1348–55. 10.1167/iovs.09-3587 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

60. Anera RG, Jimenez JR, Soler M, et al.. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol* 2006;50:483–4. 10.1007/s10384-006-0354-9 [PubMed] [CrossRef] [Google Scholar]

61. Jimenez R, Soler M, Anera RG, et al.. Ametropias in school-age children in Fada N'Gourma (Burkina Faso, Africa). *Optom Vis Sci* 2012;89:33–7. 10.1097/OPX.0b013e318238b3dd [PubMed] [CrossRef] [Google Scholar]

62. Khader YS, Batayha WQ, Abdul-Aziz SM, et al.. Prevalence and risk indicators of myopia among schoolchildren in Amman, Jordan. *East Mediterr Health J* 2006;12:434–9. [PubMed] [Google Scholar]

63. Saw SM, Shankar A, Tan SB, et al.. A cohort study of incident myopia in Singaporean children. *Invest Ophthalmol Vis Sci* 2006;47:1839–44. 10.1167/iovs.05-1081 [PubMed] [CrossRef] [Google Scholar]

64. Jones LA, Sinnott LT, Mutti DO, et al.. Parental history of myopia, sports and outdoor activities, and future myopia. *Invest Ophthalmol Vis Sci* 2007;48:3524–32. 10.1167/iovs.06-1118 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

65. Dirani M, Tong L, Gazzard G, et al.. Outdoor activity and myopia in Singapore teenage children. *Br J Ophthalmol* 2009;93:997–1000. 10.1136/bjo.2008.150979 [PubMed] [CrossRef] [Google Scholar]

66. Wu P-C, Tsai C-L, Hu C-H, et al.. Effects of outdoor activities on Myopia among rural school children in Taiwan. *Ophthalmic Epidemiol* 2010;17:338–42. 10.3109/09286586.2010.508347 [PubMed] [CrossRef] [Google Scholar]

67. Guggenheim JA, Northstone K, McMahon G, et al.. Time outdoors and physical activity as predictors of incident myopia in childhood: a prospective cohort study. *Invest Ophthalmol Vis Sci* 2012;53:2856–65. 10.1167/iovs.11-9091 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

68. Jones-Jordan LA, Mitchell GL, Cotter SA, et al.. Visual activity before and after the onset of juvenile myopia. *Invest Ophthalmol Vis Sci* 2011;52:1841–50. 10.1167/iovs.09-4997 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

69. Li SM, Li H, Li SY, et al.. Time outdoors and myopia progression over 2 years in Chinese children: the anyang childhood eye study. *Invest Ophthalmol Vis Sci* 2015;56:4734–40. 10.1167/iovs.14-15474 [PubMed] [CrossRef] [Google Scholar]

70. Sherwin JC, Reacher MH, Keogh RH, et al.. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology* 2012;119:2141–51. 10.1016/j.ophtha.2012.04.020 [PubMed] [CrossRef] [Google Scholar]

71. Deere K, Williams C, Leary S, et al.. Myopia and later physical activity in adolescence: a prospective study. *Br J Sports Med* 2009;43:542–4. 10.1136/bjsm.2008.049288 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

72. Rose KA, Morgan IG, Ip J, et al.. Outdoor activity reduces the prevalence of myopia in children. *Ophthalmology* 2008;115:1279–85. 10.1016/j.ophtha.2007.12.019 [PubMed] [CrossRef] [Google Scholar]

73. Lin LLK, Shih YF, Tsai CB, et al.. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. *Optom Vis Sci* 1999;76:275–81. 10.1097/00006324-199905000-00013 [PubMed] [CrossRef] [Google Scholar]

74. Zadnik K, Manny RE, Yu JA, et al.. Ocular component data in schoolchildren as a function of age and gender. *Optom Vis Sci* 2003;80:226–36. 10.1097/00006324-200303000-00012 [PubMed] [CrossRef] [Google Scholar]

75. He M, Xu J, Yin Q, et al.. Need and challenges of refractive correction in urban Chinese school children. *Optom Vis Sci* 2005;82:229–34. 10.1097/01.OPX.0000159362.48835.16 [PubMed] [CrossRef] [Google Scholar]

76. He MG, Huang WY, Zheng YF, et al.. Refractive error and visual impairment in school children in rural southern China. *Ophthalmology* 2007;114:374–82. 10.1016/j.ophtha.2006.08.020 [PubMed] [CrossRef] [Google Scholar]

77. Goh P-P, Abqariyah Y, Pokharel GP, et al.. Refractive error and visual impairment in school-age children in Gombak District, Malaysia. *Ophthalmology* 2005;112:678–85. 10.1016/j.ophtha.2004.10.048 [PubMed] [CrossRef] [Google Scholar]

78. Zhang M, Gazzard G, Fu Z, et al.. Validating the accuracy of a model to predict the onset of myopia in children. *Invest Ophthalmol Vis Sci* 2011;52:5836–41. 10.1167/iovs.10-5592 [PubMed] [CrossRef] [Google Scholar]

79. Pokharel GP, Negrel AD, Munoz SR, et al.. Refractive error study in children: results from Mechi Zone, Nepal. *Am J Ophthalmol* 2000;129:436–44. 10.1016/S0002-9394(99)00453-5 [PubMed] [CrossRef] [Google Scholar]

80. Maul E, Barroso S, Munoz SR, et al.. Refractive error study in children: results from La Florida, Chile. *Am J Ophthalmol* 2000;129:445–54. 10.1016/S0002-9394(99)00454-7 [PubMed] [CrossRef] [Google Scholar]

81. Naidoo KS, Raghunandan A, Mashige KP, et al.. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci* 2003;44:3764–70. 10.1167/iovs.03-0283 [PubMed] [CrossRef] [Google Scholar]

82. Rahi JS, Cumberland PM, Peckham CS. Myopia over the lifecourse: prevalence and early life influences in the 1958 British birth cohort. *Ophthalmology* 2011;118:797–804. 10.1016/j.ophtha.2010.09.025 [PubMed] [CrossRef] [Google Scholar]

83. Wong TY, Foster PJ, Hee J, et al.. Prevalence and risk factors for refractive errors in adult Chinese in Singapore. *Invest Ophthalmol Vis Sci* 2000;41:2486–94. [PubMed] [Google Scholar]

84. Farhood QK. Cycloplegic refraction in children with cyclopentolate versus atropine. *J Clin Exp Ophthalmol* 2012;3:239 10.4172/2155-9570.1000239 [CrossRef] [Google Scholar]

85. Williams C, Miller L, Northstone K, et al.. The use of non-cycloplegic autorefraction data in general studies of children's development. *Br J Ophthalmol* 2008;92: 723–4. 10.1136/bjo.2007.136051 [PubMed] [CrossRef] [Google Scholar]

86. Zhao J, Mao J, Luo R, et al.. Accuracy of noncycloplegic autorefraction in school-age children in China. *Optom Vis Sci* 2004;81:49–55. 10.1097/00006324-200401000-00010 [PubMed] [CrossRef] [Google Scholar]

87. Choong YF, Chen AH, Goh PP. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. *Am J Ophthalmol* 2006;142:68–74. 10.1016/j.ajo.2006.01.084 [PubMed] [CrossRef] [Google Scholar]

PLOS ONE

PLoS One. 2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335

PMCID: PMC8812871
PMID: 35113922

Systematic review and meta-analysis of myopia prevalence in African school children

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Aleksandra Barac, Editor

Abstract

Purpose

Increased prevalence of myopia is a major public health challenge worldwide, including in Africa. While previous studies have shown an increasing prevalence in Africa, there is no collective review of evidence on the magnitude of myopia in African school children. Hence, this study reviews the evidence and provides a meta-analysis of the prevalence of myopia in African school children.

Methods

This review was conducted using the 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Five computerized bibliographic databases, PUBMED, Scopus, Web of Science, ProQuest, and Africa Index Medicus were searched for published studies on the prevalence of myopia in Africa from 1 January 2000 to 18 August 2021. Studies were assessed for methodological quality. Data were gathered by gender, age and refraction technique and standardized to the definition of myopia as refractive error ≥ 0.50 diopter. A meta-analysis was

conducted to estimate the prevalence. Significant heterogeneity was detected among the various studies (I^2 >50%), hence a random effect model was used, and sensitivity analysis was performed to examine the effects of outliers.

Results

We included data from 24 quality assessed studies, covering 36,395 African children. The overall crude prevalence of myopia over the last two decades is 4.7% (95% CI, 3.9–5.7) in African children. Although the prevalence of myopia was slightly higher in females (5.3%, 95%CI: 4.1, 6.5) than in males (3.7%, 95% CI, 2.6–4.7; p = 0.297) and higher in older [12–18 years 5.1% (95% CI, 3.8–6.3) than younger children (aged 5–11 years, 3.4%, 95% CI, 2.5–4.4; p = 0.091), the differences were not significant. There was a significantly lower prevalence of myopia with cycloplegic compared with non-cycloplegic refraction [4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; p = 0.046].

Conclusions

Our results showed that myopia affects about one in twenty African schoolchildren, and it is overestimated in non-cycloplegic refraction. Clinical interventions to reduce the prevalence of myopia in the region should target females, and school children who are aged 12–18 years.

Introduction

Uncorrected refractive error is the most common cause of visual impairment affecting an estimated one billion people globally [1]. Myopia is the most common refractive error and an important cause of ocular morbidity, particularly among school-aged children and young adults. Worldwide, myopia is reaching epidemic proportions linked to changing lifestyles and modern technology, particularly mobile devices [2]. Globally, myopia affected 22.9% of the world's population in 2000, with projections of an increase to 49.8% by 2050 affecting 4.8 billion people [2], representing a 117% increase over 50 years. According to a 2015 report, it was estimated that globally, about 1.89 billion people are myopic and 170 million have high myopia [3].

The reported prevalence of myopia in children aged 5–17 years ranges from 1.2% in Mechi Zone, Nepal, to 73.0% in South Korea [4, 5]. Over 15 years, the prevalence of myopia increased from 79.5% to 87.7% in Chinese high school children with an average age of 18.5 ± 0.7 years [6]. In South African school children aged 5–15 years, the reported prevalence of myopia was only 2.9% with retinoscopy and 4.0% using autorefraction [7]. The authors reported that this prevalence increased to 9.6% at age 15 years.

The increase in myopia prevalence will have a significant economic impact because of associated ocular health problems and visual impairment. Uncorrected myopia of between– 1.50 D and– 4.00 D can significantly affect vision to be regarded as a cause of moderate visual impairment and blindness, respectively [8]. Apart from its direct impact on visual impairment, high myopia [usually defined as a spherical equivalent ≥ 5.00D [4, 9, 10] of myopia, although the definitions used to grade myopia are variable] increases the risk of potentially blinding ocular pathologies such as retinal holes; retinal tears; retinal degeneration; retinal detachment; and myopic macular degeneration [3, 11]. Uncorrected myopia has huge social, economic, psychological and developmental implications [12]. The economic cost of refractive errors, including myopia, has been estimated to be approximately US$ 202 billion per annum [13], far exceeding that of other eye diseases.

The increasing prevalence of myopia has led to research in the study of the possible mechanism for myopia development, which has generated two broad themes: the role of nature (genetic influences) and nurture (environmental influences including lifestyle). Understanding the mechanism for the development of myopia is also being explored in the control of myopia. Epidemiologic data from Southeast Asia has given credence to the association between near work and myopia, given the number of hours children from this region spend doing near work. Due to vast regional differences in culture, habits, socioeconomic status, educational levels and urbanization, there is uncertainty as to the exact magnitude of the myopia burden among African school–aged children and its trend over time [14].

In the last few decades, there has been a change in the lifestyle and behavior of people in Africa as a result of increasing urbanization [15]. Africa's urban population grew from 27 million in 1950 to 567 million in 2015 (a 2,000% increase), and now 50% of Africa's population live in one of the continent's 7,617 urban agglomerations of 10,000 or more inhabitants [16]. Consequently, more children and young adults in Africa are increasingly engaged in indoor and near work activities compared to earlier generations [17]. Children spend long hours doing schoolwork and, following the advent of technology, increasingly use mobile devices for gaming and other activities [18, 19]. These factors are thought to promote myopia development and/or progression [20–23].

Africa is the world's second largest and second most populous continent, after Asia, and it accounts for about 16% of the world's human population. While every global region will experience a decline in population by 2100, the African population is expected to triple. Africa's population is the youngest amongst all the continents, the median age in 2012 was 19.7 years compared to the global median of 30.4 years. This young population is an important asset for the continent's development. The challenges of the young population must be addressed in time as they constitute the bulk of the productive age of the economy. While rising myopia is a cause for global concern, it is not given due attention in Africa due to a lack of adequate prevalence data and prospective studies tracking the trend of myopia over decades [24]. Due to this, the representation of Africa is poor in studies predicting global trends of myopia [24]. The aim of this study was to systematically review the evidence and provide a meta–analysis of the prevalence of myopia in African school children which will address the knowledge gap and help understand the prevalence of myopia among this group in Africa.

Materials and methods

This systematic review followed the framework of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA. See Checklist in S1 File) [25]. The protocol for the review was registered with PROSPERO (#CRD42020187609).

Search strategy and quality assessment

Two review team members (GO and BE) performed an independent systematic search and review of myopia in Africa using published data spanning the last two decades. Refractive error came into reckoning as a cause of visual impairment in the last two decades, following the change in the definition of visual impairment which was based on presenting visual acuity [26]. The search was conducted on 25th May and 18th August 2021. A third reviewer, KO, adjudicated where there were disagreements. The quality of each selected article was assessed using the checklist developed by Downs and Black [27] and each included article was assessed and scored on a 10-item scale (scoring is shown in S1 Table). The search was restricted to articles available online, articles

mentioning prevalence of myopia in any region of Africa, and articles published in the English language. Searches included the following databases: Web of sciences, PubMed, ProQuest, MEDLINE, Scopus, and African Index Medicus from 1st of January 2000 to August 18, 2021.

We searched these databases using the following MeSH (Medical Subject Heading) terms and keywords: Refractive AND error AND Africa AND children AND prevalence. A number of iterations of these search terms were used, for example, "refractive error AND Africa AND children AND prevalence" or "refractive error AND Africa AND children". Further details about search strategy and MeSH terms are available in the (S2 File). A broader search also used terms such as epidemiology, myopia, and school children. We also identified and included relevant studies by manually searching through the reference lists of identified papers. The PRISMA flowchart presented in Fig 1 shows the process used for selecting articles.

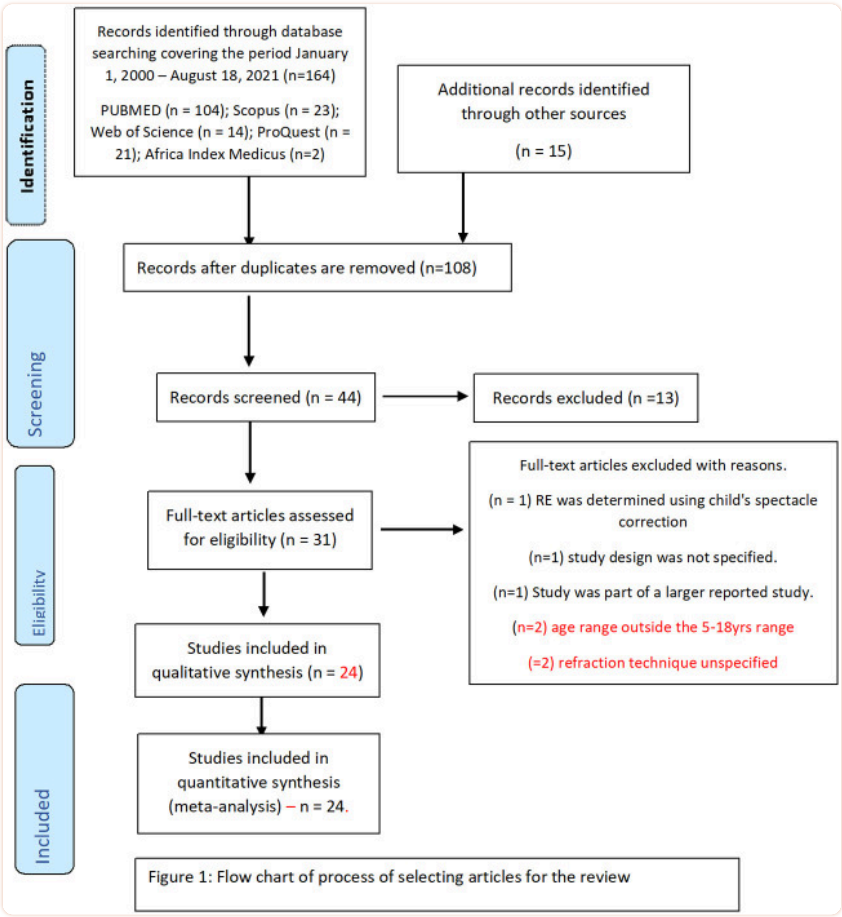


Fig 1

Flow chart of process of selecting articles for the review.

Inclusion and exclusion criteria

Studies published between 2000 and 2021, investigating the prevalence of refractive error in male and female school children aged 5 to 18 years of age were included in the review. Studies that employed an observational cross-sectional study design; had a clear description of the sampling technique; stated the method of measuring refractive error (cycloplegic or non-cycloplegic refraction), as well as objective or subjective refraction; stated the criteria for defining myopia (spherical equivalent ≥ 0.50 D of myopia [2, 28–30]; the study was either school–based or population–based; and were published in English language, were included in the review. The decision as to whether the articles met the inclusion criteria was made independently by the two reviewers (GO and BE) and where there was a disagreement, a third reviewer (KO) was consulted.

Studies where the criteria for defining myopia were not specified; the ages of the participants were either not specified or outside the age range specified for this review; or which reported findings from a hospital/clinic-based sample were excluded from the review.

Data extraction

The data extracted from each article included the following: Authors; year of publication; country of study; study design; sample size; sampling technique; the age of study participants; criteria for defining myopia; method of refractive error assessment (cycloplegic vs non-cycloplegic); method of refractive error assessment (objective vs subjective); prevalence of myopia; and the proportion of refractive error due to myopia. Where the reported prevalence was not clearly defined, the corresponding author in the published article was contacted for clarification.

Statistical methods

Meta–analysis was conducted using Stata version 14.0 (StataCorp, College Station, TX, USA). The syntax "metaprop" in Stata was used to generate forest plots and each forest plot showed the prevalence of myopia in school children, by gender, age and refraction technique in individual studies and its corresponding weight, as well as the pooled prevalence in each subset and its associated 95% confidence intervals (CI). A heterogeneity test obtained for the different studies showed a high level of inconsistency ($I^2 > 50\%$) thereby indicating the use of a random effect model in all the meta–analyses conducted. Sensitivity analysis was carried out by examining the effect of outliers, by employing similar method to that used by Patsopoulos et al. [31], which involves the process of comparing the pooled prevalence before and after eliminating one study at a time. The funnel plot was used to report the potential bias and small/large study effects and Begg's tests was used to assess asymmetry. The prevalence was subdivided into separate datasets based on overall prevalence, males or females, cycloplegic or non-cycloplegic refraction for a more detailed analysis of the prevalence of myopia. Also, to study a possible variation of the prevalence of myopia in terms of age, the age groups in the reported studies were divided into two categories: 5–11 years and 12–18 years. Their respective funnel plots are shown as (S3–S7 Files).

Results

Summary of included studies

From the described search strategy, a total of 164 potentially relevant titles/abstracts of articles were initially identified. Fig 1 presents the flowchart of the article screening and selection process. Following a quick inspection of identified studies and removal of duplicate articles, 44 relevant articles were assessed for eligibility. Using the pre–defined inclusion and exclusion criteria, 24 of 30 articles that underwent detailed review were eligible, and data from these studies were included in this study. A breakdown of the eligible studies as well as their quality assessment scores (maximum of 10) are presented in Table 1. S1 Table shows how the quality assessment scores were calculated.

Table 1

Characteristics of studies that reported the prevalence of myopia in school–aged children in Africa and were included in the meta–analysis.

First Author	Year of study	Study Country†	Age group (years)	Mean age (years)	Total Sample size	Cycloplegia	Objective refraction	Prevalence of myopia (%)	Comm refrac error
Atowa [32]	2017	Nigeria	8–15	11.5 ± 2.3	1197	Yes	Objective	2.7	
Wajuihian [33]	2017	South Africa	13–18	15.8 ± 1.6	1586	No	Objective	7	
Chebil [34]	2016	Tunisia	6–14	10.1 ± 1.8	6192	Yes	Objective	3.71	
Kedir [35]	2014	Ethiopia	7–15	Not reported	570	No	Subjective	2.6	
Soler [36]	2015	Equatorial Guinea	6–16	10.8 ± 3.1	425	Yes	Objective	10.4	
Kumah [37]	2013	Ghana	12–15	13.8	2435	Yes	Objective	3.2	
Mehari [38]	2013	Ethiopia	7–18	13.1 ± 2.5	4238	No	Objective	6	
Jimenez [39]	2012	Burkina Faso	6–16	11.2 ± 2.4	315	No	Objective	2.5	
Naidoo [7]	2003	South Africa	5–15	Not reported	4890	Yes	Objective	2.9	
Yamamah [40]	2015	Egypt	6–17	10.7 ± 3.1	2070	Yes	Objective	3.1	Astigm
Nartey [41]	2016	Ghana	6–16	10.6	811	No	Subjective	4.6	
Anera [42]	2006	Burkina Faso	5–16	10.2 ± 2.2	388	Yes	Objective	0.5	
Chukwuemeka [43]	2015	South Africa	7–14	9.9 ± 2.2	421	No	Objective	18.7	Astigm
Alrasheed [44]	2016	Sudan	6–15	10.8 ± 2.8	1678	Yes	Objective	6.8	Myopi
Abdul-Kabir [45]	2016	Ghana	10–15	Not reported	208	No	Objective	22.6	Myopi
Ebri [46]	2019	Nigeria	10–18	13.3 ± 1.9	4241	Yes	Objective	4.8	Astigm
Ezinne [47]	2018	Nigeria	5–15	9.0 ± 2.5	998	Yes	Objective	4.5	Myopi

† = country the study was conducted;

ǂ = authors provided data for only those aged 5–18 years.

The included studies comprised of the following: six (25.0%) studies from Ghana, four (16.7%) each from South Africa, and Nigeria, three from Ethiopia (12.5%), two (8.3%) from Burkina Faso, and one (4.2%) each from Sudan, Egypt, Equatorial Guinea, Somalia and Tunisia (Table 1). Of the reviewed articles, 84.2% (n = 21) were school–based, cross–sectional studies, two (8.3%) were population–based, cross–sectional studies, while one (4.2%) employed a cross–sectional study design but did not report whether it was school or population–based.

Method of measuring refractive error in African school–aged children

Of the reviewed studies, 13 (54.2%) performed cycloplegic refraction to determine the refractive error status of the children, while non-cycloplegic refraction was used in 11 (45.8%) of the studies. Regarding the technique used for refractive error measurement, over three–quarters of the studies (n = 20, 83.3%) performed objective refraction, with about one–sixth (n = 4, 16.7%) performing subjective refraction.

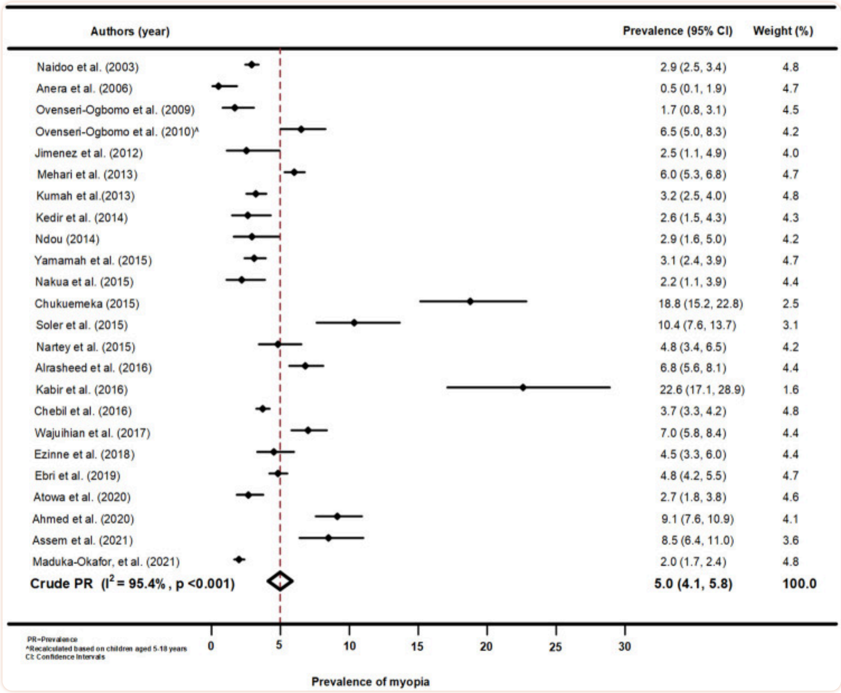
Prevalence of myopia in African school–aged children

The number of children aged 5–18 years included in the study ranged from 208 for a study conducted in Ghana [45] to 6192 for another study conducted in Tunisia [34, 55]. The prevalence of myopia reported in these studies ranged from 0.5% [42] to 10.4% [36, 52] with cycloplegic refraction. In studies where non–cycloplegic refraction was used to determine refractive error refraction in school children, the reported myopia prevalence ranged from 1.7% [51] to 22.6% [45].

Meta-analysis of myopia prevalence in children ag 5–18 years in Africa (2000–2021)

Myopia prevalence among school children in Africa

Fig 2 shows a forest plot of the prevalence of myopia among African school children aged 5–18 years. The pooled estimate of myopia in the African region was significant (5.0%, 95%CI: 4.1, 5.8; p<0.001) and about 37.5% of the studies (n = 9) reported significantly higher prevalence of myopia and 50% (n = 12) reporting significantly lower prevalence compared with the pooled estimate across Africa. The study by Abdul–Kabir found the highest prevalence (22.6%) of myopia among Ghanaian children (95%CI: 17.1, 28.9) [45], while Anera et al. found the lowest prevalence among children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9) [42]. The pooled prevalence estimates of myopia was similar to the study by Ebri [46] and Ezinne [47] (4.8%, 95%CI:4.2, 5.5), both involving children from Nigeria [46, 47]. Funnel plots and using Begg's test for Myopia in Africa indicated homogeneity (S3 File) and meta–regression analysis of myopia by year of publication indicated that publication of year increased as the proportion of myopia decreased but this relationship was not statistically significant (p = 0.423, S7 File).



[Fig 2](#)

Forest plot of myopia prevalence from the meta–analysis of African studies.

Myopia prevalence by gender of the School children in Africa (2000–2021)

Fig 3 is a forest plot for prevalence of myopia by gender among school children aged 5–18 years in Africa. The prevalence estimates varied significantly between studies in both male and female children ($p<0.001$, per gender), and the overall pooled prevalence of myopia by gender was 4.8% (95%CI: 4.1, 5.6) and similar between male and female estimates ($p = 0.297$). Compared with the overall pooled estimate, the prevalence of myopia was slightly higher in male (4.5%, 95%CI: 3.4, 5.5) children than females (5.3%, 95%CI: 4.1, 6.5) but the difference was not significant as indicted by the overlapping of the CIs with that of the overall pooled estimate. Funnel plots and using Begg's test for Myopia by gender reported absence of publication biases (S4 File).

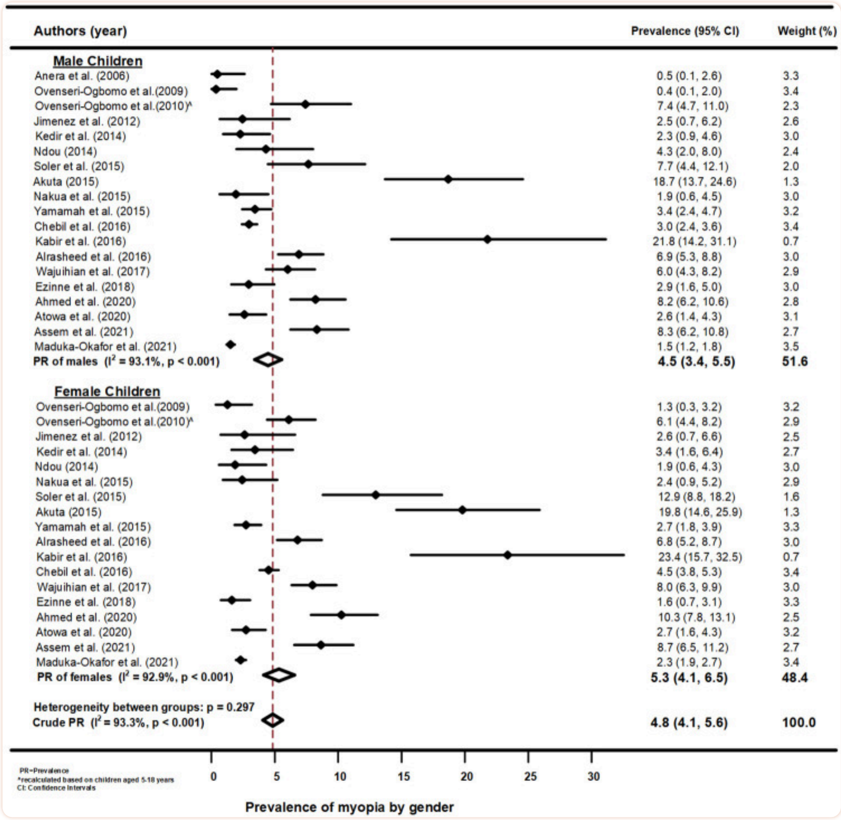


Fig 3

Forest plot of myopia prevalence by gender from the meta-analysis of African studies.

Myopia prevalence by age group of the school children in Africa (2000–2021)

The forest plot of the prevalence of myopia in children aged 5–11 years and 12–18 years is presented in Fig 4. The pooled estimate of myopia in school children aged 5–11 years and 12–18 years was lower (3.7%, 95%CI 2.6, 4.7) and higher (5.8%, 95%CI 3.8, 6.3) respectively, than the pooled estimate but none was significant as they overlapped with the pooled estimate in Africa (4.4%, 95%CI 3.6, 5.2). The heterogeneity between the groups was approaching significant (p = 0.091) but older children had a higher prevalence of myopia than younger children. Among those aged 5–11 years, the highest significant prevalence was reported in a Ghanaian study (16.4%, 95%CI: 13.0, 20.3) and a study conducted in Equatorial Guinea (8.2%, 95%CI: 5.8, 11.3) while school children in Ethiopia (0.5%, 95%CI: 0.1, 1.5) had the lowest significant prevalence estimate of myopia. Among those aged 12–18 years, children in Ghana also showed the highest significant prevalence of myopia (20.2%, 95%CI: 16.5, 24.4), but the lowest prevalence was reported among School children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9). The heterogeneity of these studies by age as subgroups analysis were low (S5 File).

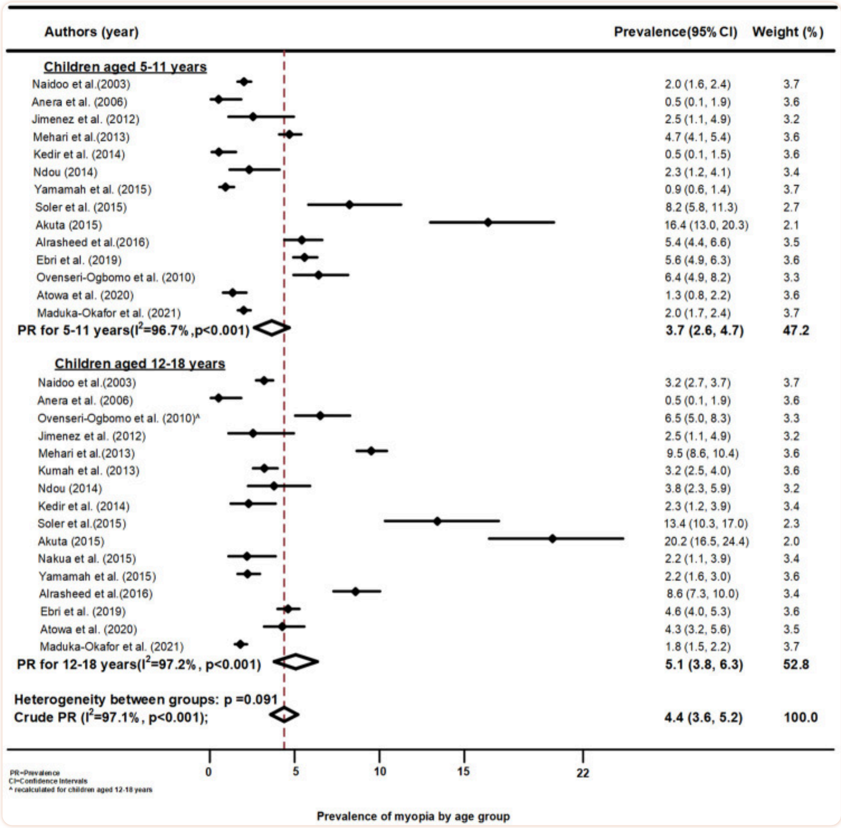


Fig 4

Forest plot of myopia prevalence by age group across African studies.

Myopia prevalence by mode of refraction among school children in Africa (2000–2021)

The forest plot displayed in Fig 5 shows the pooled estimate of myopia prevalence among school children in Africa. Using cycloplegic refraction, studies have reported significantly lower prevalence estimates of myopia among school children in Africa compared with those that used non–cycloplegic refraction (4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; p = 0.046). From the plot, it can be seen that studies that used non cycloplegic technique to determine refraction had greater variabilities in the reported myopia prevalence (ranging from 1.7 to 22.6%), but those that performed cycloplegic refraction had smaller between study variability in the reported prevalence of myopia (range from 0.5 to 10.4%). Funnel plots and the Begg's test for Myopia by refraction technique shown in S6 and S7 Files, respectively, found no publication biases.

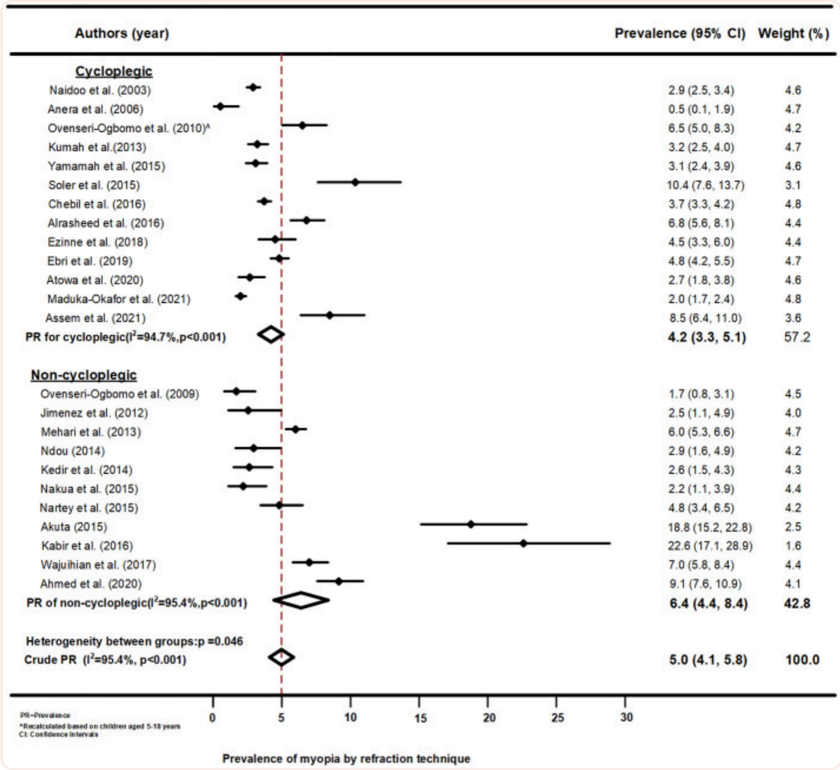


Fig 5

Forest plot of myopia prevalence by refraction technique among school children in Africa.

Discussion

Prevalence of myopia

The present study provided recent estimates of the myopia prevalence in African children using data from twenty eight studies conducted over two decades. The prevalence of myopia defined as SER ≥ 0.50D of myopia in school children across African countries was 4.7% (95%CI, 3.9, 5.7%) and there were wide variations within and between African countries. A significantly higher prevalence rate was observed in Ghana [45] and South Africa [43], with significantly lower rates in Burkina Faso [42] and Ethiopia [56]. In some countries like Ghana, the variation in the reported prevalence of myopia between studies reached 21% [37, 41, 45, 48, 51, 52]. Although the regional variations in myopia prevalence found in this study are consistent with the statement of Foster and Jiang who remarked that "Considerable regional difference exists from country to country even within the same geographical area" [57], it remains unclear why these variations exist. While the criteria for defining refractive error is often cited as the reason for the variation in the prevalence of refractive errors, including myopia, between studies, this may not be the case in our study because only studies that defined myopia as spherical equivalent of ≥ 0.50 D were included.

The overall low prevalence of myopia found across Africa is consistent with other studies that reported lower myopia prevalence in African children compared with Asian children [5, 58]. It is instructive to note that in four of the studies that were included in the current review [36, 43, 45, 52], the reported prevalence of myopia was greater than 10%. Of these, two studies [36, 52] used cycloplegic refraction, which is thought to more accurately estimate the prevalence of myopia [59]. The lower prevalence of myopia in Africa compared with the other regions may be related to the differences in genetic predisposition to myopia development, and to culture [60–62]. Although the role of genetics in the development and progression of myopia is reported to be small [12], it is believed to have a role in an individual's susceptibility to environmental risk factors for myopia [63]. In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development [60, 63]. In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) [64]. We acknowledge that a recent investigation [65] has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

Notwithstanding the relatively low prevalence of myopia found among African children, there is a need to monitor myopia prevalence among children in this region given the increasing access to, and use of, mobile devices among African population [19], including children. This is important considering the reported higher increase in the prevalence of myopia in black children living in Africa (2.8% to 5.5%) compared with other black children not living in Africa (4.8% to 19.9%) after 10 years [58]. It is assumed that black children not in Africa may have more access and exposure to near work, including mobile devices, and less outdoor activities than their counterparts in Africa.

Age and gender-based differences in myopia prevalence

There was a 34.6% increase in the prevalence of myopia between the age groups with the older age group having a higher prevalence of 5.2%. The slightly higher prevalence of myopia between the two age groups shows there is a tendency for myopia prevalence to increase with age which is consistent with previous studies from elsewhere [58, 66, 67]. This increase in myopia prevalence is thought to be associated with the increasing growth of the eyeball. Although the pooled prevalence of myopia in female children was slightly higher than in male children (4.7 versus 3.7%), the difference did not reach statistical significance. The influence of gender on the prevalence of myopia has not been unequivocal in the literature [68–72] with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls [73]. Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys [74].

Prevalence of myopia by refraction technique (cycloplegic and non-cycloplegic)

The present study demonstrated that cycloplegic refraction resulted in significantly lower estimates of myopia prevalence than non-cycloplegic refraction, which was consistent with previous studies [75–78]. It has been reported that non-cycloplegic refraction overestimates the prevalence of myopia, yields a non-reliable measurement of association of myopia risk factors [59, 76], and hence cycloplegic refraction is regarded as the gold standard for measuring myopia [59]. Over half of the studies in this review utilised cycloplegic refraction, which is particularly important in this age group where the difference between the cycloplegic and non-cycloplegic refraction is quite high [77, 78]. The fact that non-cycloplegic refraction often results in overestimation of myopia may have, in part, accounted for the high prevalence reported in one study from Ghana [45]. Furthermore, we have demonstrated that cycloplegic refraction results in a lower variability of measured refractive error than non–cycloplegic refraction (see Fig 5), which may reflect the variable accommodative state during the refraction of children of different ages. This finding underscores the need to appropriately control accommodation when performing refraction especially in young children who have a higher amplitude of accommodation and in whom accommodation is more active.

Implications of the study

This is the first systematic review and meta-analysis to estimate the prevalence of myopia among school children in Africa and its variation with age, gender and refraction technique. As previously reported, the prevalence of myopia in Africa appears low compared to other regions such as South East Asia. This study also provides baseline data for comparison and future prevalence studies to establish a trend in myopia epidemiology in this population. A further remarkable finding in this review is the demonstration that non–cycloplegic refraction overestimated the prevalence of myopia and results in more variable estimates of refractive errors compared with cycloplegic refraction. The interpretation of myopia prevalence data obtained from non–cycloplegic refraction may be potentially misleading to researchers and policymakers. As a result, it is recommended that cycloplegic refraction be used in all studies investigating the prevalence of myopia in children.

Strengths and limitations of the review

This review has certain limitations. Firstly, this review did not investigate the trend in the prevalence of myopia among school children in Africa due to the limited number of studies. Secondly, the selection of English-only studies likely biased the results towards studies in Anglophone countries or countries where the findings were reported in English. Thirdly, the current review did not explore the various factors influencing the epidemiology of myopia in this population. Despite these limitations, a major strength of this study is the selection of studies that used a uniform definition of myopia (i.e. ≥ 0.50DS of myopia) which allowed for a better comparison in the reported prevalence of myopia. In addition, the study excluded studies that were conducted in unselected groups such as hospital-based studies and studies that did not report any evidence of sampling in the study. In addition, the selected studies were evaluated for robustness in the study designs employed in each study.

Conclusions

In summary, this systematic review and meta–analysis have shown that the prevalence of myopia among schoolchildren in Africa is lower than other regions of the world. The use of non–cycloplegic refraction for estimation of myopia prevalence can be misleading as it returns higher and more variable prevalence estimates. There is a need to monitor the trend of myopia as more children in this region are increasingly being exposed to identified risk factors for myopia development including access to mobile devices, increased near work, increased online or remote learning, and limited time outdoors. Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

Supporting information

S1 Table

Quality assessment of full-text articles included in review.

(DOCX)

Click here for additional data file.(23K, docx)

S1 File

PRISMA 2020 checklist.

(DOCX)

Click here for additional data file.(32K, docx)

S2 File

Search terms for refractive error Africa children prevalence filters (2000–2021).

(DOCX)

Click here for additional data file.(13K, docx)

S3 File

Funnel plots and 95% confidence intervals of Myopia.

(DOCX)

Click here for additional data file.(15K, docx)

S4 File

Funnel plots and 95% confidence intervals of Myopia by gender.

(DOCX)

Click here for additional data file.(15K, docx)

S5 File

Funnel plots and 95% confidence intervals of Myopia by age in categories.

(DOCX)

Click here for additional data file.(15K, docx)

S6 File

Funnel plots and 95% confidence intervals of Myopia by refraction technique.

(DOCX)

Click here for additional data file.(15K, docx)

S7 File

A meta-regression analysis of Myopia by year of publication.

The vertical axis is the log proportion of Myopia, and the horizontal axis represents year of publication. Each dark dot represented one selected study, and the size of each dark dots corresponds to the weight assigned to each study. Given the slope of the regression line has descending slightly in this figure, this could be interpreted as publication of year increased, the proportion of myopia decreased and, this relationship did not differ statistically ($p = 0.5512$).

(DOCX)

Click here for additional data file.(37K, docx)

S8 File

Data used in the analysis.

(XLSX)

Click here for additional data file.(46K, xlsx)

Acknowledgments

The authors acknowledge the guidance of late Prof Alabi, O Oduntan during data collection.

Funding Statement

The authors recieved no specific funding for this work.

Data Availability

All relevant data are within the paper and its Supporting information files.

References

1. World Health Organization. WHO launches first World report on vision [cited 2021 June 8]. https://www.who.int/news/item/08-10-2019-who-launches-first-world-report-on-vision.

2. Holden BA., Fricke TR., Wilson DA., Jong M., Naidoo KS., Sankaridurg P., et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–42. doi: 10.1016/j.ophtha.2016.01.006 [PubMed] [CrossRef] [Google Scholar]

3. Holden BA, Jong M, Davis S, Wilson D, Fricke T, Resnikoff S. Nearly 1 billion myopes at risk of myopia-related sight-threatening conditions by 2050—time to act now. *Clin Exp Optom*. 2015;98(6):491–3. doi: 10.1111/cxo.12339 [PubMed] [CrossRef] [Google Scholar]

4. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt*. 2012;32(1):3–16. doi: 10.1111/j.1475-1313.2011.00884.x [PubMed] [CrossRef] [Google Scholar]

5. Grzybowski A., Kanclerz P., Tsubota K., Lanca C., Saw S-M. A review on the epidemiology of myopia in school children worldwide. *BMC Ophthalmol*. 2020;20:27–38. doi: 10.1186/s12886-019-1220-0 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

6. Chen M., Wu A., Zhang L., Wang W., Chen X., Yu X., et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. *BMC Ophthalmol*. 2018;18:159. doi: 10.1186/s12886-018-0829-8 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

7. Naidoo KS, Raghunandan A, Mashige KP, Govender P, Holden BA, Pokharel GP, et al. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci*. 2003;44(9):3764–70. doi: 10.1167/iovs.03-0283 [PubMed] [CrossRef] [Google Scholar]

8. R. R. Bennett and Rabbetts' clinical visual optics. Oxford: Butterworth-Heinemann; 1998.

9. Kempen JH, Mitchell P, Lee KE, Tielsch JM, Broman AT, Taylor HR, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol*. 2004;122(4):495–505. doi: 10.1001/archopht.122.4.495 [PubMed] [CrossRef] [Google Scholar]

10. Williams K, Hammond C. High myopia and its risks. *Community eye health*. 2019;32(105):5–6. [PMC free article] [PubMed] [Google Scholar]

11. Holden BA., Mariotti SP., Kocur I., Resnikoff S., He M., Naidoo KS., et al. *The impact of myopia and high myopia: Report of the joint World Health Organization- Brien Holden Vision Institute Global Scientific Meeting on Myopia University of New South Wales, Sydney, Australia, 16–18 March 2015*. Geneva: World Health Organization; 2017. [Google Scholar]

12. Congdon N, Burnett A, Frick K. The impact of uncorrected myopia on individuals and society. *Community eye health*. 2019;32(105):7–8. [PMC free article] [PubMed] [Google Scholar]

13. Fricke TR., Holden BA., Wilson DA., Schlenther G., Naidoo KS., Resnikoff S., et al. Global cost of correcting vision impairment from uncorrected refractive error. *Bull World Health Organ*. 2012;90:728–38. doi: 10.2471/BLT.12.104034 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

14. Rudnicka AR, Owen CG, Nightingale CM, Cook DG, Whincup PH. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: the Child Heart and Health Study in England (CHASE). *Invest Ophthalmol Vis Sci*. 2010;51(12):6270–6. doi: 10.1167/iovs.10-5528 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

15. Wachira L-J. Lifestyle Transition towards Sedentary Behavior among Children and Youth in Sub-Saharan Africa: A narrative review: IntechOpen; 2021.

16. OECD/SWAC. *Africa's Urbanisation Dynamics 2020: Africapolis, Mapping a New Urban Geography, West African Studies*. Paris: OECD Publishing; 2020. [Google Scholar]

17. Juma K, Juma PA, Shumba C, Otieno P, Asiki G. Non-Communicable Diseases and Urbanization in African Cities: A Narrative Review. In: Anugwom EE, Awofeso N, editors. Public Health in Developing Countries—Challenges and Opportunities: IntechOpen.

18. Porter G, Hampshire K, Abane A, Munthali A, Robson E, Mashiri M, et al. Youth, mobility and mobile phones in Africa: findings from a three-country study. *Information Technology for Development*. 2012;18(2):145–62. [Google Scholar]

19. Porter G, Hampshire K, Milner J, Munthali A, Robson E, de Lannoy A, et al. Mobile Phones and Education in Sub-Saharan Africa: From Youth Practice to Public Policy. *Journal of International Development*. 2016;28(1):22–39. [Google Scholar]

20. Hepsen IF, Evereklioglu C, Bayramlar H. The effect of reading and near-work on the development of myopia in emmetropic boys: a prospective, controlled, three-year follow-up study. *Vision Res*. 2001;41(19):2511–20. doi: 10.1016/s0042-6989(01)00135-3 [PubMed] [CrossRef] [Google Scholar]

21. Ip JM, Saw S-M, Rose KA, Morgan IG, Kifley A, Wang JJ, et al. Role of Near Work in Myopia: Findings in a Sample of Australian School Children. *Investigative Ophthalmology & Visual Science*. 2008;49(7):2903–10. [PubMed] [Google Scholar]

22. Huang HM, Chang DS, Wu PC. The Association between Near Work Activities and Myopia in Children-A Systematic Review and Meta-Analysis. *PLoS One*. 2015;10(10):e0140419. doi: 10.1371/journal.pone.0140419 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

23. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology*. 2012;119(10):2141–51. doi: 10.1016/j.ophtha.2012.04.020 [PubMed] [CrossRef] [Google Scholar]

24. Wolffsohn JS, Calossi A, Cho P, Gifford K, Jones L, Li M, et al. Global trends in myopia management attitudes and strategies in clinical practice. *Cont Lens Anterior Eye*. 2016;39(2):106–16. doi: 10.1016/j.clae.2016.02.005 [PubMed] [CrossRef] [Google Scholar]

25. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi: 10.1136/bmj.n71 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

26. Dandona L, Dandona R. Revision of visual impairment definitions in the International Statistical Classification of Diseases. *BMC medicine*. 2006;4:7-. doi: 10.1186/1741-7015-4-7 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

27. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377–84. doi: 10.1136/jech.52.6.377 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

28. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Gupta V, et al. Incidence and progression of myopia and associated factors in urban school children in Delhi: The North India Myopia Study (NIM Study). *PLoS One*. 2017;12(12):e0189774. doi: 10.1371/journal.pone.0189774 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

29. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Menon V, et al. Prevalence of myopia and its risk factors in urban school children in Delhi: the North India Myopia Study (NIM Study). *PLoS One*. 2015;10(2):e0117349. doi: 10.1371/journal.pone.0117349 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

30. Luo HD, Gazzard G, Liang Y, Shankar A, Tan DT, Saw SM. Defining myopia using refractive error and uncorrected logMAR visual acuity >0.3 from 1334 Singapore school children ages 7–9 years. *Br J Ophthalmol*. 2006;90(3):362–6. doi: 10.1136/bjo.2005.079657 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

31. Patsopoulos NA, Evangelou E, Ioannidis JP. Sensitivity of between-study heterogeneity in meta-analysis: proposed metrics and empirical evaluation. *International Journal of Epidemiology*. 2008;37(5):1148–57. doi: 10.1093/ije/dyn065 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

32. Atowa UC, Munsamy AJ, Wajuihian SO. Prevalence and risk factors for myopia among school children in Aba, Nigeria. *African Vision and Eye Health*; Vol 76, No 1 (2017). [Google Scholar]

33. Wajuihian SO, Hansraj R. Refractive Error in a Sample of Black High School Children in South Africa. *Optom Vis Sci*. 2017;94(12):1145–52. doi: 10.1097/OPX.0000000000001145 [PubMed] [CrossRef] [Google Scholar]

34. Chebil A, Jedidi L, Chaker N, Kort F, Largueche L, El Matri L. Epidemiologic study of myopia in a population of schoolchildren in Tunisia. *Tunis Med*. 2016;94(3):216–20. [PubMed] [Google Scholar]

35. Kedir J, Girma A. Prevalence of refractive error and visual impairment among rural school-age children of Goro District, Gurage Zone, Ethiopia. *Ethiop J Health Sci*. 2014;24(4):353–8. doi: 10.4314/ejhs.v24i4.11 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

36. Soler M, Anera RG, Castro JJ, Jiménez R, Jiménez JR. Prevalence of Refractive Errors in Children in Equatorial Guinea. *Optometry and Vision Science*. 2015;92(1). doi: 10.1097/OPX.0000000000000448 [PubMed] [CrossRef] [Google Scholar]

37. Kumah BD, Ebri A, Abdul-Kabir M, Ahmed AS, Koomson NY, Aikins S, et al. Refractive error and visual impairment in private school children in Ghana. *Optom Vis Sci*. 2013;90(12):1456–61. doi: 10.1097/OPX.0000000000000099 [PubMed] [CrossRef] [Google Scholar]

38. Mehari ZA, Yimer AW. Prevalence of refractive errors among schoolchildren in rural central Ethiopia. *Clin Exp Optom*. 2013;96(1):65–9. doi: 10.1111/j.1444-0938.2012.00762.x [PubMed] [CrossRef] [Google Scholar]

39. Jimenez R, Soler M, Anera RG, Castro JJ, Perez MA, Salas C. Ametropias in school-age children in Fada N'Gourma (Burkina Faso, Africa). *Optom Vis Sci*. 2012;89(1):33–7. doi: 10.1097/OPX.0b013e318238b3dd [PubMed] [CrossRef] [Google Scholar]

40. Yamamah GA, Talaat Abdel Alim AA, Mostafa YS, Ahmed RA, Mohammed AM. Prevalence of Visual Impairment and Refractive Errors in Children of South Sinai, Egypt. *Ophthalmic Epidemiol*. 2015;22(4):246–52. doi: 10.3109/09286586.2015.1056811 [PubMed] [CrossRef] [Google Scholar]

41. Nartey ET, van Staden DB, Amedo AO. Prevalence of Ocular Anomalies among Schoolchildren in Ashaiman, Ghana. *Optometry and Vision Science*. 2016;93(6). doi: 10.1097/OPX.0000000000000836 [PubMed] [CrossRef] [Google Scholar]

42. Anera RG, Jiménez JR, Soler M, Pérez MA, Jiménez R, Cardona JC. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol*. 50. Japan2006. p. 483–4. doi: 10.1007/s10384-006-0354-9 [PubMed] [CrossRef] [Google Scholar]

43. Chukwuemeka AG. *Prevalence of refractive errors among primary school children (7–14 years) in Motherwell Township, Eastern Cape, South Africa*. Eastern Cape, South Africa: University of Limpopo; 2015. [Google Scholar]

44. Alrasheed SH, Naidoo KS, Clarke-Farr PC. Prevalence of visual impairment and refractive error in school-aged children in South Darfur State of Sudan. *African Vision and Eye Health*; Vol 75, No 1 (2016). [Google Scholar]

45. Abdul-Kabir M, Bortey DNK, Onoikhua EE, Asare-Badiako B, Kumah DB. Ametropia among school children—a cross-sectional study in a sub-urban municipality in Ghana. *Pediatr Dimensions*. 2016;1(3):65–8. [Google Scholar]

46. Ebri AE, Govender P, Naidoo KS. Prevalence of vision impairment and refractive error in school learners in Calabar, Nigeria. *African Vision and Eye Health*; Vol 78, No 1 (2019) [Google Scholar]

47. Ezinne NE, Mashige KP. Refractive error and visual impairment in primary school children in Onitsha, Anambra State, Nigeria. *African Vision and Eye Health*; Vol 77, No 1 (2018). [Google Scholar]

48. Nakua EK, Otupiri E, Owusu-Dabo E, Dzomeku VM, Otu-Danquah K, Anderson M. Prevalence of refractive errors among junior high school students in the Ejisu Juaben Municipality of Ghana. *J Sci Tech*. 2015;35(1):52–62. [Google Scholar]

49. Ndou NP. *Uncorrected refractive errors among primary school children of Moretele sub-distric in North-west Province*, South Africa: University of Limpopo; 2014. doi: 10.5713/ajas.2013.13774 [CrossRef] [Google Scholar]

50. Abdi Ahmed Z, Alrasheed SH, Alghamdi W. Prevalence of refractive error and visual impairment among school-age children of Hargesia, Somaliland, Somalia. *East Mediterr Health J*. 2020;26(11):1362–70. doi: 10.26719/emhj.20.077 [PubMed] [CrossRef] [Google Scholar]

51. Ovenseri-Ogbomo GO, Assien R. Refractive error in school children in Agona Swedru, Ghana. *African Vision and Eye Health; South African Optometrist*: Vol 69, No 2 (2010). [Google Scholar]

52. Ovenseri-Ogbomo G, Omuemu DV. Prevalence of refractive error among school children in the Cape Coast Municipality, Ghana. *{Opto}*. 2010:59. [Google Scholar]

53. Assem AS, Tegegne MM, Fekadu SA. Prevalence and associated factors of myopia among school children in Bahir Dar city, Northwest Ethiopia, 2019. *PLoS One*. 2021;16(3):e0248936. doi: 10.1371/journal.pone.0248936 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

54. Maduka-Okafor FC, Okoye O, Ezegwui I, Oguego NC, Okoye OI, Udeh N, et al. Refractive Error and Visual Impairment Among School Children: Result of a South-Eastern Nigerian Regional Survey. *Clin Ophthalmol*. 2021;15:2345–53. doi: 10.2147/OPTH.S298929 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

55. Rushood AA, Azmat S, Shariq M, Khamis A, Lakho KA, Jadoon MZ, et al. Ocular disorders among schoolchildren in Khartoum State, Sudan. *East Mediterr Health J*. 2013;19(3):282–8. [PubMed] [Google Scholar]

56. Woldeamanuel GG, Biru MD, Geta TG, Areru BA. Visual impairment and associated factors among primary school children in Gurage Zone, Southern Ethiopia. *Afr Health Sci*. 2020;20(1):533–42. doi: 10.4314/ahs.v20i1.60 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

57. Foster PJ, Jiang Y. Epidemiology of myopia. *Eye*. 2014;28(2):202–8. doi: 10.1038/eye.2013.280 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

58. Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. *Br J Ophthalmol*. 2016;100(7):882–90. doi: 10.1136/bjophthalmol-2015-307724 [PMC free article] [PubMed]

[CrossRef] [Google Scholar]

59. Morgan IG, Iribarren R, Fotouhi A, Grzybowski A. Cycloplegic refraction is the gold standard for epidemiological studies. *Acta Ophthalmol*. 2015;93(6):581–5. doi: 10.1111/aos.12642 [PubMed] [CrossRef] [Google Scholar]

60. Ip JM, Huynh SC, Robaei D, Rose KA, Morgan IG, Smith W, et al. Ethnic Differences in the Impact of Parental Myopia: Findings from a Population-Based Study of 12-Year-Old Australian Children. *Investigative Ophthalmology & Visual Science*. 2007;48(6):2520–8. doi: 10.1167/iovs.06-0716 [PubMed] [CrossRef] [Google Scholar]

61. Goldschmidt E, Jacobsen N. Genetic and environmental effects on myopia development and progression. *Eye*. 2014;28(2):126–33. doi: 10.1038/eye.2013.254 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

62. Armarnik S, Lavid M, Blum S, Wygnanski-Jaffe T, Granet DB, Kinori M. The relationship between education levels, lifestyle, and religion regarding the prevalence of myopia in Israel. *BMC Ophthalmology*. 2021;21(1):136. doi: 10.1186/s12886-021-01891-w [PMC free article] [PubMed] [CrossRef] [Google Scholar]

63. Lim LT, Gong Y, Ah-Kee EY, Xiao G, Zhang X, Yu S. Impact of parental history of myopia on the development of myopia in mainland china school-aged children. *Ophthalmology and eye diseases*. 2014;6:31–5. doi: 10.4137/OED.S16031 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

64. The Global Economy. Business and economic data for 200 countries [cited 2021 August 12]. https://www.theglobaleconomy.com/.

65. Gajjar S, Ostrin LA. A systematic review of near work and myopia: measurement, relationships, mechanisms and clinical corollaries. *Acta Ophthalmologica*. 2021. doi: 10.1111/aos.15043 [PubMed] [CrossRef] [Google Scholar]

66. French AN, Morgan IG, Burlutsky G, Mitchell P, Rose KA. Prevalence and 5- to 6-year incidence and progression of myopia and hyperopia in Australian schoolchildren. *Ophthalmology*. 2013;120(7):1482–91. doi: 10.1016/j.ophtha.2012.12.018 [PubMed] [CrossRef] [Google Scholar]

67. Hashemi H, Fotouhi A, Mohammad K. The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic Epidemiol*. 2004;11(3):213–25. doi: 10.1080/09286580490514513 [PubMed] [CrossRef] [Google Scholar]

68. Lam CSY, Goh WSH. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. *Clinical and Experimental Optometry*. 1991;74(3):97–103. [Google Scholar]

69. Maul E, Barroso S, Munoz SR, Sperduto RD, Ellwein LB. Refractive Error Study in Children: results from La Florida, Chile. *Am J Ophthalmol*. 2000;129(4):445–54. doi: 10.1016/s0002-9394(99)00454-7 [PubMed] [CrossRef] [Google Scholar]

70. Czepita D, Mojsa A, Ustianowska M, Czepita M, Lachowicz E. Role of gender in the occurrence of refractive errors. *Ann Acad Med Stetin*. 2007;53(2):5–7. [PubMed] [Google Scholar]

71. Quek TP, Chua CG, Chong CS, Chong JH, Hey HW, Lee J, et al. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt*. 2004;24(1):47–55. doi: 10.1046/j.1475-1313.2003.00166.x [PubMed] [CrossRef] [Google Scholar]

72. Zhao J, Mao J, Luo R, Li F, Munoz SR, Ellwein LB. The progression of refractive error in school-age children: Shunyi district, China. *Am J Ophthalmol*. 2002;134(5):735–43. doi: 10.1016/s0002-9394(02)01689-6 [PubMed] [CrossRef] [Google Scholar]

73. Vision. NRCUCo. *Myopia: Prevalence and Progression*. Washington (DC): National Academies Press (US); 1989. [PubMed] [Google Scholar]

74. Gong J-F, Xie H-L, Mao X-J, Zhu X-B, Xie Z-K, Yang H-H, et al. Relevant factors of estrogen changes of myopia in adolescent females. *Chinese medical journal*. 2015;128(5):659. doi: 10.4103/0366-6999.151669 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

75. Lundberg K, Suhr Thykjaer A, Søgaard Hansen R, Vestergaard AH, Jacobsen N, Goldschmidt E, et al. Physical activity and myopia in Danish children-The CHAMPS Eye Study. *Acta Ophthalmol*. 2018;96(2):134–41. doi: 10.1111/aos.13513 [PubMed] [CrossRef] [Google Scholar]

76. Fotouhi A, Morgan IG, Iribarren R, Khabazkhoob M, Hashemi H. Validity of noncycloplegic refraction in the assessment of refractive errors: the Tehran Eye Study. *Acta Ophthalmol*. 2012;90(4):380–6. doi: 10.1111/j.1755-3768.2010.01983.x [PubMed] [CrossRef] [Google Scholar]

77. Fotedar R, Rochtchina E, Morgan I, Wang JJ, Mitchell P, Rose KA. Necessity of cycloplegia for assessing refractive error in 12-year-old children: a population-based study. *Am J Ophthalmol*. 2007;144(2):307–9. doi: 10.1016/j.ajo.2007.03.041 [PubMed] [CrossRef] [Google Scholar]

78. Hu YY, Wu JF, Lu TL, Wu H, Sun W, Wang XR, et al. Effect of cycloplegia on the refractive status of children: the Shandong children eye study. *PLoS One*. 2015;10(2):e0117482. doi: 10.1371/journal.pone.0117482 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r001

Decision Letter 0

Aleksandra Barac, Academic Editor

13 Dec 2021

PONE-D-21-28841Systematic Review and Meta-analysis of Myopia prevalence in African School children.PLOS ONE

Dear Dr. Osuagwu,

Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit but does not fully meet PLOS ONE's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

Please submit your revised manuscript by Jan 27 2022 11:59PM. If you will need more time than this to complete your revisions, please reply to this message or contact the journal office at plosone@plos.org. When you're ready to submit your revision, log on to https://www.editorialmanager.com/pone/ and select the 'Submissions Needing Revision' folder to locate your manuscript file.

Please include the following items when submitting your revised manuscript:

- A rebuttal letter that responds to each point raised by reviewers. You should upload this letter as a separate file labeled 'Response to Reviewers'.
- A marked-up copy of your manuscript that highlights changes made to the original version. You should upload this as a separate file labeled 'Revised Manuscript with Track Changes'.
- An unmarked version of your revised paper without tracked changes. You should upload this as a separate file labeled 'Manuscript'.

If you would like to make changes to your financial disclosure, please include your updated statement in your cover letter. Guidelines for resubmitting your figure files are available below the reviewer comments at the end of this letter.

If applicable, we recommend that you deposit your laboratory protocols in protocols.io to enhance the reproducibility of your results. Protocols.io assigns your protocol its own identifier (DOI) so that it can be cited independently in the future. For instructions see: https://journals.plos.org/plosone/s/submission-guidelines#loc-laboratory-protocols. Additionally, PLOS ONE offers an option for publishing peer-reviewed Lab Protocol articles, which describe protocols hosted on protocols.io. Read more information on sharing protocols at https://plos.org/protocols?utm_medium=editorial-email&utm_source=authorletters&utm_campaign=protocols.

We look forward to receiving your revised manuscript.

Kind regards,

Aleksandra Barac

Academic Editor

PLOS ONE

Journal Requirements:

When submitting your revision, we need you to address these additional requirements.

1. Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. The PLOS ONE style templates can be found at

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Reviewers' comments:

Reviewer's Responses to Questions

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

****

3. Have the authors made all data underlying the findings in their manuscript fully available?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception (please refer to the Data Availability Statement in the manuscript PDF file). The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: No

****

4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level

- They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

I think we should exclude these articles or change the inclusion criteria

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

In a meta-analysis, Gajjar (Acta ophtahlmol 2021) show that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) shows the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Reviewer #2: This is a good Meta-analysis regarding the myopia prevalence in Africa

it is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

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6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose “no”, your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

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While revising your submission, please upload your figure files to the Preflight Analysis and Conversion Engine (PACE) digital diagnostic tool, https://pacev2.apexcovantage.com/. PACE helps ensure that figures meet PLOS requirements. To use PACE, you must first register as a user. Registration is free. Then, login and navigate to the UPLOAD tab, where you will find detailed instructions on how to use the tool. If you encounter any issues or have any questions when using PACE, please email PLOS at figures@plos.org. Please note that Supporting Information files do not need this step.

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r002

Author response to Decision Letter 0

13 Jan 2022

Response to Reviewers comments

Dear Aleksandra Barac

Thanks for the very useful comments which has strengthened our manuscript. We have revised the article according to the suggested comments. We have provided a point-by-point response to all reviewers comments for clarity.

The changes made in the revised manuscript and supplementary files were highlighted using red font for easy identification.

Journal Requirements:

When submitting your revision, we need you to address these additional requirements.

1. Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. The PLOS ONE style templates can be found at

https://journals.plos.org/plosone/s/file?id=wjVg/PLOSOne_formatting_sample_main_body.pdf and

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2. Please include captions for your Supporting Information files at the end of your manuscript, and update any in-text citations to match accordingly. Please see our Supporting Information guidelines for more information: http://journals.plos.org/plosone/s/supporting-information.

Response: Done

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

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3. Have the authors made all data underlying the findings in their manuscript fully available?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception (please refer to the Data Availability Statement in the manuscript PDF file). The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: No

Response: We have included the study data used in the analysis as a spread sheet inline with PlosOne policy

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4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1:

The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

Response: Agreed and we have excluded the 4–24year-old range study (Yareed et al) and the 5-19 year study (Ovenseri-Ogbomo et al) as they do not meet our stipulated inclusion criteria of 5-18 year.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level. They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

Response: The inclusion and exclusion criteria were made clearer and as suggested, we excluded these studies as the two stipulated criteria are not specified [Rushood (39) and Woldeamanuel (47)]

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

Response: We have included the mean age in Table 1 and the study with age range 4-24years was excluded based on the exclusion criteria.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

Response: In a meta-analysis, Gajjar (Acta ophthalmol 2021) showed that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) showed the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside. However, we agree with the reviewer and have made the following revision in the discussion section:

In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development(62, 65). In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) (66). We acknowledge that a recent investigation(67) has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Response: Zadnik et al study was referring to a specific context in their study, where they found that girls tended to have steeper corneas, stronger crystalline lenses, and shorter eyes/axial length than boys. These findings are specific to their study and cannot be used to explain any result where a higher prevalence of myopia in girls is found. For example, we know that shorter axial length is generally associated with hyperopia and not myopia.

However, the new analysis after removing the 4 studies, showed no statistically significant difference in myopia prevalence between gender. Therefore, we have removed this statement and the revised section now reads:

The influence of gender on the prevalence of myopia has not been unequivocal in the literature (70-74) with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls (75). Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys (76).

Reviewer #2

This is a good Meta-analysis regarding the myopia prevalence in Africa. It is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

Response: Thanks for the suggestion. Although the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about the differences in the prevalence of myopia between ethnic groups in Africa, studies that have been conducted in Africa did not specify the different ethnicities. However, we think there is need for such comparison between black vs white vs Asian and this could be another research interest with a different research aim for another manuscript. We have suggested this in the conclusion for future study direction. The section now reads:

Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

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6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose “no”, your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

Response. Thanks for your comments

Attachment

Submitted filename: *Response to Reviewers comments.docx*

Click here for additional data file. (31K, docx)

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r003

Decision Letter 1

Aleksandra Barac, Academic Editor

17 Jan 2022

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

PONE-D-21-28841R1

Dear Dr. Osuagwu,

We're pleased to inform you that your manuscript has been judged scientifically suitable for publication and will be formally accepted for publication once it meets all outstanding technical requirements.

Within one week, you'll receive an e-mail detailing the required amendments. When these have been addressed, you'll receive a formal acceptance letter and your manuscript will be scheduled for publication.

An invoice for payment will follow shortly after the formal acceptance. To ensure an efficient process, please log into Editorial Manager at http://www.editorialmanager.com/pone/, click the 'Update My Information' link at the top of the page, and double check that your user information is up-to-date. If you have any billing related questions, please contact our Author Billing department directly at authorbilling@plos.org.

If your institution or institutions have a press office, please notify them about your upcoming paper to help maximize its impact. If they'll be preparing press materials, please inform our press team as soon as possible -- no later than 48 hours after receiving the formal acceptance. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information, please contact onepress@plos.org.

Kind regards,

Aleksandra Barac

Academic Editor

PLOS ONE

2022; 17(2): e0263335.

Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r004

Acceptance letter

Aleksandra Barac, Academic Editor

24 Jan 2022

PONE-D-21-28841R1

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

Dear Dr. Osuagwu:

I'm pleased to inform you that your manuscript has been deemed suitable for publication in PLOS ONE. Congratulations! Your manuscript is now with our production department.

If your institution or institutions have a press office, please let them know about your upcoming paper now to help maximize its impact. If they'll be preparing press materials, please inform our press team within the next 48 hours. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information please contact onepress@plos.org.

If we can help with anything else, please email us at plosone@plos.org.

Thank you for submitting your work to PLOS ONE and supporting open access.

Kind regards,

PLOS ONE Editorial Office Staff

on behalf of

Dr. Aleksandra Barac

Academic Editor

PLOS ONE

Ophthalmic Physiol Opt. 2022 Nov; 42(6): 1232–1252.
Published online 2022 Aug 12. doi: 10.1111/opo.13035
PMCID: PMC9804554
PMID: 35959749

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

Emmanuel Kobia-Acquah,[1] Daniel Ian Flitcroft,[1] Prince Kwaku Akowuah,[2] Gareth Lingham,[1] and James Loughman[1]

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

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.

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, 3, 4, 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, 8, 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.[18,19,20] 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%.[23,24,25] 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.[26,27,28,29] 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.

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.

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

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.

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.

FIGURE 1

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

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, 39, 40, 41, 42, 43, 44] six in Ethiopia,[45, 46, 47, 48, 49, 50] five in Nigeria,[51, 52, 53, 54, 55] four in South Africa,[56, 57, 58, 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.

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.

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 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]

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.

FIGURE 5

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

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 ($p = 0.08$).

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 ($p = 0.81$).

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.

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.

TABLE 2

Summary of subgroup analysis of childhood myopia prevalence in Africa

Subgroup	Number of studies	Total participants	Prevalence (%) (95% CI)	Heterogeneity: I^2 statistics (%)	Heterogeneity: Q-statistic (*df*)	*p*-value*	*p*-value (subgroup)†
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	

**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.

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.

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

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% 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).

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.

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 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, 24, 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, 90, 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, 96, 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, 101, 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.

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 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).

FUNDING INFORMATION

None.

CONFLICT OF INTEREST

JL has received research grant funding support from Health Research Board (Ireland), Nevakar and CooperVision; has consultancy relationships with Dopavision, Kubota Vision, Ocuco and Ebiga Vision; has received honoraria from Thea Pharmaceuticals and Ocuco for lectures; has received equipment on loan from Topcon and CooperVision; has two patents pending (one in myopia management data analytics and one in biomonitoring for low-dose atropine treatment in myopia) and is Director of Ocumetra, all in the field of myopia management. DIF has received research grant funding support from Health Research Board (Ireland), Nevakar and CooperVision; has consultancy or other relationships with Dopavision, Kubota Vision, Essilor, Johnson & Johnson, Thea Pharmaceuticals and Vivior; has received equipment on loan from Topcon and CooperVision; has two patents pending (one in myopia management data analytics and one in biomonitoring for low-dose atropine treatment in myopia) and is Director of Ocumetra, all in the field of myopia management.

Supporting information

Figure S1-S2

Click here for additional data file.(309K, pdf)

Table S1

Click here for additional data file.(265K, pdf)

Table S2

Click here for additional data file.(216K, pdf)

ACKNOWLEDGEMENT

Open access funding provided by IReL. Open access funding provided by IReL.

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?	Wa co me a s rel for pa
	Benin							
1.	Souvounou et al. (2008)[78]	Y	U	Y	Y	N	Y	Y
	Burkina Faso							
2.	Anera et al. (2006)[64]	Y	U	Y	U	Y	Y	N
3.	Jimenez et al (2012)[65]	Y	Y	Y	Y	Y	Y	N
	Egypt							
4.	Yamamah et al. (2015)[60]	Y	Y	Y	Y	N	Y	Y
5.	Mohamed et al. (2014)[20]	Y	Y	Y	Y	Y	Y	Y
6.	Arafa et al. (2019)[61]	Y	Y	Y	Y	N	Y	Y
	Equatorial Guinea							
7.	Soler et al. (2015)[74]	Y	Y	Y	Y	Y	Y	Y
	Ethiopia							
8.	Gessesse and Teshome	Y	Y	Y	Y	Y	Y	Y

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

Notes

Kobia-Acquah E, Flitcroft DI, Akowuah PK, Lingham G, Loughman J. Regional variations and temporal trends of childhood myopia prevalence in Africa: A systematic review and meta-analysis. *Ophthalmic Physiol Opt*. 2022;42:1232–1252. 10.1111/opo.13035 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

REFERENCES

1. Flaxman SR, Bourne RRA, Resnikoff S, Ackland P, Braithwaite T, Cicinelli MV, et al. Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. *Lancet Glob Health*. 2017;5:e1221–34. [PubMed] [Google Scholar]

2. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia aetiology. *Prog Retin Eye Res*. 2012;31:622–60. [PubMed] [Google Scholar]

3. Haarman AEG, Enthoven CA, Tideman JL, Tedja MS, Verhoeven VJM, Klaver CCW. The complications of myopia: a review and meta-analysis. *Invest Ophthalmol Vis Sci*. 2020;61:ARVO E-Abstract 49. [PMC free article] [PubMed] [Google Scholar]

4. Yokoi T, Ohno-Matsui K. Diagnosis and treatment of myopic maculopathy. *Asia Pacific J Ophthalmol*. 2019;7:415–21. [PubMed] [Google Scholar]

5. Wang Y, Huang C, Tseng Y, Zhong J, Li X. Refractive error and eye health: an umbrella review of meta-analyses. *Front Med*. 2021;8:759767. 10.3389/fmed.2021.759767 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

6. Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–42. [PubMed] [Google Scholar]

7. Chen M, Wu A, Zhang L, Wang W, Chen X, Yu X, et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. *BMC Ophthalmol*. 2018;18:1–10. 10.1186/s12886-018-0829-8 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

8. Yam JC, Tang SM, Kam KW, Chen LJ, Yu M, Law AK, et al. High prevalence of myopia in children and their parents in Hong Kong Chinese population: the Hong Kong children eye study. *Acta Ophthalmol*. 2020;98:e639–48. [PubMed] [Google Scholar]

9. Jung SK, Lee JH, Kakizaki H, Jee D. Prevalence of myopia and its association with body stature and educational level in 19-year-old male conscripts in Seoul, South Korea. *Invest Ophthalmol Vis Sci*. 2012;53:5579–83. [PubMed] [Google Scholar]

10. Vitale S, Sperduto RD, Ferris FL. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. *Arch Ophthalmol*. 2009;127:1632–9. [PubMed] [Google Scholar]

11. Alvarez-Peregrina CC, Sanchez-Tena MAMA, Martinez-Perez CC, Villa-Collar CC. Prevalence and risk factors of myopia in Spain. *J Ophthalmol*. 2019;2019:1–7. 10.1155/2019/3419576 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

12. Schuster AK, Elflein HM, Pokora R, Urschitz MS. Prevalence and risk factors of myopia in children and adolescents in Germany: results of the KiGGS survey. *Klin Padiatr*. 2017;229:234–40. [PubMed] [Google Scholar]

13. Moriconi-Ebrard F, Heinrigs P, Trémolières M, editors. *Africa's urbanisation dynamics 2020: Africapolis, mapping a new urban geography*. Paris: OECD, Sahel and West Africa Club Secretariat; 2020. [Google Scholar]

14. Walther O. Urbanisation and demography in North and West Africa, 1950-2020. West African Papers 2021, No. 33, OECD Publishing, Paris, 10.1787/4fa52e9c-en. [CrossRef]

15. UNESCO . Primary school enrollment - Country rankings [Internet]. 2021. [cited 2021 Oct 8]. Available from: http://data.uis.unesco.org/

16. Abdul-Rahaman N, Basit A, Rahaman A, Ming W, Ahmed A-R, Salma A-RS. The free senior high policy: an appropriate replacement to the progressive free senior high policy. *Int J Educ Literacy Stud*. 2018;6:26–33. [Google Scholar]

17. UNICEF . Children in Africa: key statistics on child survival and population [Internet]. 2019. [cited 2021 Oct 8]. Available from: https://data.unicef.org/resources/children-in-africa-child-survival-brochure/

18. Ben Kumah D, Aggrey Nyarko J, Afoakwa P, Nelson-Ayifah D, Ankamah E, Appenteng Osae E, et al. Prevalence of myopia among senior high school students in the Kumasi Metropolis. *JOJ Ophthalmol*. 2016;1:555566. 10.19080/JOJO.2016.01.555566 [CrossRef] [Google Scholar]

19. Otutu M, Nachega J, Harvey J, Meyer D. The prevalence of refractive error in three communities of Cape Town, South Africa. *African Vis Eye Heal*. 2012;71:32–8. [Google Scholar]

20. Mohamed A, Wasfi E, Kotb S, Khalek E. Refractive errors among primary schools children in Assiut District, Egypt. *J Educ Pract*. 2014;5:101–13. [Google Scholar]

21. Tang Y, Chen A, Zou M, Liu Z, Young CA, Zheng D, et al. Prevalence and time trends of refractive error in Chinese children: a systematic review and meta-analysis. *J Glob Health*. 2021;11:1–11. 10.7189/jogh.11.08006 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

22. Williams KM, Bertelsen G, Cumberland P, Wolfram C, Verhoeven VJM, Anastasopoulos E, et al. Increasing prevalence of myopia in Europe and the impact of education. *Ophthalmology*. 2015;122:1489–97. [PMC free article] [PubMed] [Google Scholar]

23. Ovenseri-Ogbomo G, Osuagwu UL, Ekpenyong BN, Agho K, Ekure E, Ndep AO, et al. Systematic review and meta-analysis of myopia prevalence in African school children. *PLoS One*. 2022;17:e0263335. 10.1371/journal.pone.0263335 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

24. Rudnicka A, Kapetanakis V, Wathern A, Logan N, Gilmartin B, Whincup P, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. *Br J Ophthalmol*. 2016;100:882–90. [PMC free article] [PubMed] [Google Scholar]

25. Hashemi H, Fotouhi A, Yekta A, Pakzad R, Ostadimoghaddam H, Khabazkhoob M. Global and regional estimates of prevalence of refractive errors: systematic review and meta-analysis. *J Curr Ophthalmol*. 2018;30:3–22. [PMC free article] [PubMed] [Google Scholar]

26. Ntodie M, Danquah L, Kandel H, Abokyi S. Toward eliminating blindness due to uncorrected refractive errors: assessment of refractive services in the northern and central regions of Ghana. *Clin Exp Optom*. 2014;97:511–5. [PubMed] [Google Scholar]

27. Loughman J, Nxele LL, Faria C, Thompson S, Ramson P, Chinanayi FS, et al. Rapid assessment of refractive error, presbyopia, and visual impairment and associated quality of life in Nampula, Mozambique. *J Vis Impair Blind*. 2015;109:199–212. [Google Scholar]

28. Chan VF, Mebrahtu G, Ramson P, Wepo M, Naidoo KS. Prevalence of refractive error and spectacle coverage in Zoba Ma'ekel Eritrea: a rapid assessment of refractive error. *Ophthalmic Epidemiol*. 2013;20:131–7. [PubMed] [Google Scholar]

29. Nsubuga N, Ramson P, Govender P, Chan VF, Wepo M, Naidoo KS. Uncorrected refractive errors, presbyopia and spectacle coverage in Kamuli District, Uganda. *Afr Vis Eye Health*. 2016;75:1–6. 10.4102/aveh.v75i1.327 [CrossRef] [Google Scholar]

30. Rudnicka AR, Owen CG. An introduction to systematic reviews and meta-analyses in health care. *Ophthalmic Physiol Opt*. 2012;32:174–83. [PubMed] [Google Scholar]

31. Leone J, Mitchell P, Morgan I, Kifley A, Rose KA. Use of visual acuity to screen for significant refractive errors in adolescents: is it reliable? *Arch Ophthalmol*. 2010;128:94–9. [PubMed] [Google Scholar]

32. Munn Z, MClinSc SM, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data. *Int J Evid Based Healthc*. 2015;13:147–53. [PubMed] [Google Scholar]

33. Wallace BC, Dahabreh IJ, Trikalinos TA, Lau J, Trow P, Schmid CH. Closing the gap between methodologists and end-users: R as a computational back-end. *J Stat Softw*. 2012;49:1–15. [Google Scholar]

34. Miller JJ. The inverse of the Freeman-Tukey double arcsine transformation. *Am Stat*. 1978;32:138–8. [Google Scholar]

35. Higgins JPT, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses testing for heterogeneity. *Br Med J*. 2003;327:557–60. [PMC free article] [PubMed] [Google Scholar]

36. Higgins JPT. Commentary: heterogeneity in meta-analysis should be expected and appropriately quantified. *Int J Epidemiol*. 2008;37:1158–60. [PubMed] [Google Scholar]

37. Priscilla JJ, Verkicharla PK. Time trends on the prevalence of myopia in India – a prediction model for 2050. *Ophthalmic Physiol Opt*. 2021;41:466–74. [PubMed] [Google Scholar]

38. Abdul-Kabir M, Bortey D, Onoikhua E, Asare-Bediako B, Kumah D. Ametropia among school children-a cross-sectional study in a sub-urban municipality in Ghana. *Pediatr Dimens*. 2016;1:65–8. [Google Scholar]

39. Nartey E, van Staden D, Amedo A. Prevalence of ocular anomalies among schoolchildren in Ashaiman, Ghana. *Optom Vis Sci*. 2016;93:607–11. [PubMed] [Google Scholar]

40. Ovenseri-Ogbomo G, Omuemu V. Prevalence of refractive error among school children in the Cape Coast municipality, Ghana. *Clin Optom*. 2010;2:59–66. [Google Scholar]

41. Nakua E, Otupiri E, Owusu-Dabo E, Dzomeku V, Otu-Danquah K, Anderson M. Prevalence of refractive errors among junior high school students in the Ejisu Juaben municipality of Ghana. *J Sci Technol*. 2015;35:52–62. [Google Scholar]

42. Kumah B, Ebri A, Abdul-Kabir M, Ahmed A, Koomson N, Aikins S, et al. Refractive error and visual impairment in private school children in Ghana. *Optom Vis Sci*. 2013;90:1456–61. [PubMed] [Google Scholar]

43. Ovenseri-Ogbomo G, Assien R. Refractive error in school children in Agona Swedru, Ghana. *Afr Vis Eye Health*. 2010;69:86–92. [Google Scholar]

44. Asare FA, Morjaria P. Prevalence and distribution of uncorrected refractive error among school children in the Bongo District of Ghana. *Cogent Med*. 2021;8:1911414. 10.1080/2331205X.2021.1911414 [CrossRef] [Google Scholar]

45. Gessesse S, Teshome A. Prevalence of myopia among secondary school students in Welkite town: South-Western Ethiopia. *BMC Ophthalmol*. 2020;20:176. 10.1186/s12886-020-01457-2 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

46. Kedir J, Girma A. Prevalence of refractive error and visual impairment among rural school-age children of Goro District, Gurage zone, Ethiopia. *Ethiop J Health Sci*. 2014;24:353–8. [PMC free article] [PubMed] [Google Scholar]

47. Yared A, Belaynew W, Destaye S, Ayanaw T, Zelalem E. Prevalence of refractive errors among school children in Gondar town, Northwest Ethiopia. *Middle East Afr J Ophthalmol*. 2012;19:372–6. [PMC free article] [PubMed] [Google Scholar]

48. Mehari Z, Yimer A. Prevalence of refractive errors among schoolchildren in rural Central Ethiopia. *Clin Exp Optom*. 2013;96:65–9. [PubMed] [Google Scholar]

49. Kassa T, Alene G. Prevalence of refractive errors in pre-school and school children of debark and Kola Diba towns, North-Western Ethiopia. *Ethiop J Health Dev*. 2003;17:117–24. [Google Scholar]

50. Assem AS, Tegegne MM, Fekadu SA. Prevalence and associated factors of myopia among school children in Bahir Dar city, Northwest Ethiopia, 2019. *PLoS One*. 2021;16:e0248936. 10.1371/journal.pone.0248936 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

51. Atowa UC, Munsamy AJ, Wajuihian SO. Prevalence and risk factors for myopia among school children in Aba, Nigeria. *Afr Vis Eye Health*. 2017;76:a369. 10.4102/aveh.v76i1.369 [CrossRef] [Google Scholar]

52. Ogbonna GO. Prevalence of refractive error among early primary school age children in Ado-Odo Ota local government area, Nigeria. *Res Sq*. 2020. 10.21203/rs.3.rs-24652/v1 [CrossRef] [Google Scholar]

53. Ezegwui I, Oguego N, Okoye O, Maduka-Okafor F, Udeh N, Aghaji A, et al. Prevalence of refractive errors and visual impairment in school children in Enugu South-East Nigeria. *Niger J Clin Pract*. 2021;24:380–6. [PubMed] [Google Scholar]

54. Ebri AE, Govender P, Naidoo KS. Prevalence of vision impairment and refractive error in school learners in Calabar, Nigeria. *Afr Vis Eye Health*. 2019;78:a487. 10.4102/aveh.v78i1.487 [CrossRef] [Google Scholar]

55. Ezinne N, Mashige K. Refractive error and visual impairment in primary school children in Onitsha, Anambra state, Nigeria. *Afr Vis Eye Health*. 2018;77:1–8. 10.4102/aveh.v77i1.455 [CrossRef] [Google Scholar]

56. Mabaso R, Oduntan A, Mpolokeng M. Refractive status of primary school children in Mopani district, Limpopo Province, South Africa. *Afr Vis Eye Health*. 2006;65:125–33. [Google Scholar]

57. Naidoo K, Raghunandan A, Mashige K, Govender P, Holden B, Pokharel G, et al. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci*. 2003;44:3764–70. [PubMed] [Google Scholar]

58. Wajuihian S, Hansraj R. Refractive error in a sample of black high school children in South Africa. *Optom Vis Sci*. 2017;94:1145–52. [PubMed] [Google Scholar]

59. Magakwe T, Xulu-Kasaba Z, Hansraj R. Visual impairment and refractive error amongst school-going children aged 6–18 years in Sekhukhune District (Limpopo, South Africa). *Afr Vis Eye Health*. 2020;79:a551. 10.4102/aveh.v79i1.551 [CrossRef] [Google Scholar]

60. Yamamah G, Talaat Abdel Alim A, Mostafa Y, Ahmed R, Mahmoud A. Prevalence of visual impairment and refractive errors in children of South Sinai, Egypt. *Ophthalmic Epidemiol*. 2015;22:246–52. [PubMed] [Google Scholar]

61. Arafa AEED, Ewis AAE, Mahran WM, Mohamed AAE, El-Shabrawy EM. Prevalence and risk factors of refractive errors among preparatory school students in Beni-Suef. *Egypt. J Public Health (Bangkok).* 2019;27:43–7. [Google Scholar]

62. Ragot A, Baraza M, Clarke-Farr P. Prevalence of myopia and its socio-demographic distribution amongst secondary school going adolescents in Lurambi Sub-County, Kakamega, Kenya. *Ophthalmol J*. 2020;5:64–70. [Google Scholar]

63. Muma M, Kimani K, Kariuki-Wanyoike M, Ilako D, Njuguna M. Prevalence of refractive errors among primary school pupils in Kilungu division of Makueni District, Kenya. *Med J Zambia*. 2009;36:157–64. [Google Scholar]

64. Anera R, Jiménez J, Soler M, Pérez M, Jiménez R, Cardona J. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol*. 2006;50:483–4. [PubMed] [Google Scholar]

65. Jiménez R, Soler M, Anera R, Castro J, Pérez M, Salas C. Ametropias in school-age children in Fada N′ Gourma (Burkina Faso, Africa). *Optom Vis Sci*. 2012;89:33–7. [PubMed] [Google Scholar]

66. Rushood A, Azmat S, Shariq M, Khamis A, Lakho K, Jadoon M, et al. Ocular disorders among schoolchildren in Khartoum State, Sudan. *East Mediterr Health J*. 2013;19:282–8. [PubMed] [Google Scholar]

67. Alrasheed SH, Naidoo KS, Clarke-Farr PC. Prevalence of visual impairment and refractive error in school-aged children in South Darfur State of Sudan. *Afr Vis Eye Health*. 2016;75:a355. 10.4102/aveh.v75i1.355 [CrossRef] [Google Scholar]

68. Semanyenzi S, Karimurio J, Nzayirambaho M. Prevalence and pattern of refractive errors in high schools of Nyarugenge district. *Rwanda Med J*. 2015;72:8–13. [Google Scholar]

69. Chebil A, Jedidi L, Chaker N, Kort F, Largueche L, El Matri L. Epidemiologic study of myopia in a population of schoolchildren in Tunisia. *La Tunisie Medicale*. 2016;94:216–20. [PubMed] [Google Scholar]

70. Elmajri K. A survey of the prevalence of refractive errors among children in lower primary schools in Darnah city, Libya. *Adv Ophthalmol Vis Syst*. 2017;7:378–83. [Google Scholar]

71. Ahmed Z, Alrasheed S, Alghamdi W. Prevalence of refractive error and visual impairment among school-age children of Hargesia, Somaliland, Somalia. *East Mediterr Health J*. 2020;26:1362–70. [PubMed] [Google Scholar]

72. Wedner SH, Ross DA, Todd J, Anemona A, Balira R. Myopia in secondary school students in Mwanza City, Tanzania: the need for a national screening programme. *Br J Ophthalmol*. 2002;86:1200–6. [PMC free article] [PubMed] [Google Scholar]

73. Nonon Saa K, Atobian K, Banla M. Refractive errors among schoolchildren in the central region of Togo. *J Fr Ophtalmol*. 2013;36:769–74. [PubMed] [Google Scholar]

74. Soler M, Anera R, Castro J, Jiménez R, Jiménez J. Prevalence of refractive errors in children in Equatorial Guinea. *Optom Vis Sci*. 2015;92:53–8. [PubMed] [Google Scholar]

75. Anera R, Soler M, De La Cruz CJ, Salas C, Ortiz C. Prevalence of refractive errors in school-age children in Morocco. *Clin Exp Ophthalmol*. 2009;37:191–6. [PubMed] [Google Scholar]

76. Kawuma M, Mayeku R. A survey of the prevalence of refractive errors among children in lower primary schools in Kampala district. *Afr Health Sci*. 2002;2:69–72. [PMC free article] [PubMed] [Google Scholar]

77. Msiska V, Njuguna M, Kariuki M. Magnitude and pattern of significant refractive errors in primary school children of Ntcheu, a rural district in Malawi. *East Afr J Ophthalmol*. 2009;15:18–20. [Google Scholar]

78. Sounouvou I, Tchabi S, Doutetien C, Sonon F, Yehouessi L, Bassabi S. A study of refractive errors in a primary school in Cotonou, Benin. *J Fr Ophtalmol*. 2008;31:771–5. [PubMed] [Google Scholar]

79. Hunter JP, Saratzis A, Sutton AJ, Boucher RH, Sayers RD, Bown MJ. In meta-analyses of proportion studies, funnel plots were found to be an inaccurate method of assessing publication bias. *J Clin Epidemiol*. 2014;67:897–903. [PubMed] [Google Scholar]

80. Hsu C, Huang N, Lin P, Tsai D, Tsai C, Woung L, et al. Prevalence and risk factors for myopia in second-grade primary school children in Taipei: a population-based study. *J Chin Med Assoc*. 2016;79:625–32. [PubMed] [Google Scholar]

81. Wang J, Ying G, Fu X, Zhang R, Meng J, Gu F, et al. Prevalence of myopia and vision impairment in school students in Eastern China. *BMC Ophthalmol*. 2020;20:1–10. 10.1186/s12886-019-1281-0 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

82. Hagen L, Gjelle J, Arnegard S, Pedersen H, Gilson S, Baraas R. Prevalence and possible factors of myopia in Norwegian adolescents. *Sci Rep*. 2018;8:1–10. 10.1038/s41598-018-31790-y [PMC free article] [PubMed] [CrossRef] [Google Scholar]

83. Schuster A, Krause L, Kuchenbäcker C, Prütz F, Elflein H, Pfeiffer N, et al. Prevalence and time trends in myopia among children and adolescents: results of the German KiGGS study. *Dtsch Ärztebl Int*. 2020;117:855–60. [PMC free article] [PubMed] [Google Scholar]

84. Harrington SC, Stack J, Saunders K, O'Dwyer V. Refractive error and visual impairment in Ireland schoolchildren. *Br J Ophthalmol*. 2019;103:1112–8. [PMC free article] [PubMed] [Google Scholar]

85. O'Donoghue L, McClelland JF, Logan NS, Rudnicka AR, Owen CG, Saunders KJ. Refractive error and visual impairment in school children in Northern Ireland. *Br J Ophthalmol*. 2010;94:1155–9. [PubMed] [Google Scholar]

86. French A, Morgan I, Burlutsky G, Mitchell P, Rose K. Prevalence and 5-to 6-year incidence and progression of myopia and hyperopia in Australian schoolchildren. *Ophthalmology*. 2013;120:1482–91. [PubMed] [Google Scholar]

87. Dong L, Kang Y, Li Y, Wei W, Jonas J. Prevalence and time trends of myopia in children and adolescents in China: a systemic review and meta-analysis. *Retina*. 2020;40:399–411. [PubMed] [Google Scholar]

88. United Nations Development Programme . Human development report [Internet]. 2020. [cited 2021 Oct 8]. Available from: https://hdr.undp.org/content/human-development-report-2020

89. Ramamurthy D, Lin Chua SY, Saw S-M. A review of environmental risk factors for myopia during early life, childhood and adolescence. *Clin Exp Optom*. 2015;98:497–506. [PubMed] [Google Scholar]

90. Rose KA, French AN, Morgan IG. Environmental factors and myopia. *Asia Pacific J Ophthalmol*. 2016;5:403–10. [PubMed] [Google Scholar]

91. Wenbo L, Congxia B, Hui L. Genetic and environmental-genetic interaction rules for the myopia based on a family exposed to risk from a myopic environment. *Gene*. 2017;626:305–8. [PubMed] [Google Scholar]

92. Güneralp B, Lwasa S, Masundire H, Parnell S, Seto KC. Urbanization in Africa: challenges and opportunities for conservation. *Environ Res Lett*. 2018;30:015002. 10.1088/1748-9326/aa94fe [CrossRef] [Google Scholar]

93. Nkrumah RB, Sinha V. Revisiting global development frameworks and research on universal basic education in Ghana and sub-Saharan Africa: a review of evidence and gaps for future research. *Rev Educ*. 2020;8:733–64. [Google Scholar]

94. Deloitte . Sub-Saharan Africa Mobile Observatory 2012 [Internet]. [cited 2021 Dec 29]. Available from: https://www.gsma.com/publicpolicy/wp-content/uploads/2013/01/gsma_ssamo_full_web_11_12-1.pdf

95. Foreman J, Salim AT, Praveen A, Fonseka D, Ting DSW, Guang He M, et al. Association between digital smart device use and myopia: a systematic review and meta-analysis. *Lancet Digit Health*. 2021;3:e806–18. [PubMed] [Google Scholar]

96. Loughman J, Flitcroft DI. Are digital devices a new risk factor for myopia? *Lancet Digit Health*. 2021;3:e756–7. [PubMed] [Google Scholar]

97. McCrann S, Loughman J, Butler J, Paudel N, Flitcroft D. Smartphone use as a possible risk factor for myopia. *Clin Exp Optom*. 2021;104:35–45. [PubMed] [Google Scholar]

98. Obeng-Odoom F. Africa: on the rise, but to where? *Forum Soc Econ*. 2015;44:234–50. [Google Scholar]

99. Annez P, Buckley R, Kalarickal J. African urbanization as flight? Some policy implications of geography. *Urban Forum*. 2010;21:221–34. [Google Scholar]

100. Ip JM, Rose KA, Morgan IG, Burlutsky G, Mitchell P. Myopia and the urban environment: findings in a sample of 12-year-old Australian school children. *Invest Ophthalmol Vis Sci*. 2008;49:3858–63. [PubMed] [Google Scholar]

101. Zhang M, Li L, Chen L, Lee J, Wu J, Yang A, et al. Population density and refractive error among Chinese children. *Invest Ophthalmol Vis Sci*. 2010;51:4969–76. [PubMed] [Google Scholar]

102. De Kock R, Futcher LA. Mobile device usage in higher education institutions in South Africa. In: *2016 Information Security for South Africa (ISSA)*. Johannesburg, South Africa: IEEE; 2016. p. 27–34. 10.1109/ISSA.2016.7802925 [CrossRef] [Google Scholar]

103. Zhang X, Cheung SSL, Chan HN, Zhang Y, Wang YM, Yip BH, et al. Myopia incidence and lifestyle changes among school children during the COVID-19 pandemic: a population-based prospective study. *Br J Ophthalmol*. 2021:1–7. 10.1136/bjophthalmol-2021-319307 [PubMed] [CrossRef] [Google Scholar]

104. Chen H, Liao Y, Zhou W, Dong L, Wang W, WangID X. The change of myopic prevalence in children and adolescents before and after COVID-19 pandemic in Suqian, China. *PLoS One*. 2022;17:e0262166. 10.1371/journal.pone.0262166 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

105. Ceesay EK. Potential impact of COVID-19 outbreak on education, staff development and training in Africa. *Res Glob*. 2021;3:100049. 10.1016/j.resglo.2021.100049 [CrossRef] [Google Scholar]

106. Resnikoff S, Pascolini D, Mariotti S, Pokharel G. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. *Bull World Health Organ*. 2008;86:63–70. [PMC free article] [PubMed] [Google Scholar]

107. Kandel H, Khadka J, Goggin M, Pesudovs K. Impact of refractive error on quality of life: a qualitative study. *Clin Exp Ophthalmol*. 2017;45:677–88. [PubMed] [Google Scholar]

108. Li H, Liu Y, Dong L, Zhang R, Zhou W, Wu H, et al. Global, regional, and national prevalence, disability adjusted life years, and time trends for refraction disorders, 1990–2019: findings from the global burden of disease study 2019. *BMC Public Health*. 2021;21:1–2. 10.1186/s12889-021-11648-1 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

109. Nti A, Owusu-Afriyie B, Osuagwu U, Ovenseri-Ogbomo G, Ogbuehi K, Ouzzani M, et al. Trends in myopia management attitudes and strategies in clinical practice: survey of eye care practitioners in Africa. *Cont Lens Anterior Eye*. 2022;101597. 10.1016/j.clae.2022.101597 [PubMed] [CrossRef] [Google Scholar]

110. Courtright P, Mathenge W, Kello AB, Cook C, Kalua K, Lewallen S. Setting targets for human resources for eye health in sub-Saharan Africa: what evidence should be used? *Hum Resour Health*. 2016;14:1–8. 10.1186/s12960-016-0107-x [PMC free article] [PubMed] [CrossRef] [Google Scholar]

111. UNESCO . New methodology shows that 258 million children, adolescents and youth are out of school [Internet]; 2019. [cited 2021 Oct 8]. Available from: http://uis.unesco.org/sites/default/files/documents/newmethodology-shows-258-million-children-adolescents-and-youth-are-out-school.pdf

112. Morgan IG, Iribarren R, Fotouhi A, Grzybowski A. Cycloplegic refraction is the gold standard for epidemiological studies. *Acta Ophthalmol*. 2015;93:581–5. [PubMed] [Google Scholar]

113. Farhood Q. Cycloplegic refraction in children with cyclopentolate versus atropine. *J Clin Exp Ophthalmol*. 2012;3:1–6. 10.4172/2155-9570.1000239 [CrossRef] [Google Scholar]

114. Choong Y, Chen A, Goh P. A comparison of autorefraction and subjective refraction with and without cycloplegia in primary school children. *Am J Ophthalmol*. 2006;142:68–74. [PubMed] [Google Scholar]

115. Fotouhi A, Morgan IG, Iribarren R, Khabazkhoob M, Hashemi H. Validity of noncycloplegic refraction in the assessment of refractive errors: the Tehran eye study. *Acta Ophthalmol*. 2012;90:380–6. [PubMed] [Google Scholar]

116. Grzybowski A, Kanclerz P, Tsubota K, Lanca C, Saw SM. A review on the epidemiology of myopia in school children worldwide. *BMC Ophthalmol*. 2020;20:27. 10.1186/s12886-019-1220-0 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

117. Flitcroft DI, He M, Jonas JB, Jong M, Naidoo K, Ohno-Matsui K, et al. IMI – defining and classifying myopia: a proposed set of standards for clinical and epidemiologic studies. *Invest Ophthalmol Vis Sci*. 2019;60:M20–30. [PMC free article] [PubMed] [Google Scholar]

PLOS ONE

PLoS One. 2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335

PMCID: PMC8812871
PMID: 35113922

Systematic review and meta-analysis of myopia prevalence in African school children

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Aleksandra Barac, Editor

Abstract

Purpose

Increased prevalence of myopia is a major public health challenge worldwide, including in Africa. While previous studies have shown an increasing prevalence in Africa, there is no collective review of evidence on the magnitude of myopia in African school children. Hence, this study reviews the evidence and provides a meta-analysis of the prevalence of myopia in African school children.

Methods

This review was conducted using the 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Five computerized bibliographic databases, PUBMED, Scopus, Web of Science, ProQuest, and Africa Index Medicus were searched for published studies on the prevalence of myopia in Africa from 1 January 2000 to 18 August 2021. Studies were assessed for methodological quality. Data were gathered by gender, age and refraction technique and standardized to the definition of myopia as refractive error ≥ 0.50 diopter. A meta-analysis was

conducted to estimate the prevalence. Significant heterogeneity was detected among the various studies (I^2 >50%), hence a random effect model was used, and sensitivity analysis was performed to examine the effects of outliers.

Results

We included data from 24 quality assessed studies, covering 36,395 African children. The overall crude prevalence of myopia over the last two decades is 4.7% (95% CI, 3.9–5.7) in African children. Although the prevalence of myopia was slightly higher in females (5.3%, 95%CI: 4.1, 6.5) than in males (3.7%, 95% CI, 2.6–4.7; p = 0.297) and higher in older [12–18 years 5.1% (95% CI, 3.8–6.3) than younger children (aged 5–11 years, 3.4%, 95% CI, 2.5–4.4; p = 0.091), the differences were not significant. There was a significantly lower prevalence of myopia with cycloplegic compared with non-cycloplegic refraction [4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; p = 0.046].

Conclusions

Our results showed that myopia affects about one in twenty African schoolchildren, and it is overestimated in non-cycloplegic refraction. Clinical interventions to reduce the prevalence of myopia in the region should target females, and school children who are aged 12–18 years.

Introduction

Uncorrected refractive error is the most common cause of visual impairment affecting an estimated one billion people globally [1]. Myopia is the most common refractive error and an important cause of ocular morbidity, particularly among school-aged children and young adults. Worldwide, myopia is reaching epidemic proportions linked to changing lifestyles and modern technology, particularly mobile devices [2]. Globally, myopia affected 22.9% of the world's population in 2000, with projections of an increase to 49.8% by 2050 affecting 4.8 billion people [2], representing a 117% increase over 50 years. According to a 2015 report, it was estimated that globally, about 1.89 billion people are myopic and 170 million have high myopia [3].

The reported prevalence of myopia in children aged 5–17 years ranges from 1.2% in Mechi Zone, Nepal, to 73.0% in South Korea [4, 5]. Over 15 years, the prevalence of myopia increased from 79.5% to 87.7% in Chinese high school children with an average age of 18.5 ± 0.7 years [6]. In South African school children aged 5–15 years, the reported prevalence of myopia was only 2.9% with retinoscopy and 4.0% using autorefraction [7]. The authors reported that this prevalence increased to 9.6% at age 15 years.

The increase in myopia prevalence will have a significant economic impact because of associated ocular health problems and visual impairment. Uncorrected myopia of between– 1.50 D and– 4.00 D can significantly affect vision to be regarded as a cause of moderate visual impairment and blindness, respectively [8]. Apart from its direct impact on visual impairment, high myopia [usually defined as a spherical equivalent ≥ 5.00D [4, 9, 10] of myopia, although the definitions used to grade myopia are variable] increases the risk of potentially blinding ocular pathologies such as retinal holes; retinal tears; retinal degeneration; retinal detachment; and myopic macular degeneration [3, 11]. Uncorrected myopia has huge social, economic, psychological and developmental implications [12]. The economic cost of refractive errors, including myopia, has been estimated to be approximately US$ 202 billion per annum [13], far exceeding that of other eye diseases.

The increasing prevalence of myopia has led to research in the study of the possible mechanism for myopia development, which has generated two broad themes: the role of nature (genetic influences) and nurture (environmental influences including lifestyle). Understanding the mechanism for the development of myopia is also being explored in the control of myopia. Epidemiologic data from Southeast Asia has given credence to the association between near work and myopia, given the number of hours children from this region spend doing near work. Due to vast regional differences in culture, habits, socioeconomic status, educational levels and urbanization, there is uncertainty as to the exact magnitude of the myopia burden among African school–aged children and its trend over time [14].

In the last few decades, there has been a change in the lifestyle and behavior of people in Africa as a result of increasing urbanization [15]. Africa's urban population grew from 27 million in 1950 to 567 million in 2015 (a 2,000% increase), and now 50% of Africa's population live in one of the continent's 7,617 urban agglomerations of 10,000 or more inhabitants [16]. Consequently, more children and young adults in Africa are increasingly engaged in indoor and near work activities compared to earlier generations [17]. Children spend long hours doing schoolwork and, following the advent of technology, increasingly use mobile devices for gaming and other activities [18, 19]. These factors are thought to promote myopia development and/or progression [20–23].

Africa is the world's second largest and second most populous continent, after Asia, and it accounts for about 16% of the world's human population. While every global region will experience a decline in population by 2100, the African population is expected to triple. Africa's population is the youngest amongst all the continents, the median age in 2012 was 19.7 years compared to the global median of 30.4 years. This young population is an important asset for the continent's development. The challenges of the young population must be addressed in time as they constitute the bulk of the productive age of the economy. While rising myopia is a cause for global concern, it is not given due attention in Africa due to a lack of adequate prevalence data and prospective studies tracking the trend of myopia over decades [24]. Due to this, the representation of Africa is poor in studies predicting global trends of myopia [24]. The aim of this study was to systematically review the evidence and provide a meta–analysis of the prevalence of myopia in African school children which will address the knowledge gap and help understand the prevalence of myopia among this group in Africa.

Materials and methods

This systematic review followed the framework of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA. See Checklist in S1 File) [25]. The protocol for the review was registered with PROSPERO (#CRD42020187609).

Search strategy and quality assessment

Two review team members (GO and BE) performed an independent systematic search and review of myopia in Africa using published data spanning the last two decades. Refractive error came into reckoning as a cause of visual impairment in the last two decades, following the change in the definition of visual impairment which was based on presenting visual acuity [26]. The search was conducted on 25th May and 18th August 2021. A third reviewer, KO, adjudicated where there were disagreements. The quality of each selected article was assessed using the checklist developed by Downs and Black [27] and each included article was assessed and scored on a 10-item scale (scoring is shown in S1 Table). The search was restricted to articles available online, articles

mentioning prevalence of myopia in any region of Africa, and articles published in the English language. Searches included the following databases: Web of sciences, PubMed, ProQuest, MEDLINE, Scopus, and African Index Medicus from 1st of January 2000 to August 18, 2021.

We searched these databases using the following MeSH (Medical Subject Heading) terms and keywords: Refractive AND error AND Africa AND children AND prevalence. A number of iterations of these search terms were used, for example, "refractive error AND Africa AND children AND prevalence" or "refractive error AND Africa AND children". Further details about search strategy and MeSH terms are available in the (S2 File). A broader search also used terms such as epidemiology, myopia, and school children. We also identified and included relevant studies by manually searching through the reference lists of identified papers. The PRISMA flowchart presented in Fig 1 shows the process used for selecting articles.

Fig 1

Flow chart of process of selecting articles for the review.

Inclusion and exclusion criteria

Studies published between 2000 and 2021, investigating the prevalence of refractive error in male and female school children aged 5 to 18 years of age were included in the review. Studies that employed an observational cross-sectional study design; had a clear description of the sampling technique; stated the method of measuring refractive error (cycloplegic or non-cycloplegic refraction), as well as objective or subjective refraction; stated the criteria for defining myopia (spherical equivalent ≥ 0.50 D of myopia [2, 28–30]; the study was either school–based or population–based; and were published in English language, were included in the review. The decision as to whether the articles met the inclusion criteria was made independently by the two reviewers (GO and BE) and where there was a disagreement, a third reviewer (KO) was consulted.

Studies where the criteria for defining myopia were not specified; the ages of the participants were either not specified or outside the age range specified for this review; or which reported findings from a hospital/clinic-based sample were excluded from the review.

Data extraction

The data extracted from each article included the following: Authors; year of publication; country of study; study design; sample size; sampling technique; the age of study participants; criteria for defining myopia; method of refractive error assessment (cycloplegic vs non-cycloplegic); method of refractive error assessment (objective vs subjective); prevalence of myopia; and the proportion of refractive error due to myopia. Where the reported prevalence was not clearly defined, the corresponding author in the published article was contacted for clarification.

Statistical methods

Meta–analysis was conducted using Stata version 14.0 (StataCorp, College Station, TX, USA). The syntax "metaprop" in Stata was used to generate forest plots and each forest plot showed the prevalence of myopia in school children, by gender, age and refraction technique in individual studies and its corresponding weight, as well as the pooled prevalence in each subset and its associated 95% confidence intervals (CI). A heterogeneity test obtained for the different studies showed a high level of inconsistency ($I^2 > 50\%$) thereby indicating the use of a random effect model in all the meta–analyses conducted. Sensitivity analysis was carried out by examining the effect of outliers, by employing similar method to that used by Patsopoulos et al. [31], which involves the process of comparing the pooled prevalence before and after eliminating one study at a time. The funnel plot was used to report the potential bias and small/large study effects and Begg's tests was used to assess asymmetry. The prevalence was subdivided into separate datasets based on overall prevalence, males or females, cycloplegic or non-cycloplegic refraction for a more detailed analysis of the prevalence of myopia. Also, to study a possible variation of the prevalence of myopia in terms of age, the age groups in the reported studies were divided into two categories: 5–11 years and 12–18 years. Their respective funnel plots are shown as (S3–S7 Files).

Results

Summary of included studies

From the described search strategy, a total of 164 potentially relevant titles/abstracts of articles were initially identified. Fig 1 presents the flowchart of the article screening and selection process. Following a quick inspection of identified studies and removal of duplicate articles, 44 relevant articles were assessed for eligibility. Using the pre–defined inclusion and exclusion criteria, 24 of 30 articles that underwent detailed review were eligible, and data from these studies were included in this study. A breakdown of the eligible studies as well as their quality assessment scores (maximum of 10) are presented in Table 1. S1 Table shows how the quality assessment scores were calculated.

Table 1

Characteristics of studies that reported the prevalence of myopia in school–aged children in Africa and were included in the meta–analysis.

First Author	Year of study	Study Country†	Age group (years)	Mean age (years)	Total Sample size	Cycloplegia	Objective refraction	Prevalence of myopia (%)	Comm refrac error
Atowa [32]	2017	Nigeria	8–15	11.5 ± 2.3	1197	Yes	Objective	2.7	
Wajuihian [33]	2017	South Africa	13–18	15.8 ± 1.6	1586	No	Objective	7	
Chebil [34]	2016	Tunisia	6–14	10.1 ± 1.8	6192	Yes	Objective	3.71	
Kedir [35]	2014	Ethiopia	7–15	Not reported	570	No	Subjective	2.6	
Soler [36]	2015	Equatorial Guinea	6–16	10.8 ± 3.1	425	Yes	Objective	10.4	
Kumah [37]	2013	Ghana	12–15	13.8	2435	Yes	Objective	3.2	
Mehari [38]	2013	Ethiopia	7–18	13.1 ± 2.5	4238	No	Objective	6	
Jimenez [39]	2012	Burkina Faso	6–16	11.2 ± 2.4	315	No	Objective	2.5	
Naidoo [7]	2003	South Africa	5–15	Not reported	4890	Yes	Objective	2.9	
Yamamah [40]	2015	Egypt	6–17	10.7 ± 3.1	2070	Yes	Objective	3.1	Astigm
Nartey [41]	2016	Ghana	6–16	10.6	811	No	Subjective	4.6	
Anera [42]	2006	Burkina Faso	5–16	10.2 ± 2.2	388	Yes	Objective	0.5	
Chukwuemeka [43]	2015	South Africa	7–14	9.9 ± 2.2	421	No	Objective	18.7	Astigm
Alrasheed [44]	2016	Sudan	6–15	10.8 ± 2.8	1678	Yes	Objective	6.8	Myopi
Abdul-Kabir [45]	2016	Ghana	10–15	Not reported	208	No	Objective	22.6	Myopi
Ebri [46]	2019	Nigeria	10–18	13.3 ± 1.9	4241	Yes	Objective	4.8	Astigm
Ezinne [47]	2018	Nigeria	5–15	9.0 ± 2.5	998	Yes	Objective	4.5	Myopi

† = country the study was conducted;

ǂ = authors provided data for only those aged 5–18 years.

The included studies comprised of the following: six (25.0%) studies from Ghana, four (16.7%) each from South Africa, and Nigeria, three from Ethiopia (12.5%), two (8.3%) from Burkina Faso, and one (4.2%) each from Sudan, Egypt, Equatorial Guinea, Somalia and Tunisia (Table 1). Of the reviewed articles, 84.2% (n = 21) were school–based, cross–sectional studies, two (8.3%) were population–based, cross–sectional studies, while one (4.2%) employed a cross–sectional study design but did not report whether it was school or population–based.

Method of measuring refractive error in African school–aged children

Of the reviewed studies, 13 (54.2%) performed cycloplegic refraction to determine the refractive error status of the children, while non-cycloplegic refraction was used in 11 (45.8%) of the studies. Regarding the technique used for refractive error measurement, over three–quarters of the studies (n = 20, 83.3%) performed objective refraction, with about one–sixth (n = 4, 16.7%) performing subjective refraction.

Prevalence of myopia in African school–aged children

The number of children aged 5–18 years included in the study ranged from 208 for a study conducted in Ghana [45] to 6192 for another study conducted in Tunisia [34, 55]. The prevalence of myopia reported in these studies ranged from 0.5% [42] to 10.4% [36, 52] with cycloplegic refraction. In studies where non–cycloplegic refraction was used to determine refractive error refraction in school children, the reported myopia prevalence ranged from 1.7% [51] to 22.6% [45].

Meta-analysis of myopia prevalence in children ag 5–18 years in Africa (2000–2021)

Myopia prevalence among school children in Africa

Fig 2 shows a forest plot of the prevalence of myopia among African school children aged 5–18 years. The pooled estimate of myopia in the African region was significant (5.0%, 95%CI: 4.1, 5.8; p<0.001) and about 37.5% of the studies (n = 9) reported significantly higher prevalence of myopia and 50% (n = 12) reporting significantly lower prevalence compared with the pooled estimate across Africa. The study by Abdul–Kabir found the highest prevalence (22.6%) of myopia among Ghanaian children (95%CI: 17.1, 28.9) [45], while Anera et al. found the lowest prevalence among children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9) [42]. The pooled prevalence estimates of myopia was similar to the study by Ebri [46] and Ezinne [47] (4.8%, 95%CI:4.2, 5.5), both involving children from Nigeria [46, 47]. Funnel plots and using Begg's test for Myopia in Africa indicated homogeneity (S3 File) and meta–regression analysis of myopia by year of publication indicated that publication of year increased as the proportion of myopia decreased but this relationship was not statistically significant (p = 0.423, S7 File).

Fig 2

Forest plot of myopia prevalence from the meta–analysis of African studies.

Myopia prevalence by gender of the School children in Africa (2000–2021)

Fig 3 is a forest plot for prevalence of myopia by gender among school children aged 5–18 years in Africa. The prevalence estimates varied significantly between studies in both male and female children ($p<0.001$, per gender), and the overall pooled prevalence of myopia by gender was 4.8% (95%CI: 4.1, 5.6) and similar between male and female estimates ($p = 0.297$). Compared with the overall pooled estimate, the prevalence of myopia was slightly higher in male (4.5%, 95%CI: 3.4, 5.5) children than females (5.3%, 95%CI: 4.1, 6.5) but the difference was not significant as indicted by the overlapping of the CIs with that of the overall pooled estimate. Funnel plots and using Begg's test for Myopia by gender reported absence of publication biases (S4 File).

Fig 3

Forest plot of myopia prevalence by gender from the meta-analysis of African studies.

Myopia prevalence by age group of the school children in Africa (2000–2021)

The forest plot of the prevalence of myopia in children aged 5–11 years and 12–18 years is presented in Fig 4. The pooled estimate of myopia in school children aged 5–11 years and 12–18 years was lower (3.7%, 95%CI 2.6, 4.7) and higher (5.8%, 95%CI 3.8, 6.3) respectively, than the pooled estimate but none was significant as they overlapped with the pooled estimate in Africa (4.4%, 95%CI 3.6, 5.2). The heterogeneity between the groups was approaching significant ($p = 0.091$) but older children had a higher prevalence of myopia than younger children. Among those aged 5–11 years, the highest significant prevalence was reported in a Ghanaian study (16.4%, 95%CI: 13.0, 20.3) and a study conducted in Equatorial Guinea (8.2%, 95%CI: 5.8, 11.3) while school children in Ethiopia (0.5%, 95%CI: 0.1, 1.5) had the lowest significant prevalence estimate of myopia. Among those aged 12–18 years, children in Ghana also showed the highest significant prevalence of myopia (20.2%, 95%CI: 16.5, 24.4), but the lowest prevalence was reported among School children in Burkina Faso (0.5%, 95%CI: 0.1, 1.9). The heterogeneity of these studies by age as subgroups analysis were low (S5 File).

Fig 4

Forest plot of myopia prevalence by age group across African studies.

Myopia prevalence by mode of refraction among school children in Africa (2000–2021)

The forest plot displayed in Fig 5 shows the pooled estimate of myopia prevalence among school children in Africa. Using cycloplegic refraction, studies have reported significantly lower prevalence estimates of myopia among school children in Africa compared with those that used non–cycloplegic refraction (4.2%, 95%CI: 3.3, 5.1 versus 6.4%, 95%CI: 4.4, 8.4; $p = 0.046$). From the plot, it can be seen that studies that used non cycloplegic technique to determine refraction had greater variabilities in the reported myopia prevalence (ranging from 1.7 to 22.6%), but those that performed cycloplegic refraction had smaller between study variability in the reported prevalence of myopia (range from 0.5 to 10.4%). Funnel plots and the Begg's test for Myopia by refraction technique shown in S6 and S7 Files, respectively, found no publication biases.

Fig 5

Forest plot of myopia prevalence by refraction technique among school children in Africa.

Discussion

Prevalence of myopia

The present study provided recent estimates of the myopia prevalence in African children using data from twenty eight studies conducted over two decades. The prevalence of myopia defined as SER ≥ 0.50D of myopia in school children across African countries was 4.7% (95%CI, 3.9, 5.7%) and there were wide variations within and between African countries. A significantly higher prevalence rate was observed in Ghana [45] and South Africa [43], with significantly lower rates in Burkina Faso [42] and Ethiopa [56]. In some countries like Ghana, the variation in the reported prevalence of myopia between studies reached 21% [37, 41, 45, 48, 51, 52]. Although the regional variations in myopia prevalence found in this study are consistent with the statement of Foster and Jiang who remarked that "Considerable regional difference exists from country to country even within the same geographical area" [57], it remains unclear why these variations exist. While the criteria for defining refractive error is often cited as the reason for the variation in the prevalence of refractive errors, including myopia, between studies, this may not be the case in our study because only studies that defined myopia as spherical equivalent of ≥ 0.50 D were included.

The overall low prevalence of myopia found across Africa is consistent with other studies that reported lower myopia prevalence in African children compared with Asian children [5, 58]. It is instructive to note that in four of the studies that were included in the current review [36, 43, 45, 52], the reported prevalence of myopia was greater than 10%. Of these, two studies [36, 52] used cycloplegic refraction, which is thought to more accurately estimate the prevalence of myopia [59]. The lower prevalence of myopia in Africa compared with the other regions may be related to the differences in genetic predisposition to myopia development, and to culture [60–62]. Although the role of genetics in the development and progression of myopia is reported to be small [12], it is believed to have a role in an individual's susceptibility to environmental risk factors for myopia [63]. In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development [60, 63]. In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) [64]. We acknowledge that a recent investigation [65] has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

Notwithstanding the relatively low prevalence of myopia found among African children, there is a need to monitor myopia prevalence among children in this region given the increasing access to, and use of, mobile devices among African population [19], including children. This is important considering the reported higher increase in the prevalence of myopia in black children living in Africa (2.8% to 5.5%) compared with other black children not living in Africa (4.8% to 19.9%) after 10 years [58]. It is assumed that black children not in Africa may have more access and exposure to near work, including mobile devices, and less outdoor activities than their counterparts in Africa.

Age and gender-based differences in myopia prevalence

There was a 34.6% increase in the prevalence of myopia between the age groups with the older age group having a higher prevalence of 5.2%. The slightly higher prevalence of myopia between the two age groups shows there is a tendency for myopia prevalence to increase with age which is consistent with previous studies from elsewhere [58, 66, 67]. This increase in myopia prevalence is thought to be associated with the increasing growth of the eyeball. Although the pooled prevalence of myopia in female children was slightly higher than in male children (4.7 versus 3.7%), the difference did not reach statistical significance. The influence of gender on the prevalence of myopia has not been unequivocal in the literature [68–72] with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls [73]. Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys [74].

Prevalence of myopia by refraction technique (cycloplegic and non-cycloplegic)

The present study demonstrated that cycloplegic refraction resulted in significantly lower estimates of myopia prevalence than non-cycloplegic refraction, which was consistent with previous studies [75–78]. It has been reported that non-cycloplegic refraction overestimates the prevalence of myopia, yields a non-reliable measurement of association of myopia risk factors [59, 76], and hence cycloplegic refraction is regarded as the gold standard for measuring myopia [59]. Over half of the studies in this review utilised cycloplegic refraction, which is particularly important in this age group where the difference between the cycloplegic and non-cycloplegic refraction is quite high [77, 78]. The fact that non-cycloplegic refraction often results in overestimation of myopia may have, in part, accounted for the high prevalence reported in one study from Ghana [45]. Furthermore, we have demonstrated that cycloplegic refraction results in a lower variability of measured refractive error than non–cycloplegic refraction (see Fig 5), which may reflect the variable accommodative state during the refraction of children of different ages. This finding underscores the need to appropriately control accommodation when performing refraction especially in young children who have a higher amplitude of accommodation and in whom accommodation is more active.

Implications of the study

This is the first systematic review and meta-analysis to estimate the prevalence of myopia among school children in Africa and its variation with age, gender and refraction technique. As previously reported, the prevalence of myopia in Africa appears low compared to other regions such as South East Asia. This study also provides baseline data for comparison and future prevalence studies to establish a trend in myopia epidemiology in this population. A further remarkable finding in this review is the demonstration that non–cycloplegic refraction overestimated the prevalence of myopia and results in more variable estimates of refractive errors compared with cycloplegic refraction. The interpretation of myopia prevalence data obtained from non–cycloplegic refraction may be potentially misleading to researchers and policymakers. As a result, it is recommended that cycloplegic refraction be used in all studies investigating the prevalence of myopia in children.

Strengths and limitations of the review

This review has certain limitations. Firstly, this review did not investigate the trend in the prevalence of myopia among school children in Africa due to the limited number of studies. Secondly, the selection of English-only studies likely biased the results towards studies in Anglophone countries or countries where the findings were reported in English. Thirdly, the current review did not explore the various factors influencing the epidemiology of myopia in this population. Despite these limitations, a major strength of this study is the selection of studies that used a uniform definition of myopia (i.e. ≥ 0.50DS of myopia) which allowed for a better comparison in the reported prevalence of myopia. In addition, the study excluded studies that were conducted in unselected groups such as hospital-based studies and studies that did not report any evidence of sampling in the study. In addition, the selected studies were evaluated for robustness in the study designs employed in each study.

Conclusions

In summary, this systematic review and meta–analysis have shown that the prevalence of myopia among schoolchildren in Africa is lower than other regions of the world. The use of non–cycloplegic refraction for estimation of myopia prevalence can be misleading as it returns higher and more variable prevalence estimates. There is a need to monitor the trend of myopia as more children in this region are increasingly being exposed to identified risk factors for myopia development including access to mobile devices, increased near work, increased online or remote learning, and limited time outdoors. Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

Supporting information

S1 Table

Quality assessment of full-text articles included in review.

(DOCX)

Click here for additional data file.(23K, docx)

S1 File

PRISMA 2020 checklist.

(DOCX)

Click here for additional data file. (32K, docx)

S2 File

Search terms for refractive error Africa children prevalence filters (2000–2021).

(DOCX)

Click here for additional data file. (13K, docx)

S3 File

Funnel plots and 95% confidence intervals of Myopia.

(DOCX)

Click here for additional data file. (15K, docx)

S4 File

Funnel plots and 95% confidence intervals of Myopia by gender.

(DOCX)

Click here for additional data file. (15K, docx)

S5 File

Funnel plots and 95% confidence intervals of Myopia by age in categories.

(DOCX)

Click here for additional data file.(15K, docx)

S6 File

Funnel plots and 95% confidence intervals of Myopia by refraction technique.

(DOCX)

Click here for additional data file.(15K, docx)

S7 File

A meta-regression analysis of Myopia by year of publication.

The vertical axis is the log proportion of Myopia, and the horizontal axis represents year of publication. Each dark dot represented one selected study, and the size of each dark dots corresponds to the weight assigned to each study. Given the slope of the regression line has descending slightly in this figure, this could be interpreted as publication of year increased, the proportion of myopia decreased and, this relationship did not differ statistically (p = 0.5512).

(DOCX)

Click here for additional data file.(37K, docx)

S8 File

Data used in the analysis.

(XLSX)

Click here for additional data file.(46K, xlsx)

Acknowledgments

The authors acknowledge the guidance of late Prof Alabi, O Oduntan during data collection.

Funding Statement

The authors recieved no specific funding for this work.

Data Availability

All relevant data are within the paper and its Supporting information files.

References

1. World Health Organization. WHO launches first World report on vision [cited 2021 June 8]. https://www.who.int/news/item/08-10-2019-who-launches-first-world-report-on-vision.

2. Holden BA., Fricke TR., Wilson DA., Jong M., Naidoo KS., Sankaridurg P., et al. Global Prevalence of Myopia and High Myopia and Temporal Trends from 2000 through 2050. *Ophthalmology*. 2016;123:1036–42. doi: 10.1016/j.ophtha.2016.01.006 [PubMed] [CrossRef] [Google Scholar]

3. Holden BA, Jong M, Davis S, Wilson D, Fricke T, Resnikoff S. Nearly 1 billion myopes at risk of myopia-related sight-threatening conditions by 2050—time to act now. *Clin Exp Optom*. 2015;98(6):491–3. doi: 10.1111/cxo.12339 [PubMed] [CrossRef] [Google Scholar]

4. Pan CW, Ramamurthy D, Saw SM. Worldwide prevalence and risk factors for myopia. *Ophthalmic Physiol Opt*. 2012;32(1):3–16. doi: 10.1111/j.1475-1313.2011.00884.x [PubMed] [CrossRef] [Google Scholar]

5. Grzybowski A., Kanclerz P., Tsubota K., Lanca C., Saw S-M. A review on the epidemiology of myopia in school children worldwide. *BMC Ophthalmol*. 2020;20:27–38. doi: 10.1186/s12886-019-1220-0 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

6. Chen M., Wu A., Zhang L., Wang W., Chen X., Yu X., et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. *BMC Ophthalmol*. 2018;18:159. doi: 10.1186/s12886-018-0829-8 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

7. Naidoo KS, Raghunandan A, Mashige KP, Govender P, Holden BA, Pokharel GP, et al. Refractive error and visual impairment in African children in South Africa. *Invest Ophthalmol Vis Sci*. 2003;44(9):3764–70. doi: 10.1167/iovs.03-0283 [PubMed] [CrossRef] [Google Scholar]

8. R. R. Bennett and Rabbetts' clinical visual optics. Oxford: Butterworth-Heinemann; 1998.

9. Kempen JH, Mitchell P, Lee KE, Tielsch JM, Broman AT, Taylor HR, et al. The prevalence of refractive errors among adults in the United States, Western Europe, and Australia. *Arch Ophthalmol*. 2004;122(4):495–505. doi: 10.1001/archopht.122.4.495 [PubMed] [CrossRef] [Google Scholar]

10. Williams K, Hammond C. High myopia and its risks. *Community eye health*. 2019;32(105):5–6. [PMC free article] [PubMed] [Google Scholar]

11. Holden BA., Mariotti SP., Kocur I., Resnikoff S., He M., Naidoo KS., et al. *The impact of myopia and high myopia: Report of the joint World Health Organization- Brien Holden Vision Institute Global Scientific Meeting on Myopia University of New South Wales, Sydney, Australia, 16–18 March 2015*. Geneva: World Health Organization; 2017. [Google Scholar]

12. Congdon N, Burnett A, Frick K. The impact of uncorrected myopia on individuals and society. *Community eye health*. 2019;32(105):7–8. [PMC free article] [PubMed] [Google Scholar]

13. Fricke TR., Holden BA., Wilson DA., Schlenther G., Naidoo KS., Resnikoff S., et al. Global cost of correcting vision impairment from uncorrected refractive error. *Bull World Health Organ*. 2012;90:728–38. doi: 10.2471/BLT.12.104034 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

14. Rudnicka AR, Owen CG, Nightingale CM, Cook DG, Whincup PH. Ethnic differences in the prevalence of myopia and ocular biometry in 10- and 11-year-old children: the Child Heart and Health Study in England (CHASE). *Invest Ophthalmol Vis Sci*. 2010;51(12):6270–6. doi: 10.1167/iovs.10-5528 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

15. Wachira L-J. Lifestyle Transition towards Sedentary Behavior among Children and Youth in Sub-Saharan Africa: A narrative review: IntechOpen; 2021.

16. OECD/SWAC. *Africa's Urbanisation Dynamics 2020: Africapolis, Mapping a New Urban Geography, West African Studies*. Paris: OECD Publishing; 2020. [Google Scholar]

17. Juma K, Juma PA, Shumba C, Otieno P, Asiki G. Non-Communicable Diseases and Urbanization in African Cities: A Narrative Review. In: Anugwom EE, Awofeso N, editors. Public Health in Developing Countries—Challenges and Opportunities: IntechOpen.

18. Porter G, Hampshire K, Abane A, Munthali A, Robson E, Mashiri M, et al. Youth, mobility and mobile phones in Africa: findings from a three-country study. *Information Technology for Development*. 2012;18(2):145–62. [Google Scholar]

19. Porter G, Hampshire K, Milner J, Munthali A, Robson E, de Lannoy A, et al. Mobile Phones and Education in Sub-Saharan Africa: From Youth Practice to Public Policy. *Journal of International Development*. 2016;28(1):22–39. [Google Scholar]

20. Hepsen IF, Evereklioglu C, Bayramlar H. The effect of reading and near-work on the development of myopia in emmetropic boys: a prospective, controlled, three-year follow-up study. *Vision Res*. 2001;41(19):2511–20. doi: 10.1016/s0042-6989(01)00135-3 [PubMed] [CrossRef] [Google Scholar]

21. Ip JM, Saw S-M, Rose KA, Morgan IG, Kifley A, Wang JJ, et al. Role of Near Work in Myopia: Findings in a Sample of Australian School Children. *Investigative Ophthalmology & Visual Science*. 2008;49(7):2903–10. [PubMed] [Google Scholar]

22. Huang HM, Chang DS, Wu PC. The Association between Near Work Activities and Myopia in Children-A Systematic Review and Meta-Analysis. *PLoS One*. 2015;10(10):e0140419. doi: 10.1371/journal.pone.0140419 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

23. Sherwin JC, Reacher MH, Keogh RH, Khawaja AP, Mackey DA, Foster PJ. The association between time spent outdoors and myopia in children and adolescents: a systematic review and meta-analysis. *Ophthalmology*. 2012;119(10):2141–51. doi: 10.1016/j.ophtha.2012.04.020 [PubMed] [CrossRef] [Google Scholar]

24. Wolffsohn JS, Calossi A, Cho P, Gifford K, Jones L, Li M, et al. Global trends in myopia management attitudes and strategies in clinical practice. *Cont Lens Anterior Eye*. 2016;39(2):106–16. doi: 10.1016/j.clae.2016.02.005 [PubMed] [CrossRef] [Google Scholar]

25. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71. doi: 10.1136/bmj.n71 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

26. Dandona L, Dandona R. Revision of visual impairment definitions in the International Statistical Classification of Diseases. *BMC medicine*. 2006;4:7-. doi: 10.1186/1741-7015-4-7 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

27. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377–84. doi: 10.1136/jech.52.6.377 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

28. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Gupta V, et al. Incidence and progression of myopia and associated factors in urban school children in Delhi: The North India Myopia Study (NIM Study). *PLoS One*. 2017;12(12):e0189774. doi: 10.1371/journal.pone.0189774 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

29. Saxena R, Vashist P, Tandon R, Pandey RM, Bhardawaj A, Menon V, et al. Prevalence of myopia and its risk factors in urban school children in Delhi: the North India Myopia Study (NIM Study). *PLoS One*. 2015;10(2):e0117349. doi: 10.1371/journal.pone.0117349 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

30. Luo HD, Gazzard G, Liang Y, Shankar A, Tan DT, Saw SM. Defining myopia using refractive error and uncorrected logMAR visual acuity >0.3 from 1334 Singapore school children ages 7–9 years. *Br J Ophthalmol*. 2006;90(3):362–6. doi: 10.1136/bjo.2005.079657 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

31. Patsopoulos NA, Evangelou E, Ioannidis JP. Sensitivity of between-study heterogeneity in meta-analysis: proposed metrics and empirical evaluation. *International Journal of Epidemiology*. 2008;37(5):1148–57. doi: 10.1093/ije/dyn065 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

32. Atowa UC, Munsamy AJ, Wajuihian SO. Prevalence and risk factors for myopia among school children in Aba, Nigeria. *African Vision and Eye Health*; Vol 76, No 1 (2017). [Google Scholar]

33. Wajuihian SO, Hansraj R. Refractive Error in a Sample of Black High School Children in South Africa. *Optom Vis Sci*. 2017;94(12):1145–52. doi: 10.1097/OPX.0000000000001145 [PubMed] [CrossRef] [Google Scholar]

34. Chebil A, Jedidi L, Chaker N, Kort F, Largueche L, El Matri L. Epidemiologic study of myopia in a population of schoolchildren in Tunisia. *Tunis Med*. 2016;94(3):216–20. [PubMed] [Google Scholar]

35. Kedir J, Girma A. Prevalence of refractive error and visual impairment among rural school-age children of Goro District, Gurage Zone, Ethiopia. *Ethiop J Health Sci*. 2014;24(4):353–8. doi: 10.4314/ejhs.v24i4.11 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

36. Soler M, Anera RG, Castro JJ, Jiménez R, Jiménez JR. Prevalence of Refractive Errors in Children in Equatorial Guinea. *Optometry and Vision Science*. 2015;92(1). doi: 10.1097/OPX.0000000000000448 [PubMed] [CrossRef] [Google Scholar]

37. Kumah BD, Ebri A, Abdul-Kabir M, Ahmed AS, Koomson NY, Aikins S, et al. Refractive error and visual impairment in private school children in Ghana. *Optom Vis Sci*. 2013;90(12):1456–61. doi: 10.1097/OPX.0000000000000099 [PubMed] [CrossRef] [Google Scholar]

38. Mehari ZA, Yimer AW. Prevalence of refractive errors among schoolchildren in rural central Ethiopia. *Clin Exp Optom*. 2013;96(1):65–9. doi: 10.1111/j.1444-0938.2012.00762.x [PubMed] [CrossRef] [Google Scholar]

39. Jimenez R, Soler M, Anera RG, Castro JJ, Perez MA, Salas C. Ametropias in school-age children in Fada N'Gourma (Burkina Faso, Africa). *Optom Vis Sci*. 2012;89(1):33–7. doi: 10.1097/OPX.0b013e318238b3dd [PubMed] [CrossRef] [Google Scholar]

40. Yamamah GA, Talaat Abdel Alim AA, Mostafa YS, Ahmed RA, Mohammed AM. Prevalence of Visual Impairment and Refractive Errors in Children of South Sinai, Egypt. *Ophthalmic Epidemiol*. 2015;22(4):246–52. doi: 10.3109/09286586.2015.1056811 [PubMed] [CrossRef] [Google Scholar]

41. Nartey ET, van Staden DB, Amedo AO. Prevalence of Ocular Anomalies among Schoolchildren in Ashaiman, Ghana. *Optometry and Vision Science*. 2016;93(6). doi: 10.1097/OPX.0000000000000836 [PubMed] [CrossRef] [Google Scholar]

42. Anera RG, Jiménez JR, Soler M, Pérez MA, Jiménez R, Cardona JC. Prevalence of refractive errors in school-age children in Burkina Faso. *Jpn J Ophthalmol*. 50. Japan2006. p. 483–4. doi: 10.1007/s10384-006-0354-9 [PubMed] [CrossRef] [Google Scholar]

43. Chukwuemeka AG. *Prevalence of refractive errors among primary school children (7–14 years) in Motherwell Township, Eastern Cape, South Africa*. Eastern Cape, South Africa: University of Limpopo; 2015. [Google Scholar]

44. Alrasheed SH, Naidoo KS, Clarke-Farr PC. Prevalence of visual impairment and refractive error in school-aged children in South Darfur State of Sudan. *African Vision and Eye Health*; Vol 75, No 1 (2016). [Google Scholar]

45. Abdul-Kabir M, Bortey DNK, Onoikhua EE, Asare-Badiako B, Kumah DB. Ametropia among school children—a cross-sectional study in a sub-urban municipality in Ghana. *Pediatr Dimensions*. 2016;1(3):65–8. [Google Scholar]

46. Ebri AE, Govender P, Naidoo KS. Prevalence of vision impairment and refractive error in school learners in Calabar, Nigeria. *African Vision and Eye Health*; Vol 78, No 1 (2019) [Google Scholar]

47. Ezinne NE, Mashige KP. Refractive error and visual impairment in primary school children in Onitsha, Anambra State, Nigeria. *African Vision and Eye Health*; Vol 77, No 1 (2018). [Google Scholar]

48. Nakua EK, Otupiri E, Owusu-Dabo E, Dzomeku VM, Otu-Danquah K, Anderson M. Prevalence of refractive errors among junior high school students in the Ejisu Juaben Municipality of Ghana. *J Sci Tech*. 2015;35(1):52–62. [Google Scholar]

49. Ndou NP. *Uncorrected refractive errors among primary school children of Moretele sub-distric in North-west Province*, South Africa: University of Limpopo; 2014. doi: 10.5713/ajas.2013.13774 [CrossRef] [Google Scholar]

50. Abdi Ahmed Z, Alrasheed SH, Alghamdi W. Prevalence of refractive error and visual impairment among school-age children of Hargesia, Somaliland, Somalia. *East Mediterr Health J*. 2020;26(11):1362–70. doi: 10.26719/emhj.20.077 [PubMed] [CrossRef] [Google Scholar]

51. Ovenseri-Ogbomo GO, Assien R. Refractive error in school children in Agona Swedru, Ghana. *African Vision and Eye Health; South African Optometrist*: Vol 69, No 2 (2010). [Google Scholar]

52. Ovenseri-Ogbomo G, Omuemu DV. Prevalence of refractive error among school children in the Cape Coast Municipality, Ghana. *{Opto}*. 2010:59. [Google Scholar]

53. Assem AS, Tegegne MM, Fekadu SA. Prevalence and associated factors of myopia among school children in Bahir Dar city, Northwest Ethiopia, 2019. *PLoS One*. 2021;16(3):e0248936. doi: 10.1371/journal.pone.0248936 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

54. Maduka-Okafor FC, Okoye O, Ezegwui I, Oguego NC, Okoye OI, Udeh N, et al. Refractive Error and Visual Impairment Among School Children: Result of a South-Eastern Nigerian Regional Survey. *Clin Ophthalmol*. 2021;15:2345–53. doi: 10.2147/OPTH.S298929 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

55. Rushood AA, Azmat S, Shariq M, Khamis A, Lakho KA, Jadoon MZ, et al. Ocular disorders among schoolchildren in Khartoum State, Sudan. *East Mediterr Health J*. 2013;19(3):282–8. [PubMed] [Google Scholar]

56. Woldeamanuel GG, Biru MD, Geta TG, Areru BA. Visual impairment and associated factors among primary school children in Gurage Zone, Southern Ethiopia. *Afr Health Sci*. 2020;20(1):533–42. doi: 10.4314/ahs.v20i1.60 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

57. Foster PJ, Jiang Y. Epidemiology of myopia. *Eye*. 2014;28(2):202–8. doi: 10.1038/eye.2013.280 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

58. Rudnicka AR, Kapetanakis VV, Wathern AK, Logan NS, Gilmartin B, Whincup PH, et al. Global variations and time trends in the prevalence of childhood myopia, a systematic review and quantitative meta-analysis: implications for aetiology and early prevention. *Br J Ophthalmol*. 2016;100(7):882–90. doi: 10.1136/bjophthalmol-2015-307724 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

59. Morgan IG, Iribarren R, Fotouhi A, Grzybowski A. Cycloplegic refraction is the gold standard for epidemiological studies. *Acta Ophthalmol*. 2015;93(6):581–5. doi: 10.1111/aos.12642 [PubMed] [CrossRef] [Google Scholar]

60. Ip JM, Huynh SC, Robaei D, Rose KA, Morgan IG, Smith W, et al. Ethnic Differences in the Impact of Parental Myopia: Findings from a Population-Based Study of 12-Year-Old Australian Children. *Investigative Ophthalmology & Visual Science*. 2007;48(6):2520–8. doi: 10.1167/iovs.06-0716 [PubMed] [CrossRef] [Google Scholar]

61. Goldschmidt E, Jacobsen N. Genetic and environmental effects on myopia development and progression. *Eye*. 2014;28(2):126–33. doi: 10.1038/eye.2013.254 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

62. Armarnik S, Lavid M, Blum S, Wygnanski-Jaffe T, Granet DB, Kinori M. The relationship between education levels, lifestyle, and religion regarding the prevalence of myopia in Israel. *BMC Ophthalmology*. 2021;21(1):136. doi: 10.1186/s12886-021-01891-w [PMC free article] [PubMed] [CrossRef] [Google Scholar]

63. Lim LT, Gong Y, Ah-Kee EY, Xiao G, Zhang X, Yu S. Impact of parental history of myopia on the development of myopia in mainland china school-aged children. *Ophthalmology and eye diseases*. 2014;6:31–5. doi: 10.4137/OED.S16031 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

64. The Global Economy. Business and economic data for 200 countries [cited 2021 August 12]. https://www.theglobaleconomy.com/.

65. Gajjar S, Ostrin LA. A systematic review of near work and myopia: measurement, relationships, mechanisms and clinical corollaries. *Acta Ophthalmologica*. 2021. doi: 10.1111/aos.15043 [PubMed] [CrossRef] [Google Scholar]

66. French AN, Morgan IG, Burlutsky G, Mitchell P, Rose KA. Prevalence and 5- to 6-year incidence and progression of myopia and hyperopia in Australian schoolchildren. *Ophthalmology*. 2013;120(7):1482–91. doi: 10.1016/j.ophtha.2012.12.018 [PubMed] [CrossRef] [Google Scholar]

67. Hashemi H, Fotouhi A, Mohammad K. The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic Epidemiol*. 2004;11(3):213–25. doi: 10.1080/09286580490514513 [PubMed] [CrossRef] [Google Scholar]

68. Lam CSY, Goh WSH. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. *Clinical and Experimental Optometry*. 1991;74(3):97–103. [Google Scholar]

69. Maul E, Barroso S, Munoz SR, Sperduto RD, Ellwein LB. Refractive Error Study in Children: results from La Florida, Chile. *Am J Ophthalmol*. 2000;129(4):445–54. doi: 10.1016/s0002-9394(99)00454-7 [PubMed] [CrossRef] [Google Scholar]

70. Czepita D, Mojsa A, Ustianowska M, Czepita M, Lachowicz E. Role of gender in the occurrence of refractive errors. *Ann Acad Med Stetin*. 2007;53(2):5–7. [PubMed] [Google Scholar]

71. Quek TP, Chua CG, Chong CS, Chong JH, Hey HW, Lee J, et al. Prevalence of refractive errors in teenage high school students in Singapore. *Ophthalmic Physiol Opt*. 2004;24(1):47–55. doi: 10.1046/j.1475-1313.2003.00166.x [PubMed] [CrossRef] [Google Scholar]

72. Zhao J, Mao J, Luo R, Li F, Munoz SR, Ellwein LB. The progression of refractive error in school-age children: Shunyi district, China. *Am J Ophthalmol*. 2002;134(5):735–43. doi: 10.1016/s0002-9394(02)01689-6 [PubMed] [CrossRef] [Google Scholar]

73. Vision. NRCUCo. *Myopia: Prevalence and Progression*. Washington (DC): National Academies Press (US); 1989. [PubMed] [Google Scholar]

74. Gong J-F, Xie H-L, Mao X-J, Zhu X-B, Xie Z-K, Yang H-H, et al. Relevant factors of estrogen changes of myopia in adolescent females. *Chinese medical journal*. 2015;128(5):659. doi: 10.4103/0366-6999.151669 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

75. Lundberg K, Suhr Thykjaer A, Søgaard Hansen R, Vestergaard AH, Jacobsen N, Goldschmidt E, et al. Physical activity and myopia in Danish children-The CHAMPS Eye Study. *Acta Ophthalmol*. 2018;96(2):134–41. doi: 10.1111/aos.13513 [PubMed] [CrossRef] [Google Scholar]

76. Fotouhi A, Morgan IG, Iribarren R, Khabazkhoob M, Hashemi H. Validity of noncycloplegic refraction in the assessment of refractive errors: the Tehran Eye Study. *Acta Ophthalmol*. 2012;90(4):380–6. doi: 10.1111/j.1755-3768.2010.01983.x [PubMed] [CrossRef] [Google Scholar]

77. Fotedar R, Rochtchina E, Morgan I, Wang JJ, Mitchell P, Rose KA. Necessity of cycloplegia for assessing refractive error in 12-year-old children: a population-based study. *Am J Ophthalmol*. 2007;144(2):307–9. doi: 10.1016/j.ajo.2007.03.041 [PubMed] [CrossRef] [Google Scholar]

78. Hu YY, Wu JF, Lu TL, Wu H, Sun W, Wang XR, et al. Effect of cycloplegia on the refractive status of children: the Shandong children eye study. *PLoS One*. 2015;10(2):e0117482. doi: 10.1371/journal.pone.0117482 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r001

Decision Letter 0

Aleksandra Barac, Academic Editor

13 Dec 2021

PONE-D-21-28841Systematic Review and Meta-analysis of Myopia prevalence in African School children.PLOS ONE

Dear Dr. Osuagwu,

Thank you for submitting your manuscript to PLOS ONE. After careful consideration, we feel that it has merit but does not fully meet PLOS ONE's publication criteria as it currently stands. Therefore, we invite you to submit a revised version of the manuscript that addresses the points raised during the review process.

Please submit your revised manuscript by Jan 27 2022 11:59PM. If you will need more time than this to complete your revisions, please reply to this message or contact the journal office at plosone@plos.org. When you're ready to submit your revision, log on to https://www.editorialmanager.com/pone/ and select the 'Submissions Needing Revision' folder to locate your manuscript file.

Please include the following items when submitting your revised manuscript:

- A rebuttal letter that responds to each point raised by reviewers. You should upload this letter as a separate file labeled 'Response to Reviewers'.
- A marked-up copy of your manuscript that highlights changes made to the original version. You should upload this as a separate file labeled 'Revised Manuscript with Track Changes'.
- An unmarked version of your revised paper without tracked changes. You should upload this as a separate file labeled 'Manuscript'.

If you would like to make changes to your financial disclosure, please include your updated statement in your cover letter. Guidelines for resubmitting your figure files are available below the reviewer comments at the end of this letter.

If applicable, we recommend that you deposit your laboratory protocols in protocols.io to enhance the reproducibility of your results. Protocols.io assigns your protocol its own identifier (DOI) so that it can be cited independently in the future. For instructions see: https://journals.plos.org/plosone/s/submission-guidelines#loc-laboratory-protocols. Additionally, PLOS ONE offers an option for publishing peer-reviewed Lab Protocol articles, which describe protocols hosted on protocols.io. Read more information on sharing protocols at https://plos.org/protocols?utm_medium=editorial-email&utm_source=authorletters&utm_campaign=protocols.

We look forward to receiving your revised manuscript.

Kind regards,

Aleksandra Barac

Academic Editor

PLOS ONE

Journal Requirements:

When submitting your revision, we need you to address these additional requirements.

1. Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. The PLOS ONE style templates can be found at

https://journals.plos.org/plosone/s/file?id=wjVg/PLOSOne_formatting_sample_main_body.pdf and

https://journals.plos.org/plosone/s/file?id=ba62/PLOSOne_formatting_sample_title_authors_affiliations.pdf

2. Please include captions for your Supporting Information files at the end of your manuscript, and update any in-text citations to match accordingly. Please see our Supporting Information guidelines for more information: http://journals.plos.org/plosone/s/supporting-information.

[Note: HTML markup is below. Please do not edit.]

Reviewers' comments:

Reviewer's Responses to Questions

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

****

3. Have the authors made all data underlying the findings in their manuscript fully available?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception (please refer to the Data Availability Statement in the manuscript PDF file). The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: No

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4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1: The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level

- They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

I think we should exclude these articles or change the inclusion criteria

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

In a meta-analysis, Gajjar (Acta ophtahlmol 2021) show that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) shows the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Reviewer #2: This is a good Meta-analysis regarding the myopia prevalence in Africa

it is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

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6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose “no”, your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

[NOTE: If reviewer comments were submitted as an attachment file, they will be attached to this email and accessible via the submission site. Please log into your account, locate the manuscript record, and check for the action link "View Attachments". If this link does not appear, there are no attachment files.]

While revising your submission, please upload your figure files to the Preflight Analysis and Conversion Engine (PACE) digital diagnostic tool, https://pacev2.apexcovantage.com/. PACE helps ensure that figures meet PLOS requirements. To use PACE, you must first register as a user.

Registration is free. Then, login and navigate to the UPLOAD tab, where you will find detailed instructions on how to use the tool. If you encounter any issues or have any questions when using PACE, please email PLOS at figures@plos.org. Please note that Supporting Information files do not need this step.

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r002

Author response to Decision Letter 0

13 Jan 2022

Response to Reviewers comments

Dear Aleksandra Barac

Thanks for the very useful comments which has strengthened our manuscript. We have revised the article according to the suggested comments. We have provided a point-by-point response to all reviewers comments for clarity.

The changes made in the revised manuscript and supplementary files were highlighted using red font for easy identification.

Journal Requirements:

When submitting your revision, we need you to address these additional requirements.

1. Please ensure that your manuscript meets PLOS ONE's style requirements, including those for file naming. The PLOS ONE style templates can be found at

https://journals.plos.org/plosone/s/file?id=wjVg/PLOSOne_formatting_sample_main_body.pdf and

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Response: Done

2. Please include captions for your Supporting Information files at the end of your manuscript, and update any in-text citations to match accordingly. Please see our Supporting Information guidelines for more information: http://journals.plos.org/plosone/s/supporting-information.

Response: Done

Comments to the Author

1. Is the manuscript technically sound, and do the data support the conclusions?

The manuscript must describe a technically sound piece of scientific research with data that supports the conclusions. Experiments must have been conducted rigorously, with appropriate controls, replication, and sample sizes. The conclusions must be drawn appropriately based on the data presented.

Reviewer #1: Yes

Reviewer #2: Yes

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2. Has the statistical analysis been performed appropriately and rigorously?

Reviewer #1: Yes

Reviewer #2: Yes

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3. Have the authors made all data underlying the findings in their manuscript fully available?

The PLOS Data policy requires authors to make all data underlying the findings described in their manuscript fully available without restriction, with rare exception (please refer to the Data Availability Statement in the manuscript PDF file). The data should be provided as part of the manuscript or its supporting information, or deposited to a public repository. For example, in addition to summary statistics, the data points behind means, medians and variance measures should be available. If there are restrictions on publicly sharing data—e.g. participant privacy or use of data from a third party—those must be specified.

Reviewer #1: Yes

Reviewer #2: No

Response: We have included the study data used in the analysis as a spread sheet inline with PlosOne policy

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4. Is the manuscript presented in an intelligible fashion and written in standard English?

PLOS ONE does not copyedit accepted manuscripts, so the language in submitted articles must be clear, correct, and unambiguous. Any typographical or grammatical errors should be corrected at revision, so please note any specific errors here.

Reviewer #1: Yes

Reviewer #2: Yes

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5. Review Comments to the Author

Please use the space provided to explain your answers to the questions above. You may also include additional comments for the author, including concerns about dual publication, research ethics, or publication ethics. (Please upload your review as an attachment if it exceeds 20,000 characters)

Reviewer #1:

The authors conducted a review and meta-analysis of articles on the prevalence of myopia in African children.

This study follows the recommendations for this type of review.

Several points of detail should be reported

1 ° In the inclusion criteria, the authors report having excluded studies in which the ages of the participants were either not specified or outside the age range specified. But they did not clearly define the age ranges of this review themselves.

Response: Agreed and we have excluded the 4–24year-old range study (Yareed et al) and the 5-19 year study (Ovenseri-Ogbomo et al) as they do not meet our stipulated inclusion criteria of 5-18 year.

2 ° Two articles have been included but pose a problem in my opinion.

- They did not report whether it was school- or population-based. The inclusion / exclusion criteria are not clear at this level. They did not specify the method used to determine the refractive error. However, it is clearly specified in the inclusion criteria "stated the method of measuring refractive error - cycloplegic or non-cycloplegic refraction, as well as objective or subjective refraction"

Response: The inclusion and exclusion criteria were made clearer and as suggested, we excluded these studies as the two stipulated criteria are not specified [Rushood (39) and Woldeamanuel (47)]

3 ° in the table, in addition to the age limits, the median or average of the ages must be included in each article. Moreover, the authors specify it for an article: In another study (43) however, the children were aged 4 - 24 years but with a mean age of 12 years.

Response: We have included the mean age in Table 1 and the study with age range 4-24years was excluded based on the exclusion criteria.

4 ° in the discussion, when the authors evoke the fact that fewer children await early education and learning in many African countries, compared with Asian countries, means that the children do less near work and are more involved with outdoor tasks, nuances must be made.

Response: In a meta-analysis, Gajjar (Acta ophthalmol 2021) showed that the role of near vision is still questionable and that the study of the literature does not allow a conclusion. On the other hand, Tang Y (J Glob Health. 2021) showed the existence of a difference in the prevalence of myopia in China depending on whether the children live in the city or in the countryside. However, we agree with the reviewer and have made the following revision in the discussion section:

In addition, several studies have shown the major involvement of environmental factors such as near work (writing, reading, and working on a computer) in myopia development(62, 65). In many African countries, children do not start education and learning at the same early age as in other countries of Asia. African children are therefore exposed to less near work and are more involved with outdoor activities, resulting in less risk of developing myopia compared with their Asian counterparts. This assertion is supported by the fact that in 2010, the pre-primary school enrolment rate in the most populous country in Africa (Nigeria) was 41.83% compared to 89.12% in 2012 in China (the most populous country in Asia) (66). We acknowledge that a recent investigation(67) has shown that more precise objective measures are required to make definitive conclusions about the relationship between myopia and near work.

5° The authors said that "he apparent higher prevalence of myopia in girls may be due to girls having ... shorter axial length than boys". That surprising !!!

Response: Zadnik et al study was referring to a specific context in their study, where they found that girls tended to have steeper corneas, stronger crystalline lenses, and shorter eyes/axial length than boys. These findings are specific to their study and cannot be used to explain any result where a higher prevalence of myopia in girls is found. For example, we know that shorter axial length is generally associated with hyperopia and not myopia.

However, the new analysis after removing the 4 studies, showed no statistically significant difference in myopia prevalence between gender. Therefore, we have removed this statement and the revised section now reads:

The influence of gender on the prevalence of myopia has not been unequivocal in the literature (70-74) with some suggesting that the slightly higher prevalence in females may be related to the different ages of onset of puberty between boys and girls (75). Other factors that could account for the reported apparent higher prevalence of myopia in girls include limited outdoor activity time than boys (76).

Reviewer #2

This is a good Meta-analysis regarding the myopia prevalence in Africa. It is good structured and well-written; however, it would be better if you add a figure showing prevalence of myopia by ethnicity (black vs white vs asian in the same region) to show if it affects the prevalence of myopia or not

Response: Thanks for the suggestion. Although the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about the differences in the prevalence of myopia between ethnic groups in Africa, studies that have been conducted in Africa did not specify the different ethnicities. However, we think there is need for such comparison between black vs white vs Asian and this could be another research interest with a different research aim for another manuscript. We have suggested this in the conclusion for future study direction. The section now reads:

Future studies are needed to understand the role of ethnicity on the myopia prevalence in Africa as the inclusion and comparison of the different ethnicities (Black vs White vs Asian) in the same region would add useful information about whether significant differences in the prevalence of myopia among different ethnicity in Africa exists.

6. PLOS authors have the option to publish the peer review history of their article (what does this mean?). If published, this will include your full peer review and any attached files.

If you choose "no", your identity will remain anonymous but your review may still be made public.

Do you want your identity to be public for this peer review? For information about this choice, including consent withdrawal, please see our Privacy Policy.

Reviewer #1: No

Reviewer #2: No

Response. Thanks for your comments

Attachment

Submitted filename: *Response to Reviewers comments.docx*

Click here for additional data file. (31K, docx)

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r003

Decision Letter 1

Aleksandra Barac, Academic Editor

17 Jan 2022

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

PONE-D-21-28841R1

Dear Dr. Osuagwu,

We're pleased to inform you that your manuscript has been judged scientifically suitable for publication and will be formally accepted for publication once it meets all outstanding technical requirements.

Within one week, you'll receive an e-mail detailing the required amendments. When these have been addressed, you'll receive a formal acceptance letter and your manuscript will be scheduled for publication.

An invoice for payment will follow shortly after the formal acceptance. To ensure an efficient process, please log into Editorial Manager at http://www.editorialmanager.com/pone/, click the 'Update My Information' link at the top of the page, and double check that your user information is up-to-date. If you have any billing related questions, please contact our Author Billing department directly at authorbilling@plos.org.

If your institution or institutions have a press office, please notify them about your upcoming paper to help maximize its impact. If they'll be preparing press materials, please inform our press team as soon as possible -- no later than 48 hours after receiving the formal acceptance. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information, please contact onepress@plos.org.

Kind regards,

Aleksandra Barac

Academic Editor

PLOS ONE

2022; 17(2): e0263335.
Published online 2022 Feb 3. doi: 10.1371/journal.pone.0263335.r004

Acceptance letter

Aleksandra Barac, Academic Editor

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24 Jan 2022

PONE-D-21-28841R1

Systematic Review and Meta-analysis of Myopia prevalence in African School children.

Dear Dr. Osuagwu:

I'm pleased to inform you that your manuscript has been deemed suitable for publication in PLOS ONE. Congratulations! Your manuscript is now with our production department.

If your institution or institutions have a press office, please let them know about your upcoming paper now to help maximize its impact. If they'll be preparing press materials, please inform our press team within the next 48 hours. Your manuscript will remain under strict press embargo until 2 pm Eastern Time on the date of publication. For more information please contact onepress@plos.org.

If we can help with anything else, please email us at plosone@plos.org.

Thank you for submitting your work to PLOS ONE and supporting open access.

Kind regards,

PLOS ONE Editorial Office Staff

on behalf of

Dr. Aleksandra Barac

Academic Editor

PLOS ONE