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Global Prevalence of Myopia (2024)

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In this article

Myopia, or nearsightedness, is a condition that continues to affect millions worldwide. As the world becomes more urbanized and digitalized, the rates of myopia have been on the rise, prompting researchers and healthcare professionals to investigate the causes, consequences, and potential solutions to this growing epidemic.

This article will explore the current global prevalence of myopia, highlighting the most significant statistics and trends across different age groups and regions. We'll also discuss projected trends in myopia, along with potential solutions and interventions to address this growing public health concern.

Global Myopia Prevalence: Key Statistics and Trends

Myopia Rates by Age Group

- In several Asian countries, the prevalence of myopia among late teenagers and young adults (Korea, Taiwan, and China) is reported to be between 84% and 97%.
-

In the United States, approximately 41.0% of children aged 5 to 17 in urban areas have myopia, with a nationwide prevalence estimated at 36.1%.

- Nearly 224 million people worldwide, or almost 3% of the population, are highly nearsighted. This means they need glasses or contacts stronger than -5.00 diopters to see clearly.

Myopia Prevalence in Developed vs. Developing Countries

The prevalence of myopia varies significantly between developed and developing countries. Higher rates are observed in developed regions, particularly urban East Asian countries.

Region	Myopia Prevalence
Urban East Asia	80–90%
United States	42%
Germany (adults 35–74)	35.1%
United Kingdom (adults 48+)	23.0%
Australia (adults 49+)	15.0%
Nigeria (adults 40+)	16.1%

Projected Myopia Rates by 2050

- Nearly 50% of the world's population is projected to be myopic by 2050, which equates to almost 5 billion people
- The projected prevalence of high myopia, in particular, is expected to reach almost 10% of the global population by 2050, translating to around 1 billion people at a significantly increased risk of permanent vision impairment
- In the United States, it's predicted that between 27% and 43% of cases of uncorrectable visual impairment in 2050 may be directly attributable to myopia

Economic Burden of Myopia Worldwide

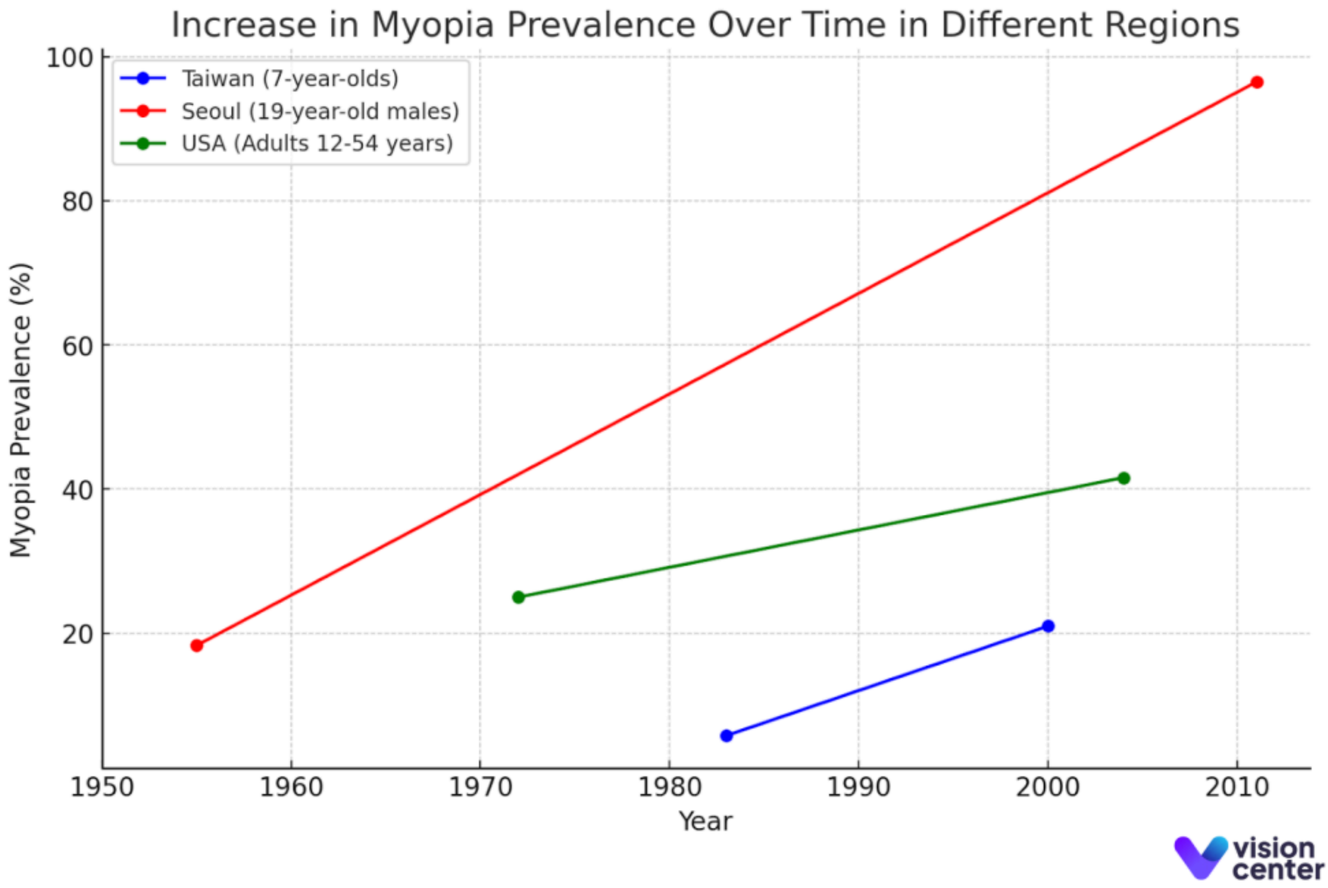
- The global potential productivity loss associated with vision impairment (VI) and blindness due to uncorrected myopia in 2015 was estimated at $244 billion
- Southeast Asia, South Asia, and East Asia were the regions significantly affected by lost productivity due to myopia, with productivity loss estimated at $40 billion and $35 billion, respectively
- The East Asia region, which includes China, had the greatest potential burden of productivity loss, around $150 billion

Trends in Myopia Prevalence Over Time

Studies have shown that the prevalence of myopia has been increasing rapidly over the past few decades, particularly in East Asian countries.

In Taiwan, for example, the prevalence of myopia among 7-year-old children increased from 5.8% in 1983 to 21% in 2000. Similarly, in Seoul, South Korea, the prevalence of myopia among 19-year-old males increased from 18.3% in 1955 to 96.5% in 2011.

This trend isn't limited to East Asia; other regions have also experienced a significant increase in myopia prevalence. In the United States, the prevalence of myopia among adults aged 12 to 54 years increased from 25% in 1971–1972 to 41.6% in 1999–2004.



Causes of the Myopia Epidemic

Several factors have been identified as potential contributors to the increasing prevalence of myopia worldwide:

1. **Increased near work and screen time:** The rise in digital device use and extended periods of near work, such as reading and studying, have been associated with a higher risk of myopia development.
2. **Reduced outdoor time:** Spending less time outdoors has been linked to an increased risk of myopia. Exposure to natural light and distant focusing may protect against myopia development.
3. **Urbanization and education:** Urban environments and higher levels of education have been associated with a higher prevalence of myopia. This is possibly due to increased near work and reduced outdoor time.
4. **Genetic factors:** While environmental factors play a significant role in myopia development, genetic predisposition also contributes to an individual's risk of developing myopia.

Potential Solutions and Interventions

To address the growing myopia epidemic, several potential solutions and interventions have been proposed:

1. **Outdoor time:** Encouraging children to spend more time outdoors, particularly during daylight hours, may help reduce the risk of myopia development and progression
2. **Eye breaks and visual hygiene:** Promoting regular eye breaks during extended near work, such as the 20-20-20 rule (looking at an object 20 feet away for 20 seconds every 20 minutes), can help reduce eye strain and potentially slow myopia progression
3. **Myopia control therapies:** Interventions such as atropine eye drops, orthokeratology (ortho-k) lenses, and multifocal contact lenses have shown promise in slowing myopia progression in children
4. **Education and awareness:** Increasing public awareness about myopia, its risk factors, and the importance of regular eye examinations can help promote early detection and intervention
5. **Research and innovation:** Continued research into the causes, mechanisms, and potential treatments for myopia is crucial for developing effective strategies to combat this growing epidemic

The global prevalence of myopia has reached epidemic proportions, with rates continuing to rise across all age groups and regions. The projected rates of myopia by 2050 paint a concerning picture. Nearly half of the world's population is expected to be myopic, and a significant portion is at risk of permanent vision impairment due to high myopia.

The economic burden associated with myopia is substantial, with productivity losses in the billions of dollars, particularly in regions such as East Asia, South Asia, and Southeast Asia. Investing in vision correction services and myopia control measures could potentially lead to significant savings in productivity and improve the quality of life for millions of individuals worldwide.

Several factors, including increased work and screen time, reduced outdoor time, urbanization, and genetic predisposition, have been identified as potential contributors to the increasing prevalence of myopia. A multifaceted approach involving outdoor time, visual hygiene, myopia control therapies, education, and research is necessary to address this growing public health concern.

As the world continues to evolve and become more urbanized and digitized, it's crucial to address the growing myopia epidemic through proactive interventions and innovative solutions. By understanding the current prevalence, projected trends, causes, and potential solutions, we can work towards developing effective strategies to prevent, control, and manage myopia.

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Prevalence, sociodemographic risk factors, and coverage of myopia correction among adolescent students in the central region of Portugal

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Abstract

Background

Knowing the prevalence of myopia at school age is essential to implement preventive measures and appropriate interventions, ensure access to vision care, promote a healthier educational environment and improve academic performance. The purpose of this study was to determine the prevalence of myopia and its associated sociodemographic risk factors, as well as to estimate the coverage of myopia correction among adolescents in center of Portugal.

Methods

This cross-sectional study evaluated 1115 adolescents from the 5th to the 9th year of school, with an average of 12.9 years *(SD = 1.5)* ranging from 10.0 to 18.0 years. Optometric evaluations were carried out in a school environment and consisted of the evaluation of distance visual acuity, assessed using a logarithmic visual acuity chart (ETDRS charts 1 and 2) at 4 m, and measured by refractive error with a pediatric autorefractometer (Plusoptix), by non-cycloplegic. Myopia was defined as spherical equivalent (SE ≤ -0.50 diopter (D)) and uncorrected visual acuity (UVA ≤ 95VAR). Adjusted logistic regression analysis was applied to investigate risk factors.

Results

We found a myopia rate of 21.5% and a high myopia rate of 1.4%. Higher school level and attendance at urban schools were associated with myopia, but no association was found with age or sex. Only 34.6% of myopic adolescents use the best optical correction and 26.4% do not use any type of optical correction.

Conclusions

Data on the prevalence of refractive problems in Portugal are scarce and heterogeneous. This study, although regional, provides a valuable contribution with a clear and reproducible methodology, following international guidelines and filling gaps in the existing literature. The results show that the rate of myopia in this age group is similar to reports from other European studies. The high rate of adolescents with uncorrected or under-corrected myopia in Portugal is a problem that deserves attention.

Keywords: Adolescence, Myopia, Sociodemographic factors, Visual acuity, Myopia correction coverage, Urban-suburban disparity

Background

Myopia is a refractive condition that tends to develop in pre-adolescence, worsening during puberty and progressing into early adulthood [1]. The greater the degree of myopia, the greater the risk of ocular complications that can lead to vision loss that is not recoverable [2].

The definition of myopia, the methods used to measure ocular refraction and the inconsistent use of cycloplegics, influence the quantifications of myopia prevalence. In most epidemiological studies, myopia is defined by SE≤-0.50D and high myopia by SE≤-5.00D, with cycloplegic refraction [3]. However, the literature often uses non-cycloplegic refractive techniques and considers the same myopia definition [4–6]. Large-scale myopia studies rarely use cycloplegics, so there is a tendency to overestimate the rate of myopia [5].

The prevalence rates of myopia, when assessed using refractive techniques with cycloplegia, are higher in Asia than in compared to Europe [7]. Studies reporting non-cycloplegic refractive measurements show a similar pattern of differences but at even higher rates [4, 8]. Although cycloplegic refraction is considered the most appropriate technique for myopia studies, the use of cycloplegic means it takes a long time to measure refraction and can cause temporary side effects, such as blurred near vision and photophobia, which reduces adherence. [9].

Autorefractometers (AR) are instruments frequently used to obtain ocular refraction in epidemiological studies, but closed-field AR’s induce an overestimation of myopia. The use of open-field AR allows us to obtain refractive measurements close to cycloplegic refractive methods since it eliminates the stimulation of accommodation caused by instrument proximity [5]. It has also been recommended to measure non-cicloplegic autorefraction and visual acuity (VA) without correction, for higher accuracy in detecting myopia [9, 10]. The World Health Organization recommends measuring distance VA in vision screenings [11]. Employing a pinhole test in these screenings can reveal unmet refractive needs, as an improvement in VA with pinhole suggests the presence of correctable refractive errors [2, 11].

Although the magnitude of this problem presents geographic differences, an increase in the prevalence, incidence and progression rates has been observed globally. In Europe, population prevalence rates are estimated at around 40.0% and in certain parts of East Asia, rates exceed 60.0%, and there is strong evidence that these rates vary greatly with age [7]. This vision eye condition has become a growing concern in eye health, especially among school-age children and adolescents. Current trends show that children and adolescents are becoming myopic at an earlier age and that the degree of myopia continues to progress as these children age [2, 12]. The scientific literature reports that the prevalence of myopia tends to increase from the age of 6 years [7]. East Asia exhibits the highest rates of myopia, while Africa and South America have lower reported rates [13].

Health promotion and screening interventions are essential to prevent myopia and other refractive errors by identifying vision problems early. In addition, these actions can change behaviors by educating about the importance of spectacles and addressing common reasons for non-adherence to their use, such as discomfort or social stigma, thus improving acceptance and appropriate management of vision eye conditions. In Portugal, there is little data allowing to know the real extent of myopia. The National programme for eye health estimates that around 20.0% of children and around 50.0% of the adult population suffer from refractive errors in general, including myopia and other refractive conditions [14]. A study carried out with Portuguese university students recorded an increase in the prevalence of myopia from 23.4 to 41.3% between 2002 and 2014 [15]. Another study, based on the analysis of prescription and sales of ophthalmic lenses, estimated an increase in myopia from 40.0% in 2010 to more than 50.0% in 2020 [16].

The prevalence of refractive problems in Portugal is a topic where available data is relatively scarce and presents significant heterogeneity. Furthermore, these studies often present methodological descriptions that can be considered insufficiently detailed. This work aims to estimate the prevalence of myopia in adolescents who attend school from the 5th to the 9th year in the central region of Portugal. We also intend to understand the association of myopia with some sociodemographic parameters in these adolescents, and to estimate the coverage of myopia correction among this population.

Methods

Study design and participants

This is an epidemiological, cross-sectional and observational study. Participants were children and adolescents attending the 2nd cycle of basic education (5th and 6th grades) and the 3rd cycle of basic education (7th, 8th and 9th grades) in Covilhã, a city in the central area of Portugal.

All schools in the urban area of the municipality where the study was conducted were included, covering 2 schools from the second cycle and 4 schools from the third cycle of basic education. Due to the small number of students in suburban schools and their significant geographic dispersion, 2 from each educational cycle in suburban area were selected based on having the highest number of enrolled students. All children enrolled in the participating schools were invited to join the study, with those receiving authorization from their legal guardians included, without participant randomization.

The inclusion criteria were being a child /adolescent attending the 2nd or 3rd cycle of basic education, aged between 10 and 18 years old, having the authorization from their legal tutor and providing verbal consent on the day of the screening. Incomplete screening records or those with poor cooperation were excluded from the data analysis. Students undergoing treatment with orthokeratology or atropine were also excluded, as this treatment can temporarily influence visual acuity and myopia measurement.

Procedures

The study protocol consisted of the acquisition of refractive measurements in eye screening actions in schools. The study was approved from the Ethics Committee of the National School of Public Health (CEENSP nº 29/2023) and was previously authorized by the Ministry of Education (nº

1307100001). Data were collected between November 2023 and February 2024. The examination and vision testing was performed by AN and MC.

Socio-demographic data were collected, such as age, sex, school level, school location (urban or suburban area), place of birth, and special educational needs.

All study volunteers underwent monocular distance visual acuity measurement and ocular refraction assessement using an autorefractometer Additionally, for participants who wore spectacles on the screening day, the prescription value of the spectacles was also recorded.

Visual acuity

VA was measured with ETDRS (Original Series Chart 1 and Chart 2; Good-Lite; USA) at 4 m under photopic lighting conditions. The lighting in the room was measured with a digital luxmeter (Luxmeter PCE-L335; PCE instruments; Tobarra, Spain) and values equal to or greater than 400 lx were considered acceptable [17]. The ETDRS charts are considered reliable, repeatable and easy to use in screening actions [18]. All VA were recorded on the Visual Acuity Rating scale (VAR), which is a more intuitive system for using a logarithmic charts and allows scoring letter by letter instead of line by line [18, 19]. In this rating system, each letter has a score of 1VAR; each line has 5VAR and the decimal VA = 1.0 is equivalent to 100VAR, and decimal VA = 0.8 is equivalent to 95VAR.

The protocol recommended by the WHO was followed to calculate the effective refractive correction coverage rate [2]. To determine UVA, all children were assessed monocularly and without any refractive correction. Visual acuity with usual correction (VAUC) was assessed in all children who wore glasses or contact lenses with their usual correction. In cases where the presented visual acuity (PVA) - defined as UVA for those not wearing corrective lenses or VAUC for those who did - was less than 95VAR, pinhole visual acuity (phVA) was also assessed. The diametre of pinhole was 1.5 mm. The same procedure was applied to record all visual acuity measurements. The patient started at the 80VAR line on the chart (equivalente 0,4 logMAR) and continued reading downwards until reaching a line where they could no longer correctly identify at least three letters. If the patient couldn´t read the 80VAR line, they started at the top of the cgart. The final score was based on the number of letters correctly identified. A different card was used for each eye to avoid learning effects.

Autorefraction

AR was performed under non-cycloplegic conditions, using the PlusOptix, model A09 (PlusOptix; Nuremberg, Germany). The PlusOptix is a device that measures ocular refraction at a distance of 1 m from the eyes, reducing the effects of instrumental myopia compared to closed-field AR. The refraction obtained with the PlusOptix A09 has shown agreement with the refraction of cycloplegic retinoscopy and is indicated as a screening method in myopic children [20, 21]. The ocular refraction of each participant was measured three times and the mean value of the SE of the three measurements was calculated. The SE was obtained by adding the spherical component to half the cylindrical component of the ocular refraction measured with the AR. When PlusOptix reported that the participant’s ocular refraction exceeded its measurement capacity, the refraction of the student’s usual spectacles was considered.

Definition of myopia

In screening activities, some authors recommend the combined use of refraction and VA, recognizing that this combination maximizes the sensitivity of screening in signaling myopia [10, 11, 22]. For children over 6 years of age, some authors recommend a decimal VA ≥ 1.0, equivalent to 0.0logMAR or 100VAR [23, 24], other authors recommend a decimal VA ≥ 0.8, equivalent to 0.1logMAR or 95VAR [9, 24].

In this study, the criteria of UAV < 95VAR and SE≤-0.50D were used to define myopia. To facilitate comparison with other studies, only the SE≤-0.50D criterion was also used. To characterize severity, we considered high myopia SE≤-6.00D, moderate myopia − 6.00D < SE≤-3.00D and mild myopia − 3.00D < SE≤-0.50D.

Statistical analysis

The data were analyzed using SPSS version 28 (IBM SPSS Statistics; New York, USA). Continuous variables were expressed as mean *(SD)* and categorical variables were presented as counts or proportions. The study of differences between the eyes for the continuous variables was carried out using the paired samples t-test. Chi-square test was used to compare categorical variables between groups. A multivariate logistic regression analysis was carried out using a stepwise backward method to explore the sociodemographic factors associated with myopia. The results of the logistic regression were reported as odds ratios (OR). For all analyses, a two-sided *p-value* < 0.05 was considered statistically significant. Confidence intervals (CI) were calculated at 95%.

Results

A total of 1115 students from urban and suburban schools took part in the study. The average age was 12.9 *(SD = 1.5)* years, ranging from 10.0 to 18.0 years. The male sex represented 50.9% of the total sample, and 67.4% of the students attended urban schools. There was also a rate of 11.7% of adolescents flagged in school files as having special educational needs (SEN) and 15.6% of participants were from other countries. The majority of migrant students originated from America (*n* = 99, with 92 from Brazil) and Africa (*n* = 49, with 43 from Angola). There were 19 adolescents from other European countries and 7 from Asia. The origin of 2 migrant students was not documented. The characteristics of the sample according to various factors are presented in Table 1. The results of the study of the differences between the groups, as well as the prevalence of myopia according to each of the factors analyzed, are also included.

Table 1

General characteristics of the sample

Characteristics		**Size [N (%)]**	**Age [years] (Average ± SD)**	**UVA [< 95VAR] N(%)**	**Myopia SE≤-0.50D**		**SE≤-0.50D and UVA < 95VAR**	
					N(%)	**p-value (χ^2)**	**N(%)**	**p-value (χ^2)**
Total sample		1115(100)	12.7 ± 1.5	516(46.3)	262(23.5)	--	240(21.5)	--
Sex	Male	568(51.0)	12.7 ± 1.5	245(43.1)	133(23.4)	0.957	121(21.3)	0.857
	Female	547(49.0)	12.7 ± 1.5	271(49.5)	129(23.6)		119(21.8)	
Nature	Portuguese	941(84.4)	12.6 ± 1.5	438(46.5)	221(23.5)	0.982	201(21.4)	0.756
	Migrants	174(15.6)	12.8 ± 1.5	78(44.9)	41(23.6)		39(22.4)	
School level	2nd cycle	437(39.2)	11.2 ± 0.7	190(43.5)	77(17.8)	**< 0.001****	74(16.9)	**0.003****
	3rd cycle	678(60.8)	13.6 ± 1.0	326(48.1)	185(27.3)		166(24.5)	
SEN	Positive	131(11.7)	13.0 ± 1.4	74(56.5)	29(21.1)	0.686	25(19.1)	0.469
	Negative	984(88.3)	12,6 ± 1.5	442(44.9)	233(23.7)		215(21.8)	
School location	Urban	751(67.4)	12.8 ± 1.5	360(47.9)	195(26)	**0.005****	176(23.4)	**0.026***
	Suburban	364(32.6)	12.5 ± 1.5	156(42.9)	67(18.4)		64(17.6)	

N - counts; % - proportions; SD – standard deviation - UVA – uncorrected visual acuity; VAR – visual acuity rating scale; SE – spherical equivalent; SEN – special educational needs

*Significant at 0.05 level; ** significant at 0.001 level

Prevalence of myopia and risk factors

The mean values for UVA were 90.6 ± 17VAR and 89.4 ± 17VAR for the right and left eyes respectively, and this difference was statistically significant (t = 5.656, p < 0.001). The visual acuity of the worst eye was used to classify myopia. An UVA worse than 95VAR in at least one eye occurred in 516 participants (46.3%; 95% CI: 42.4–50.4%) (Table 1).

For the SE≤-0.50D criterion, a prevalence of myopia was found to be 23.4% (95% CI: 21.0–26.0%), and for the SE≤-0.50D and UAV < 95VAR criteria, it was 21.5% (95% CI: 18.9–24.4%). The average value of the SE of the myopic population (n = 262) was − 2.70D *(SD = 1.86)*, in a range between − 0.50D and − 10.37D. Considering SE≤-6.00D, we account for 16 cases, that is a rate of 1.4% (95% CI: 0.9–2.3%) was found for high myopia. The average value of the SE in high myopia was − 7.52 *(SD = 1.32)*.

The proportion of myopic participants was not significantly different between girls and boys, between Portuguese and migrant students or between participants with and without SEN. However, it was significantly different between the school level, with a higher proportion of adolescents with myopia in the 3rd cycle; as well as between schools in urban and rural areas, with a higher proportion found in schools in the urban areas. These results was observed for both myopia classification criteria.

The association between the presence of myopia and age, sex, geographical location of the school and school level was studied using the odds ratio (OR) (Table 2).

Table 2

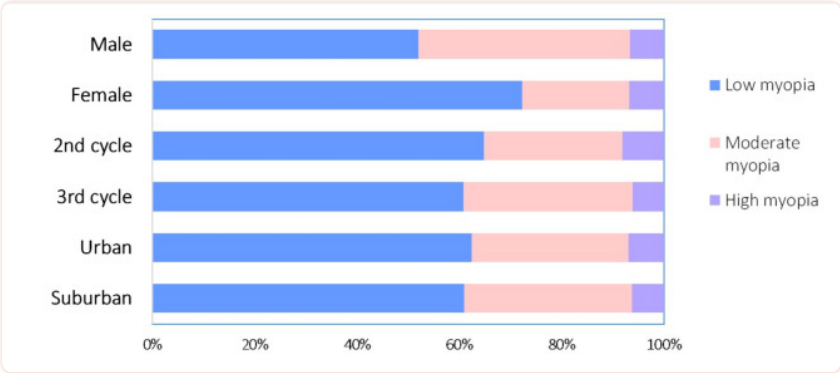
Myopia risk factors

Factor	OR crude (95% CI)	*p*-value	OR Adjusted (95% CI)	*p*-value
Age (numeric)	1.097 (0.996–1.208)	0.061	0.924 (0.786–1.085)	0.336
Sex	1.027 (0.772–1.367)	0.854	1.008 (0.756–1.344)	0.958
[male vs. female]				
School location [suburban vs. urban]	1.435 (1.044–1.973)	**0.026***	1.409 (1.022–1.941)	**0.036***
School level	1.590 (1.172–2.158)	**0.003****	1.889 (1.152–3.097)	0.012*
[2nd cycle vs. 3rd cycle]				

*Significant at 0.05 level; ** significant at 0.001 level

The crude OR revealed an association between myopia and the school location, as well as between myopia and the school level. The adjusted OR showed that adolescents from urban schools were 1.4 times more likely to have myopia than those from rural schools, after adjusting for age, sex and cycle of studies. Adolescents in the 3rd cycle of studies were also 1.9 times more likely to have myopia than adolescents in the 2nd cycle, after adjusting for age, sex and school location.

Figure 1 shows the distribution of myopia severity, according to sociodemographic characteristics. Low myopia is more common in all subgrups, but there were sex differences ($\chi^2 = 11.868$, $p = 0.003$). Low myopia is more common in both boys and girls, but of the universe of myopic boys (121), 52.0% have low myopia and 41.3% have moderate myopia, while of the universe of myopic girls (119), 72.3% have a low degree of myopia and 21.0% have moderate myopia. In the studied sample, boys have the highest proportion of moderate myopia. The distribution of myopia severity did not reveal differences between adolescents at different school levels ($\chi^2 = 1.077$, $p = 0.584$) ou between school location ($\chi^2 = 0.109$, $p = 0.947$).



[Fig. 1](#)

Myopia distribution by severity. *Legend* (Low myopia, Moderate myopia, High myopia). The number in the bars corresponds to the number of adolescents with the condition

Covarage of myopia correction

We found that 35.8% of the screened population reported wearing spectacles or contact lenses (n = 400). There were significant differences between sex in the use of spectacles, with a higher proportion of girls (218 girls, 54,5% and 182 boys, 45.5%) reporting the use of these devices (χ^2 = 6.409, p = 0.011). However, no significant differences were found between urban and suburban areas, nor among different levels of education. Among the adolescents who reported using some optical correction, 13.0% (95% CI: 9.7–16.3%) did not show up with their usual correction on the screening day (n = 53). Among the adolescents who attended with their usual optical correction (n = 347), the majority (n = 212) used a myopic prescription, with SE ≤-0.50D. However, 36 of the students who use myopia correction do not meet the myopia criterion (UVA < 95VAR AND AR SE >-0.50D). Hence, of the 240 students with myopia that have been identified, 176 use optical correction. In summary, we found a myopia rate of 21.5% (95% CI: 18.9–24.4%), of which 73.3% (95% CI: 67.8–78.9%) already use some optical correction. Moreover 3.2% (95% CI: 0.8–5.6%) of the sample use prescriptions for myopia while they not need it. It was also noted that the majority use monofocal lenses, with only 12 reported cases using myopia control lenses. There were no records of orthokeratology or atropine usage.

Table [3](#) shows the counts and proportions of adolescents who habitually use optical correction, according to presenting VA (UVA for those who do not use any correction, or VAUC for those who have spectacles or contact lenses). It also shows the number of cases in which VA improved when measured with the pinhole. It can be observed that only 34.6% (95% CI: 28.6–40.6%) of the myopic population is optically well corrected. Of the myopic teenagers who already use optical correction, a large percentage use insufficient correction to achieve a good vision. It was observed that 38.7% (95% CI: 32.5–44.9%) of the myopic population uses partial correction and 26.7% (95% CI: 21.1–32.3%) does not use any type of correction. The assessment of VA with pinhole in uncorrected or partially corrected myopic adolescents (n = 157) revealed that in 80.3% (95% CI: 74.1–86.5%) of cases it is possible to improve vision with adequate optical correction.

Table 3

Counts and proportions of myopic adolescents who already use some optical correction, according to the limits of uncorrected visual acuity (UVA) and corrected visual acuity (VAUC). SE – spherical equivalent; PhVA – pinhole visual acuity

Criteria	N	%
SE≤ (-0.50D) and UVA < 95VAR	240	100
VAUC ≥ 95VAR [already wear spectacles or Contact lenses]	83	34.6
VAUC < 95VAR [already wear spectacles or Contact lenses]	93	38.7
UVA < 95VAR [do not wear spectacles or Contact lenses]	64	26.7
PhVA (N= (93 + 64)) [improved]	126	80.3%

Discussion

This study evaluated the prevalence of myopia in adolescents attending school from the 5th to the 9th year. For the SE≤-0.50D and UVA < 95VAR criteria, there was a prevalence of myopia of 21.5% (95%CI:18.9–24.4%) and for high myopia there was a prevalence of 1.4% (95%CI:0.9–2.3%). Attending the 3rd cycle of studies and attending schools in urban areas were factors associated with a higher prevalence of myopia, while age and sex were not associated with increased odds of myopia. We also observed that only 34.6% (95% CI: 28.6–40.6%) of myopic students were well-corrected and 26.7% (95% CI: 21.1–32.3%) did not use any optical refraction.

Myopia is notably more prevalent in Asia, with scientific literature indicating that children and adolescents in East Asia experience exceptionally high rates of myopia. In some regions, the prevalence has been reported to exceed 80.0% [25]. Given the limited information on myopia prevalence among adolescents in Portugal, it is more practical to analyze and compare myopia trends within the European context, where data are more robust. While extensive research exists in regions such as China, utilizing data from European countries provides a more relevant comparison to Portugal's situation and enables a more immediate and applicable analysis of local trends and predictors.

Studies on the prevalence of myopia in European children and adolescents are few, and those we found that had been published in the last 5 years report rates ranging from 10% in Sweden to 24.8% in Austria [26, 27]. When cycloplegic refraction is used, rates are lower [26, 28, 29] than when cycloplegia is not used [27, 30]. It should also be noted that most studies use SE≤-0.50D as the definition of myopia [22, 26, 28–30] but some studies use a more myopic cutoff point [31] and the joint assessment of autorefraction and visual acuity [32].

The myopia rate found in the present study is similar to that reported in other studies from European countries. A comparison of our results with reports from other studies that used more conservative criteria to define myopia (e.g., SE≤-0.50 and UVA ≤ 95VAR) reveals that myopia is slightly more prevalent among adolescents in Portugal (21.5%) than in Bulgaria (19.0%) [26], and very similar to the prevalence reported in Germany (21.5%), where the definition of myopia used a cutoff point SE≤-0.75D [31]. For a broader comparison with the SE≤-0.50D criterion, we found a prevalence rate of 23.4%. This value is very close to that reported by other studies with children and adolescents in Europe, which used the same definition of myopia. In Austria, a rate of 24.8% was found between the ages of 15 and 18, and in Spain, a rate of 20.1% was reported in children aged 6 to 7 [22, 30].

The prevalence of myopia and associated risk factors among children has not yet been determined. It is known that genetic and environmental factors play a role in its etiology. Risk factors for myopia may include a combination of genetic, environmental and lifestyle factors, with the most obvious being genetics, time outdoors, near work and sex [33]. The literature also reports that the prevalence of myopia increases with age, is more frequent in girls and in the urban areas [22, 34]. In the present study, there was no association between myopia and age, but an association was found with school level, with a higher prevalence of mypia in the 3rd cycle. Although a higher school level necessarily requires an older age, the age-adjusted multivariate analysis revealed that age has no association and that the probability of myopia is 1.9 times greater in adolescents in the 3rd cycle. We believe that this association is influenced by other factors that also contribute to myopia, such as the intensity of close work and excessive use of digital screens [34]. Adolescents in the 3rd cycle of studies have a greater academic workload, which requires them to dedicate more time to tasks with near vision. Furthermore, the excessive use of digital screens, both for academic support and leisure, tends to be greater among older adolescents [35].

Regarding sex, there is no consensus in the literature, with older studies reporting that men have a higher prevalence of myopia, while more recent studies report that women show higher prevelances [34]. Other authors also report finding no association between sex and myopia [36], in line with the results from our study. The urban environment is also described as a factor associated with myopia and urban-rural differences tend to be stronger where there is a greater disparity in living conditions [37, 38]. This study also found this association, with adolescents attending an urban school being 1.4 times more likely to have myopia than those attending a suburban school. In a study carried out in India, where the location of the school was also taken into account, it was observed that the rate of myopia was 1.3 times higher in urban schools than in suburban schools [39].

Multi-ethnic population-based studies suggest that the prevalence of myopia varies according to ethnicity. The scientific literature reports that the prevalence of myopia is highest in Asian populations (above 50.0%), and lowest in African regions (around 15.0%) and shows values between 20.0 and 40.0% in Europe and America [3, 13]. In our study, no significant differences were found in myopia rates between Portuguese and migrant adolescents. For the most conservative criterion, SE≤-0.50D and UVA < 95VAR, the prevalence of myopia was 21.4% for the Portuguese and 22.4% for the migrants' adolescents. The migrant population in this study was mostly from Brazil and African countries, with a low rate of students from Asia. We believe that the low representation of Asian adolescents is the main reason why the migrant population had a prevalence rate similar to that of adolescents born in Portugal.

Scientific literature reports that children with special educational needs have a higher prevalence of vision dysfunction when compared to population samples, and one of the main causes of this disability is refractive errors [40]. In our study, there were no significant differences in the proportion of myopic adolescents between those with (vs. without) SEN. Since adolescents with low levels of autonomy and low capacity for collaboration in the acquisition of measurements have been excluded from the study, adolescents from the SEN group with greater potential for vision impairment may have been left out of our sample. On the other hand, this analysis is limited to myopia, and refractive errors such as hyperopia or astigmatism in individuals with SEN may be more frequent [41].

Another finding from our study that deserves reflection concerns the use of optical correction. Other authors report that the use of corrective spectacles improves the cognitive and educational well-being, psychological well-being, mental health, and quality of life of school-age children and adolescents [42]. Several authors have reported high rates of uncorrected myopia in school-age children [24, 43]. Our study found that only 34.6% of adolescents with myopia were well-corrected, with 38.7% being under-corrected, and 26.7% not using any correction. According to WHO recommendations, in screening activities, an improvement in visual acuity with a pinhole means that the problem of vision impairment can be solved with the use of suitable spectacles [11]. In the present study, when evaluating visual acuity with the pinhole in uncorrected or undercorrected myopic participants, an improvement was obtained in 80.3% of cases, which means that these adolescents can see their vision improved with a simple pair of appropriately prescribed spectacles. We also found that there is a significant percentage of teenagers who report having spectacles, but who do not use them regularly (13.0%). Several studies have explored compliance to spectacle use in impairement vision due to refractive errors, and a systematic review reveals that non-adherence rates in children are hiegh, even when glasses are freely provided. The reasons for non-adherence are varief, including factors such as broken glasses, forgetfulness, parental perceptions, and peer pressure [44, 45]. The design of the present study did not allow us to explore the reasons for this behavior, but it reinforces the message that teenagers' refusal to wear prescribed spectacles puts their eye health and their professional and academic future at risk [42]. Health professionals and the educational community must come together to raise awareness of the risks of non-compliance with spectacles, promote educational campaigns, and debunk myths and beliefs.

The main strength of this work lies in its analysis of data on myopia from a large sample of adolescents in the central region of Portugal, providing valuable insights into the prevalence of myopia in Portugal. However, there are also some limitations. One of the main limitations of this study is the fact that cycloplegic refraction was not used. Nevertheless, we sought a methodological design that would minimize this aspect, looking for a reliable alternative. An open-field autorefractometer was used, an instrument that is described as the closest technique to cycloplegic refraction [21, 37]. Another important measure was to combine the spherical equivalent measurement with uncorrected visual acuity, as proposed by others authors [9, 10], enabling to confer more confidence to the myopia prevalence values found in the present study. The definition of a refractive threshold and a visual acuity threshold as a cut-off point for myopia is therefore an added value and strengthens the findings of this study. The selection of the eye with poorer visual acuity may have contributed to some overestimation of myopia prevalence compared to studies that consider only one eye. However, this approach has also been adopted in similar studies [28, 32]. The association between myopia prevalence and the presence of modifiable environmental risk factors (e.g., shorter distance and longer time spent for near work) was not addressed in this study, representing an opportunity for future work. Studying modifiable environemental risk factors is fundamental for understanding which habits and behaviors of adolescents are associated with the development of myopia, providing relevant evidence for the development of recommendations for its prevention and management.

Conclusions

This paper is a cross-sectional study of myopia in adolescents at a center in Portugal. It shows that myopia in adolescence is comparable to that reported by other European countries, being at the upper end of reported rates (above 20.0%). Moreover, it showed that mypia was higher among higher school levels and among students of urban schools.

The high prevalence of uncorrected or under-corrected myopia is a worrying aspect. Another pertinent aspect concerns non- compliance with spectacles, as a considerable number of students who reported having spectacles were not wearing them at the time of the assessment. Adolescents' refusal to wear their usual spectacles puts their ocular health and their school and professional future at risk.

The epidemiological burden of myopia among schoolchildren necessitates a cross-sectoral approach, involving both health and education sectors, to ensure systematic screening, effective refractive error services, optical correction, and ongoing follow-up for affected children. Our results also highlight the critical need for public education on eye care and the development of an effective and sustainable school-age vision screening program to prevent vision impairment and blindness. By integrating public education with practical screening initiatives, we can ensure early detection and treatment, ultimately safeguarding children's vision health.

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Abbreviations

SE	Spherical equivalent
AR	Autorefroctometer
VA	Visual acuity
ETDRS	Early Treatment of Diabetic Retinopathy Study
UVA	Uncorrected visual acuity
VAUC	Visual acuity with usual correction
PhVA	Pinhole visual acuity
VAR	Visual Acuity Rating
OR	Odds ratio
CI	Confidence interval
SEN	Special educational needs

Author contributions

AFN, MCBS and CAG contributed to the concept of the study. AFN and MC acquired and analyzed the data. AFN and CAG helped with the interpretation of the data. AFN and MC drafted the manuscript. MCBS and CAG supervised the study. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study conformed to the principles of the Declaration of Helsinki, and informed consent was signed by the participants' parents. The Ethics Committee of the National School of Public Health, approved this study (approval number CEENSP nº 29/2023).

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Footnotes

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Recent Epidemiology Study Data of Myopia

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Abstract

Myopia, a pandemic refractive error, is affecting more and more people. The progression of myopia could cause numerously serious complications, even leading to blindness. This review summarizes the epidemiological studies on myopia after 2018 and analyzes the risk factors associated with myopia. The prevalence of myopia varies in different regions, age, and observation time. East Asia has been gripped by an unprecedented rise in myopia, and other parts of the world have also seen an increase. The prevalence of myopia in children continues to rise and aggravates with age. The prevalence of high myopia has also increased along with myopia. Racial dependence and family aggregation can be seen frequently in myopia patients. Increased outdoor activities are proven to be protective factors for myopia, as near-distance work and higher education levels affect in the opposite. The impact of gender or urbanization on myopia is controversial. The relationship between nutrition, digital screens, Kawasaki disease, pregnant women smoking during pregnancy, and myopia is still not clear for lack of sufficient evidence. Understanding the various factors that affect myopia helps to clarify the mechanism of myopia formation and also to formulate reasonable prevention and control measures of myopia to protect people's health, especially for adolescents.

1. Introduction

Uncorrected refractive error is not only the second leading cause of global blindness but also the leading cause of preventable visual impairment in children [1]. Myopia, the main manifestation of refractive error, is now an alarming pandemic: 2.5 billion people could be affected by myopia by the end of this decade [2]. In many regions, such as eastern China, myopia is often addressed as a "simple" refractive error, instead of a disease [3]. However, it undeniably increases the risk of diseases of blindness such as macular degeneration, retinal detachment, cataracts, and glaucoma [4-6]. Almost 15 years ago, myopic macular degeneration had already driven myopia to become the leading cause of permanent monocular blindness in Japan [7] and the most frequent cause of severe visual impairment and blindness in the elderly Chinese population in Taiwan [8]. Apart from its deleterious effects on functional vision, the loss of visual acuity associated with uncorrected myopia or permanent vision loss significantly affects all aspects of an individual's quality of life. The constraints that affected individuals experience are likely to further limit their independent choices and pose additional monetary and physical burdens [9]. Furthermore, the economic and financial burden of myopia on families incorporate both the cost of optical devices or other refractive modalities and the need for frequent and long-term management of the condition by an eye-care practitioner [10]. For Chinese urban migrant families, merely the cost of spectacles deters the parents from providing refractive error correction for their children [11], resulting in an increase in myopia and deteriorating functional vision that will certainly damage the future lives of the young. Naidoo et al. reported that the potential global productivity loss associated with the burden of visual impairment was estimated at US$244 billion from uncorrected myopia in 2015 [12]. Controlling myopia, therefore, should be emphasized as a major worldwide public health objective.

2. Global Prevalence of Myopia and High Myopia

In 2016, Holden et al. estimated that the global prevalence of myopia was 1.406 billion people worldwide (22.9% of the global population), and that 163 million people had high myopia in 2000. They also concluded that, by 2050, there will be 4.758 billion people with myopia (49.8% of the global population), and 938 million will have high myopia [13]. In accordance with Holden's methodology, we searched PubMed (National Library of Medicine) on March 1, 2020, for epidemiological studies on myopia after January 1, 2018, regardless of the original language of publication. Population-based studies were chosen because they reflect the real-world data of the epidemic. Countries were grouped based on the continent they belonged to. A summary of the data is given in Table 1, showing that the prevalence of myopia varies significantly between different regions, ages, and observation times.

Table 1

Population-based epidemiology study results of myopia and high myopia published from January 1, 2018, to March 1, 2020, in PubMed (National Library of Medicine) database.

Reference	Region, country	Participant number	Age range, year/cohort	Cycloplegia	Mean age (SD), year	Myopia Definition	Prev (95% %
Chen et al. [14]	East Asia, China (East)	43858	Third-year high school students	No	18.4 (0.7) overall	SE < −0.5 D	79.5 in 20 87.7 in
Huang et al. [15]	East Asia, China (Taiwan)	6069	6–15	No	10.5 (2.3)	SE < 0.0 D	76.6
Wang et al. [16]	East Asia, China (East)	4801	5–20	No	12.3 (3.8)	SE ≤ −0.5 D + UCVA ≤ 20/25	63.1 6
Thorn et al. [17]	East Asia, China (East)	13220	5–16	No	9.4 (1.9)	SE ≤ −1.0 D	49.5
Choy et al. [18]	East Asia, China (Hong Kong)	1396	6–13	No	8.8 (N/A)	SE ≤ −0.5 D	37.7 4
Wang et al. [19]	East Asia, China (southwest)	1626	40–80	No	N/A	SE < −0.5 D	26.4 2 ov 31.5 35 Ha 16.8 20.8
Wang et al. [20]	East Asia, China (Inner Mongolia)	2090	40–80	No	N/A	SE < −0.5 D	29.4 3 ov 31.8 34 Ha 23.0 26 Mor
Yam et al. [21]	East Asia, China (Hong	10137 (4257	6–8 and parents	No*	7.6 (1.0) in children and	SE ≤ −0.5 D (in children) and	25.0 in cl

SE, spherical equivalent; N/A, not available; UCVA, uncorrected visual acuity. *Cycloplegic measurements in patients needed a detailed eye examination. †Cycloplegic measurements in 135 patients. ‡The last recorded refraction including autorefraction, cycloplegic refraction, and/or subjective refractions. §Cycloplegic measurements in 633 patients. ||Cycloplegic measurements in 379 patients.

According to epidemiological surveys from the past two years, the prevalence of myopia varies depending on the continent, country, and region. East Asia has been gripped by an unprecedented rise in myopia, and other parts of the world have also seen an increase. As Morgan et al. referred to in their review, the highest rates occur in China, Japan, and Singapore [46]. In China, the highest prevalence occurs in the eastern areas, which are the economically developed parts of China, as shown in Table 1. In South Asia, the prevalence is much lower than in East Asia. In India, the prevalence of myopia is similar to that of the nearby Tibetan province of China where the prevalence is nearly the lowest in all of China. A meta-analysis concluded that only 5.3% of children younger than 16 years of age are myopic in India [47]. The prevalence of myopia in Europe and North America ranges from 6.2% to 26.2% (Table 1).

At present, most of the epidemiological studies of myopia are based on cross-sectional data, while there are relatively few cohort studies. Cohort studies are more informative since they present the annual incidence and progress of myopia, and currently, they all suggest that the prevalence of myopia is increasing every year. According to the published research, the prevalence of myopia among 12- to 17-year-old students in the United States from 1971 to 2004 increased from 12.0% to 31.2%, and over the past 30 years, the prevalence in all ages has increased significantly [48]. A retrospective study of myopia in Taiwan showed that the average prevalence in 7-year-olds increased from 5.8% in 1983 to 21% in 2000; at the age of 12, the prevalence of myopia was 36.7% in 1983 and increased to 61% by 2000 [49]. In southern China, a 5-year follow-up survey was conducted on 6- to 15-year-old children. The cumulative average annual myopia progression was −2.20 D, and the annual change rate of myopia was −0.43 D [50]. Another study in Beijing, North China, showed that the annual incidence of myopia was 7.8%, and the progression of myopia was −0.17 D [51].

A critical parameter for the epidemiological analysis of myopia is age, since prevalence rates have been known to increase significantly with age, as shown in Table 1. In Finland, a total of 240 myopic school children with a mean spherical equivalent (SE) of −1.43 D at baseline were followed up for 22 years, at the end of which, the mean SE of the more myopic eye was −5.29 D. About 32% of the children receiving their first myopic glasses between and around 11 years of age had high myopia (SE ≤ −6.00 D in one eye) in adulthood. A younger onset age of myopia predicted a greater prevalence of high myopia after 22 years, suggested by a prevalence of 65% for those with baseline ages between 8.8 and 9.7 years and 7% for those aged between 11.9 and 12.8 years [52]. An epidemic of high myopia occurs parallel to myopia, as shown in Table 1, perhaps because early-onset myopia progresses more and more before it stabilizes [46].

3. The Risk Factors of Myopia

The pathogenesis of myopia is not entirely clear from the current research, and more is believed to be the result of genetic and environmental interactions [53]. The rapid development of the modern economy, the process of industrialization, and the improvement of living standards have all affected the occurrence and development of myopia. Similar to other chronic eye diseases, the risks of myopia can be classified as genetic or environmental factors, the latter of which includes outdoor activities, near-distance work, education, gender, and urban environment, among others, as shown in Table 2.

Table 2

Risk factors for the prevalence of myopia.

Risk factors	Reference	Region, country	Odds ratio: prevalence with factor vs. without factor
Parental myopia	Atowa et al. [54]	Africa, Nigeria	6.80 for one myopic parent and 9.47 for two myopic parents
	Yang et al. [43]	North America, Canada (suburban)	2.52
	Harrington et al. [36]	Europe, Ireland	2.4 (paternal)
	Kim et al. [55]	East Asia, Korea	1.84 for myopia and 3.48 for high myopia
Low outdoor activity	Singh et al. [28]	South Asia, India (North)	19.73 (<1.5 hours per day)
	Hagen et al. [34]	Europe, Norway	1.96 (less sport outdoors) and 0.67 (less other outdoors)
	Atowa et al. [54]	Africa, Nigeria	1.25
	Yang et al. [43]	North America, Canada (suburban)	1.17
Time spent on near work/studying/playing	Harrington et al. [36]	Europe, Ireland	3.7 (using screens >3 hours per day) and 2.2 (frequently reading/writing)
	Singh et al. [28]	South Asia, India (North)	2.94 (reading/writing > 4 hours daily) and 8.33 (playing video games > 2 hours daily)
	Wang et al. [16]	East Asia, China (East)	1.88 (moderate school workload) and 2.36 (high school workload)
	Chiang et al. [41]	North America, U.S.	1.27 (watched 2 hours of television daily) and 1.28 (used the computer for 1 hour daily)
High level of education	Wang et al. [19]	East Asia, China (Southwest)	2.50 (undergraduate/graduate)
	Wang et al. [20]	East Asia, China (Inner Mongolia)	1.52 (middle/high school) and 3.77 (undergraduate/graduate)
	Chiang et al. [41]	North America, U.S.	1.79 (senior high school graduate education)
	Yang et al. [32]	Europe, Austria	1.3–1.7 (≥graduated from professional training or served an apprenticeship) in 2013–2017
	[illegible]	[illegible]	[illegible]

3.1. Genetics/Parental Myopia

The common characteristics of hereditary diseases are race-dependency and familial aggregation, both of which are often seen with myopia. A study based on children of different races found that Asians had the highest prevalence of myopia (18.5%), followed by Hispanics (13.2%), and Caucasians had the lowest prevalence (4.4%) [56]. The apparent familial aggregation of myopia can be shown by the high ratio of parental myopia. A study of Chinese children with an average age of 11.45 years found that the prevalence of myopia in children with one or two myopic parents was 2-3 times higher than that in subjects without parental myopia [53]. In Poland, if both parents are myopic, the odds ratio (OR) of the children having high myopia in adulthood has been shown to be 3.9 [52]. Children with parental myopia also have larger SEs and longer eye axial lengths. To a large extent, family association is considered a genetic factor of myopia, rather than inheritance, because family members have the same environment. However, genetic change cannot explain the rapid changes in prevalence that have taken place over the past one or two generations. Genetics play an important role in early-onset myopia and impose a level of baseline risk, while changes in the environment, especially education and outdoor activities, are the main cause of the emergence of myopia epidemics [46]. To date, more than 25 myopic loci have been discovered via linkage analyses, most of which are on autosomal chromosomes. These loci can be found in the Online Mendelian Inheritance in Man (OMIM) database [57]. A few reports have indicated an interactive effect between genetic predisposition and environmental stress [58]; however, the underlying mechanism remains unclear.

3.2. Outdoor Activity

Increasing outdoor activity has been proven to be a protective factor for myopia in many epidemiological investigations, as shown in Table 2. In Guangzhou, 3 years after an increase in outdoor activity in the first grade of a primary school, the accumulation of myopia was 37% lower than that in students without the intervention, and the difference was statistically significant ($P > 0.05$) [59]. Similar results were found in school children in North Ireland, Brazil, and Poland [60–62]. Ho et al. even suggested that 120 min/day of outdoor light exposure during school can prevent the incidence of myopia [63].

The protective mechanism of outdoor activities in relation to myopia is complicated and includes higher illuminance, reduced peripheral defocus, vitamin D, chromatic spectrum of light, physical activity, circadian rhythms, spatial frequency characteristics, and less near-distance work [64]. Among them, higher illuminance is the most well-established theory with evidence shown in both animal and human studies. Norton and Siegwart used animal models to study the relationship between refractive status and light conditions and found that low light (1 to 50 lux) and darkness (<1 lux) are conducive to the extension of the eye axial length, leading to myopia. Strong light (1000–2800 lux), however, delays the occurrence and development of myopia [65]. This effect may be a result of an increase in dopamine receptor D1 activity in the ON pathway [66]. Additionally, Landis et al. measured the amount of time 102 children spent in scotopic (<1–1 lux), mesopic (1–30 lux), indoor photopic (>30–1000 lux), and outdoor photopic (>1000 lux) light during both weekdays and weekends using wearable light sensors, and they found that rod pathways stimulated by dim light exposure are also important in human myopia development. They then suggested that the optimal strategy for preventing myopia with environmental light includes both dim and bright light exposure [67]. Apart from illuminance, many more studies have emerged that focus on the “outdoor light-dopamine” mechanism. Dopamine is a key regulator of both circadian rhythms and eye growth [68]. Natural light from outdoor activities stimulates the retina to secrete more dopamine, and this dopamine was found to control eye growth [69].

We believe that some reported risk factors for myopia may be ascribed to outdoor activity, for example, the seasonal change of myopia growth. Gwiazda et al. found that the speed of myopia progression changes from month to month and is slower from April to September. Therefore, the average progress in winter is higher than that of summer, and the difference is statistically significant ($P < 0.0001$), which may be due to children spending more time outdoors in summer than in winter [70]. In Czech, Rusnak et al. observed 398 eyes of 12-year-old children and found significantly higher axial length growth during the winter period than the summer period. They suggested that the lack of daylight exposure in winter may lead to myopia progression [71].

3.3. Near-Distance Work

Many studies have shown that near-distance work is an important risk factor for myopia, such as reading, writing, and working on a computer, as shown in Table 2. Sherwin et al. demonstrated that children working at a distance less than 30 cm had 2.5 times the rate of myopia than those working at longer distances. Additionally, children who would read for more than 30 min at a time had a higher incidence of myopia than children who read for less than 30 min [72]. Research on the effect of near-distance work and eye movement parameters on myopia has speculated that long-term near-distance work maintains the retina image in a defocused state for a long time. Adjusting to the blurred image, then, results in an increased adjustment lag, which, together with other parameters that make chronic hyperopia defocused for a long time, induces the retina to produce some neurotransmitters or growth factors to regulate the inappropriate growth of the eye axial length, leading to the progression of myopia [73]. Working long hours at a close distance and with a low frequency of breaks during study may also be risk factors for myopia, but further research is still needed.

3.4. Education

Studies in Singapore, Germany, and other countries found that higher levels of education increase the prevalence of myopia [74, 75]. Previous studies have even shown that the higher the level of education, the higher the prevalence of myopia, as shown in Table 2. Better schools or cram schools have also been shown to be risk factors for myopia [76, 77]. A study that tested the biological interaction of genetic predisposition and the education level on myopia risk found that individuals with high genetic risk combined with a college education have a high risk of myopia, and patients with high genetic risk but only primary education have a much lower risk of myopia [78]. Education may reflect a complex combination of higher levels of exposure to near-reading and correspondingly lower levels of outdoor physical activity, leading to an upregulation of high-risk genes, excessive eye growth, and the development of myopia.

3.5. Others

Other myopia-related risk factors such as gender, urbanization, nutrition, digital screens [79, 80], Kawasaki disease [81], and maternal grandmother smoking during pregnancy [82] have been reported, but most of them lack sufficient evidence. Data concerning the effect of gender or urbanization on myopia prevalence, for example, is conflicting. In one study in India on children younger than 16 years old, girls living in urban areas were significantly more likely to have myopia than boys [47], whereas Reed et al. found the opposite to be true [39]. In the same report from Indian, the prevalence of myopia was shown to be higher in urban areas compared to rural areas (OR 2.12) [47], supporting the idea that severe air pollution in cities may accelerate myopia progression [83]. However, Morris et al. did not find strong evidence associating urban or rural status with the incidence of myopia in a United Kingdom cohort of 3,512 children. In that study, the association between the geographical setting and myopia was considered to be potentially driven by underlying confounding factors such as education and time spent outdoors [84].

Nutrition is important for eye development in children and has been suggested to play a role in the incidence of myopia in early life. For example, children who were breastfed during the first 6 months of life were found to be less likely to have myopia [85]. However, the association between diet and myopia is controversial [86, 87]. Recently, there was no significant correlation between an infant's diet at 6, 9, and 12 months and SE, axial length, or myopia at age three years in a Singapore cohort study [88].

4. Conclusions

In summary, myopia not only affects the physical and mental health of individuals but also puts a great burden on society. Myopic adolescents are more likely to be anxious than those without myopia [89]. Knowing the various factors that affect the occurrence and development of adolescent myopia is conducive to clarifying the mechanism of myopia formation and also to formulating reasonable prevention and control measures of myopia to protect the health of adolescents.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Xiang Zhao-Yu contributed to the literature search, manuscript preparation, manuscript editing, and manuscript review. Zou Hai-Dong contributed to the concept, design, definition of intellectual content, literature search, data acquisition, data analysis, manuscript preparation, manuscript editing, and manuscript review.

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

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Abstract

Purpose

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

Methods

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

Results

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

Conclusions

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

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

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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).

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CONFLICT OF INTEREST

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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)

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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]

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