• Investigation •

Prevalence of refractive errors in school-aged and preadolescent children in Colombia

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Abstract

● **AIM:** To describe the distribution of refractive errors by age and sex among schoolchildren in Soacha, Colombia.

● **METHODS:** This was an observational cross-sectional study conducted in five urban public schools in the municipality of Soacha. A total of 1161 school-aged and pre-adolescent children, aged 5-12y were examined during the school year 2021-2022. Examinations included visual acuity and static refraction. Spherical equivalent (SE) was analysed as follows: myopia SE≤-0.50 D and uncorrected visual acuity of 20/25 or worse; high myopia SE≤-6.00 D; hyperopia SE≥+1.00 D (≥7y) or SE≥+2.00 D (5-6y); significant hyperopia SE≥+3.00 D. Astigmatism was defined as a cylinder in at least one eye ≥1.00 D (≥7y) or ≥1.75 D (5-6y). If at least one eye was ametropic, children were classified according to the refractive error found.

● **RESULTS:** Of the 1139 schoolchildren included, 50.6% were male, 58.8% were aged between 5 and 9y, and 12.1% were already using optical correction. The most common refractive error was astigmatism (31.1%), followed by myopia (20.8%) and hyperopia (13.1%). There was no significant relationship between refractive error and sex. There was a significant increase in astigmatism (*P*<0.001) and myopia (*P*<0.0001) with age.

● **CONCLUSION:** Astigmatism is the most common refractive error in children in an urban area of Colombia. Emmetropia decreased and myopia increased with age.

● **KEYWORDS:** Colombia; prevalence; refractive errors; myopia; hyperopia; astigmatism; children

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INTRODUCTION

Emmetropisation is the process by which the dioptric power of the cornea and lens equilibrates with the axial length of the eye during postnatal development, so that the far point is at optical infinity when accommodation is relaxed[1]. Therefore, as eye size increases, the refractive error is expected to decrease towards emmetropia. However, genetic, environmental, and behavioural factors can contribute to the dyshomeostasis of the emmetropisation process resulting in a lack of coordination between the growth rates of the components of the eye[2], favouring the development of refractive errors such as myopia, hyperopia, and astigmatism.

Uncorrected refractive error is now recognised as the most common preventable eye disease affecting all age groups and is therefore considered a public health challenge. According to the World Report on Vision, refractive error is the leading cause of moderate or severe visual impairment in distance vision and blindness, affecting 123.7 million people worldwide, particularly in low- and middle-income countries[3], so reducing the prevalence of uncorrected refractive error is a major challenge in meeting the global eye care needs of preventable visual impairment and blindness. Uncorrected refractive error can lead to changes in the early literacy process[4] and poor academic performance[5], affecting a child's well-being, productivity and quality of life[6].

Colombia, the third most populous country in Latin America, presents a complex scenario due to the limited number of epidemiological studies dedicated to the detection of refractive errors[7-8]. However, reports from the Ibero-American Epidemiological Network on Visual and Ocular Health (REISVO, by its acronym in Spanish), indicate that data from the Individual Records of the Provision of Health Services

(RIPS, by its acronym in Spanish) show that between 16.6% and 24% of the population have refractive errors. In the 5-14y age group, the 2009 data show that 27.7% had hyperopia, 19% had myopia and 53.3% had astigmatism. In 2010, the same refractive errors were at 29.0% (hyperopia), 17.9% (myopia) and 53.1% (astigmatism)[9].

Several studies in Colombia have looked at this problem. A study in Bogotá of 109 children aged 4 to 9y reported 15.1% with astigmatism, 13.8% with hyperopia and 2.3% with myopia[10]. Another study examined a sample of 112 children between the ages of 2 and 14 years old from an educational institution in Bogotá and found a prevalence of refractive errors of 18.8%[11]. These studies indicate a high prevalence of refractive errors in the Colombian young population and the importance of conducting studies in larger groups. The high rate of refractive errors has a significant impact in developing countries such as Colombia, especially due to factors such as low socioeconomic levels and insufficient visual health care infrastructure[10]. The statistics of refractive errors vary according to geographical location, especially for myopia, where the prevalence rates are higher in urban areas (15.7%) compared to rural areas (9.2%)[7]. The results of the present study are of great academic interest and provide epidemiological figures in regions that, although urban, have limited access to health care and major economic and cultural problems.

In view of the above, it is of the utmost importance to obtain data on the prevalence of refractive errors in the Colombian paediatric population. The analysis and understanding of these results will allow the implementation of effective interventions and the prevention of adverse and irreversible changes in the ocular anatomy leading to uncorrected refractive errors, especially in the context of the school population at the national level.

The aim of this study was to determine the frequency of refractive errors, by age and sex, in school-age and preadolescent children living in Soacha, Colombia, who have access to free education in the public schools of the municipality.

PARTICIPANTS AND METHODS

Ethical Approval This research adhered to the Declaration of Helsinki and was approved by the Ethics Committee of the Universidad El Bosque (code: PIS-2021-042) in Bogotá, Colombia. Informed consent was obtained from the children and their parents to participate and undergo clinical optometric examinations.

Design and Sampling This was a quantitative, observational, cross-sectional study in five public schools in the municipality of Soacha, selected by non-probability sampling from among 21 public schools. Soacha is a municipality with a high population density, considered one of the highest in Latin America. Its accelerated demographic growth since 1993 is linked to territorial expansion, migration and forced displacement. According to projections based on the latest census carried out by the National Department of Statistics of Colombia (DANE, by its acronym in Spanish), the number of children aged between the ages of 5 and 12 in Soacha in 2020 was 89 304. The sample of children to be included was calculated using the free software OpenEpi, based on the frequency of myopia and hyperopia in children between 8 and 10 years of age of 34.3%, reported in Bucaramanga, Colombia[8], with a confidence level of 95% and an absolute precision of 2.8%, giving a result of 1091 children.

In each school, all children from kindergarten to eighth grade were invited to participate. A letter was sent to the parents informing them of the objectives of the study and asking them to give permission for their children to participate. Due to the socio-economic conditions of the residents of Soacha, both parents usually work during the day, so it was not possible for them to accompany the children during the visual examination. A total of 1161 primary school children were enrolled.

Eligibility Criteria Children aged between 5 and 12y were eligible for inclusion. Children with irregularities or opacities in the refractive media of the eye and those with cognitive and/or motor disabilities that limited the quality of their responses were excluded.

Visual Assessment For the visual assessment of the children, the study used the visual acuity and retinoscopy protocol proposed in the Refractive Errors Studies in Children (RESC) protocol, developed by the World Health Organization (WHO)[12]. The tests were first performed on university students to standardise the procedures. This pilot study was performed on 10 participants.

The visual assessment was carried out at each school that the children regularly attended. A data collection form was used to record the personal, socio-demographic and clinical information of the participants. Visual acuity at 3 m, with and without correction, and refractive status were assessed by static non-cycloplegic retinoscopy. Distance visual acuity was measured with a logMAR chart with five optotypes on each line, using the Lea symbols chart and the Lea numbers chart. Acuity was measured from the top line (20/200).

The child was asked to read the letters one at a time as they moved down the chart. If four or more optotypes were read correctly, the child was then tested by moving down to line 4 (20/100). If one or no optotypes were missed, testing resumed at line 7 (20/50) and continued to line 10 (20/25) and finally line 11 (20/20). If the child missed at least four optotypes at any level, the line immediately above the failed line was tested until success was achieved. The right eye was tested first, followed by the left, each time with the fellow eye occluded. Visual acuity was first measured with spectacles, if the child wore them, followed by measurement of uncorrected (unaided) vision.

Refraction Participants were seated in a classroom with natural lighting, the optotype was 3 m away and this was the fixation point. Manifest retinoscopy was performed by optometrists with more than 10y experience, at a distance of 50 cm and with a +2.00 diopter (D) lens in the trial frame.

Participants with visual acuity ≤20/40 underwent cycloplegic refraction at the optometry services of two private universities in Bogota, Colombia. The protocol used for cycloplegic refraction was 1% cyclopentolate, one drop in each eye, followed by a second drop 5min later, and refraction was performed 15-20min later, when the pupil diameter was >6 mm. The two reference centres for performing cycloplegia in children requiring it adopted the RESC procedure to perform the same refraction protocol. In eyes with successful cycloplegia, refraction was performed with a streak retinoscope in a dimly lit room, with the examiner at a distance of 50 cm and a +2.00 D lens in the trial frame.

Definition of Refractive Errors Myopia was defined as a combination of spherical equivalent (SE) ≤-0.50 D and uncorrected visual acuity (UCVA) of 20/25 or worse, taking into account that cycloplegia was not used in all the children. High myopia was defined as SE≤-6.00 D. Hyperopia was defined as SE≥+1.00 D (≥7y) or SE ≥+2.00 D (5-6y) and significant hyperopia SE≥+3.00 D. Cylindrical refractive error in at least one eye ≥1.00 D (≥7y) or ≥1.75 D (5-6y) was considered astigmatism[13]. Children were classified as emmetropes if emmetropia was found in both eyes. If at least one eye was ametropic, children were classified according to the refractive error found. If both eyes were different in terms of ametropia, the patient was included in the anisometropia group[8].

Statistical Analysis Categorical variables were expressed as absolute and relative frequencies. Normality of distribution of continuous variables was assessed using the Shapiro-Wilk test and measures of central tendency and dispersion were analysed using non-parametric methods. Comparison of the SE by age was performed using the Kruskal-Wallis test and by sex using the Mann-Whitney test. Analysis of refractive error type and sex was performed using the *Z*-test for comparison of proportions. The association between age and myopia or astigmatism was evaluated by calculating the odds ratio (OR) and the Chi-square test. For all analyses, *P*-values of <0.05 were considered indicative of statistical significance. Analyses were performed using the Stata 14 statistical package (StataCorp, College Station, TX, USA) and Epidat 3.1 (Xunta de Galicia and PAHO-WHO).

Table 1 Distribution of the study population by age and sex *n* (%)

Age (y)	Female	Male	Total
5	44 (7.8)	42 (7.3)	86 (7.5)
6	64 (11.4)	80 (13.9)	144 (12.6)
7	92 (16.3)	106 (18.4)	198 (17.4)
8	70 (12.4)	62 (10.8)	132 (11.6)
9	43 (7.6)	67 (11.6)	110 (9.7)
10	60 (10.7)	49 (8.5)	109 (9.6)
11	45 (8.0)	45 (7.8)	90 (7.9)
12	31 (5.5)	30 (5.2)	61 (5.4)
No data	114 (20.3)	95 (16.5)	209 (18.3)
Total	563 (100)	576 (100)	1139 (100)

Table 2 Distribution of refractive error in the right and left eyes D

Items	Right eye			Left eye		
	Sphere	Cylinder	SE	Sphere	Cylinder	SE
Minimum	-18.00	-8.50	-20.25	-16.00	-6.25	-19.00
25th percentile	0.00	-1.00	-0.25	0.00	-1.00	-0.25
Median	+0.25	-0.50	+0.13	+0.25	-0.50	+0.13
75th percentile	+0.75	0.00	+0.50	+0.75	0.00	+0.50
Maximum	+12.00	0.00	+12.00	+11.00	0.00	+10.25

D: Diopters; SE: Spherical equivalent.

RESULTS

A total of 1161 children attended the five urban public schools in the municipality of Soacha in the department of Cundinamarca, Colombia. Of these, 16 were excluded because they did not meet the age criteria and 6 were excluded because of missing refractive data. Of the 1139 children included, 138 (12.1%) were already using optical correction, of which 76 (55.1%) required a change in prescription. In total, glasses to 360 children (31.6%) were provided with spectacles. Of the total number of children examined, 119 (10.24%) were referred to university centres for cycloplegic refraction.

The study population consisted of 576 males (50.6%). Age was not normally distributed (Shapiro-Wilk *P*<0.000); the median age for girls was 8y [interquartile range (IQR) 3] and for boys was 8y (IQR 4). The most common age was 7y and the least common was 12y; 58.8% of the study population was aged between 5 and 9y (Table 1).

The distribution of refractive error in both eyes tended towards emmetropia, although high levels of myopia and hyperopia were found (Table 2).

The distribution of the SE was similar in both eyes, with many myopic and hyperopic outliers (Figure 1).

Comparison of the SE by age showed statistically significant differences (Kruskal-Wallis, *P*=0.0001; Figure 2).

Clinical emmetropia was the most common refractive state [65.7%; 95% confidence interval (CI) 62.9%-68.5%], followed by myopia (20.8%; 95%CI 18.4-23.2) and hyperopia (13.1%; 95%CI 11.1%-15.1%; Figure 3). Anisometropia was present

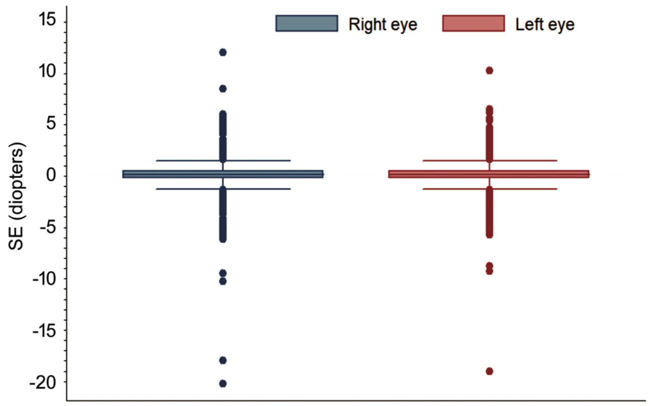

Figure 1 SE distribution of the right and left eye SE: Spherical equivalent.

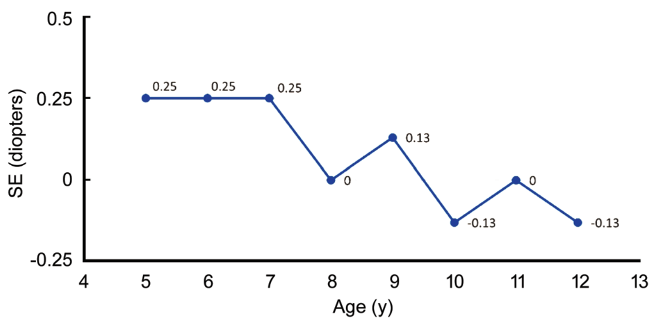

Figure 2 SE (median) by age SE: Spherical equivalent.

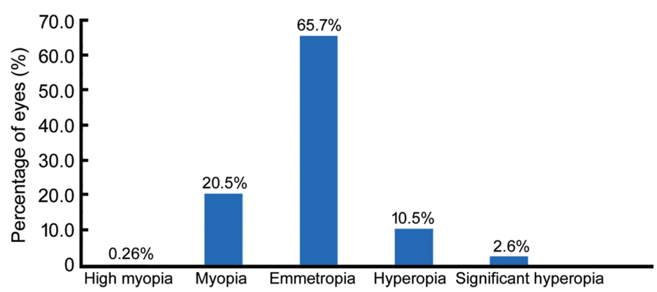

Figure 3 Distribution of refractive error in the study population.

Table 3 Prevalence of refractive error by sex

Refractive error	Female		Male		Total
	n (%)	95%CI	*n* (%)	95%CI	P^a
Hyperopia	80 (14.2)	11.2-7.2	69 (12.0)	9.2-4.7	0.3038
Myopia	116 (20.6)	17.2-24.0	121 (21.0)	17.6-24.4	0.9247
Astigmatism	178 (31.6)	27.7-35.6	176 (30.6)	26.7-34.4	0.7469

[a]Comparison of proportions using *Z*-statistics. CI: Confidence interval.

in 0.4% of the children. Astigmatism in at least one eye ≥1.00 D (≥7y) or ≥1.75 D (5-6y) was present in 31.1%. High myopia occurred in 0.26% of the children, unilateral myopia in 3.3% and significant hyperopia in 2.6% (Figure 4).

There was no significant association between the type of refractive error and sex (Table 3). Furthermore, there was no significant difference between boys and girls when comparing the SE (median SE: +0.13 D in both eyes for girls and boys; Mann-Whitney test, right eye *P*=0.6022 and left eye *P*=0.0910).

Finally, a significant association was observed between age (9-12y *vs* 5-8y) and myopia diagnosis (OR 1.89; 95%CI 1.37-2.59, *P*<0.0001). Similarly, an association was observed between age and astigmatism (OR 1.65; 95%CI 1.25-2.18, *P*<0.001). No significant association was found between age and hyperopia (OR 1.17; 95%CI 0.81-1.70, *P*=0.483).

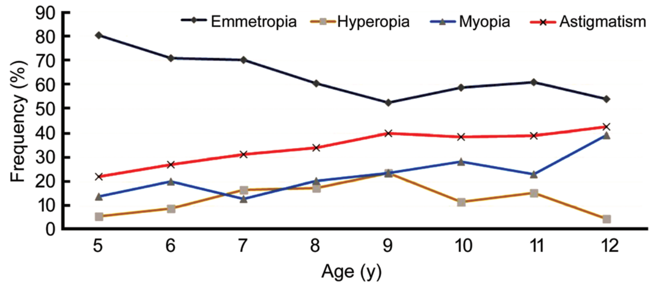

Figure 4 Frequency of refractive error by age.

DISCUSSION

The most common refractive errors in Colombian children were astigmatism (31.1%) and myopia (20.8%). Several factors may influence the prevalence of refractive errors such as ethnicity, family history, age, diagnostic method, and classification. Astigmatism is known to be associated with prematurity, family history, general health, ocular health, biometric components, and eyelid muscle tension[14-16], while myopia is associated with genetic, environmental, and occupational factors, schooling[17-18], and methods of refractive correction. Myopia could be the result of the use of traditional corrective lenses, which interfere with the emmetropisation process, leading to an increase in the negative magnitude, as the power of the corrective lens would add to the power of the eye, making it more myopic[19].

Corneal astigmatism is typically present from birth, with a greater predominance in newborns with low birth weight and lower postconceptional age[15], and tends to decrease during childhood due to the compensating effect of internal astigmatism[20]; however, when the magnitude is high (≥3.00 D), the prevalence increases during adolescence, then seems to stabilise in adulthood, before increasing again in old age with a tendency to be mainly corneal in nature, with a symmetrical axis and against the rule[21].

The estimated global prevalence of astigmatism is 14.9% in children and 40.4% in adults[22]. Up to 20% of untreated cases with astigmatism ≥2.00 D may develop amblyopia[23]. It has been suggested that uncorrected astigmatism may influence the development and progression of myopia[15]. In addition, its association with myopia increases the likelihood of posterior pole damage[24] and may affect vision at all distances, contrast sensitivity, and proper processing of stimuli, which may interfere with cognitive function, language ability, and fine motor tasks[25].

In terms of the prevalence of refractive errors in the Americas, Colombia is in the middle range of global data, with a lower frequency of myopia than in European and Asian studies[7].

However, until 2017, the Americas had the highest prevalence of hyperopia (37.2%) and astigmatism (27.2%) in children and adults, and this trend has not changed in recent years[26]. This suggests an important role for family history and genetic factors in the causation of refractive errors[16]. The reported prevalence of myopia in Latin America was 16% between 1997 and 2017, with considerable differences between rural (1.4%) and urban areas (14.3%), and a lower prevalence rate up to the age of 20y (8.9%) compared to adults (26.9%)[27].

The highest prevalence of myopia in the Americas was reported in Puerto Rico between the ages of 5 and 17y (20.7%), higher in females (23.3%) than males (18.0%) and associated with a significant increase with age, up to -0.65 D in the 17-year-old group compared to 5-year-old children[28]. Similarly, the prevalence of myopia in the present study was 20.8% in schoolchildren aged between 5 and 12y. This is despite the fact that non-cycloplegic manifest retinoscopy was used and that the study population was younger (up to 12 years of age) compared to the study conducted in Puerto Rico (up to 17 years of age).

Galvis *et al*[7] reported the frequency of refractive errors in children and adolescents aged 8-17y living in rural Bucaramanga, Colombia. The prevalence of hyperopia, myopia, and high myopia was 23%, 11.2%, and 0.2%, respectively. These results differ with regard to the frequency of myopia and hyperopia in the present study, which may be due to the different geographical setting. This study was carried out in an urban school, an environment conducive to greater academic activity in children and associated with a twofold higher risk of having myopia[7]. In this study, the frequency of myopia increased from 10.2% in the 9-10 years age group to 23% in the 17 years age group[8], although in most cases the refractive error did not exceed -3.00 D. In the present study, there was also a statistically and clinically significant relationship between myopia and increasing age. This suggests a need for targeted interventions for children at this age, as the process of emmetropisation slows down and the anatomical and refractive regulation can be altered by school, environmental, and occupational factors[17].

Emmetropisation is an active feedback mechanism that regulates the refraction of the eye, and this process is thought to occur between 6 and 8 years of age. However, recent research suggests that the process of emmetropisation may continue into adolescence, and it may not progress towards emmetropia in all cases due to optical corrections that affect the course of refraction. Thus, it is postulated that myopia may be the result of interference with emmetropisation by negative corrections during childhood and adolescence. Similarly, stabilisation will also depend on differences in habits and the anatomical capacity of the orbit[19].

The prevalence of astigmatism reported in earlier years was lower, whereas in more recent studies, children with astigmatism had longer axial lengths and less outdoor activity[29-30]. In children aged 7 to 11 years of age with astigmatism and longer axial lengths (AL≥24.5 mm), more rapid changes in cylinder power of up to -0.50 D were found after two years of follow-up. It has been suggested that larger eyes may interact more with the eyelids, increasing cylinder power and, in the case of high astigmatism, promoting myopia progression[31].

In general, AL elongation is associated with structural changes, such as a decrease in the density of photoreceptor cells and the retinal pigment epithelium (RPE), leading to a thinning of the retina, particularly at the equator, accompanied by a reduction in the thickness of the choroid and sclera, especially at the ora serrata. It has been estimated that for every millimetre of change in AL, myopia increases by approximately -2 D[32]. These changes can progress even after 15y in 50% of cases[33].

Globally, an increase in the prevalence of myopia has been reported in recent years; for example, in Spain, the prevalence of myopia increased from 16.8% in 2016 to 21.2% in 2020; this was largely attributed to an increase in the amount of time spent in near vision and the excessive use of digital devices[34].

In Latin America, a 2018 study in Chile found that the prevalence of myopia in first graders was 5.6%, while myopic astigmatism in the same age group increased the prevalence to 33%. In line with the results of the present study, the same research showed an increase in the 6th graders, 18.1% of whom were myopic[35]. Similarly, a study carried out in Puerto Rico in 2023 on children aged between the ages of 5 and 17y showed that 1 in 5 children (20.7%) had a significant tendency towards myopia[28], which is similar to the results of the present study.

Regarding hyperopia, in a study of schoolchildren aged 6-8y in Colombia (2020), the prevalence of hyperopia with SE≥+2.00 D was 33.5%. The refractive errors were associated with diet, physical activity, and personality traits, with hyperopes showing lower abilities in the safety and doubt scales, using the ESPQ personality questionnaire for children by Coan and Cattell, adapted to Spanish[36]. In general, the prevalence of hyperopia has been calculated using different cut-off points; for example, a study in Colombia[8] proposed values starting from SE>+0.50 D, but other reported values start from ≥+2.00 D[28]. These parameters should be evaluated carefully, as the use of different parameters may lead to different prevalence rates, making comparisons between studies impossible. In the present study, 13.1% of children presented with hyperopia, using an age-based classification[13]. This value is the same as that reported by Solano *et al*[10], who applied cycloplegia to all the children studied, but lower than that reported by Galvis *et al*[8] and slightly higher than that reported by Santiago *et al*[28], possibly due to the use of different cut-off points. The lack of cycloplegic refraction may have led to an underestimation of hyperopia due to accommodation.

In contrast, the results for anisometropia in the present study (0.4%) are different from those of Solano *et al*[10] (4.6%) in children from Bogotá, but similar to those of Galvis *et al*[8] (0.4%) in children from Bucaramanga, again due to differences in the definition of refractive error.

In a study of urban schoolchildren in Chile, 10.8% used optical correction at the time of the examination. In the present study, 12.1% had an optical correction. The low percentage of correction use may be due to socio-economic conditions that hinder access to health services and the purchase of optical products, but also to forgetfulness, aesthetic reasons, or damage to glasses, and the tendency of children to wear glasses occasionally[37].

Visual assessment and refraction were carried out in the schools and refraction under cycloplegia was not possible in this non-clinical scenario, due to potential serious side effects such as fever, tachycardia, seizures, delirium, or visual hallucinations, which could not be controlled in the educational setting. In cases where cycloplegia was required, children were referred to universities, where trained healthcare professionals were available to manage any adverse complications associated with the use of cycloplegia[34]. Although the REISVO clinical protocol followed international standards, the recommendation for the paediatric population was to ensure the inactivity of accommodation by refraction under cycloplegia[17]; this limitation may have overestimated the frequency of myopia and astigmatism in this study. Similarly, it is suggested that future studies should measure the AL of the eye, which could also contribute to a more accurate identification of eyes with disproportionate anatomical characteristics and optical parameters. In addition, the selection of the study population was guided by the intention to contribute to a social cause by providing free access to optical correction for children with financial constraints. Therefore, these results may not be fully generalisable to children of different socioeconomic status and those with greater access to technological devices, sports, and recreational activities. This study aimed to conduct a study with participants up to the age of 17y to further investigate the relationship between refractive error and the use of optical correction with academic demands and other educational challenges faced by adolescents. Other research priorities include the assessment of myopia progression of in children corrected with monofocal negative lenses, studies of myopic astigmatism, and the associated risk factors, and multidisciplinary research on neonatal care research involving ophthalmologists and obstetricians to identify modifiable factors that can help control myopia and astigmatism.

In conclusion, astigmatism and myopia were the most common refractive errors in urban schoolchildren in Colombia. It seems that the rates of emmetropia decrease with age and the frequency of myopia increases. Furthermore, the prevalence of hyperopia was found to decrease after the completion of the emmetropisation process. These results highlight the need for a systematic update of the epidemiological data on refractive errors in Colombia. It is also necessary to analyse the genetic, environmental, occupational, and socio-demographic factors that may influence the prevalence of refractive errors in the region. There is also a need to follow up myopic and astigmatic children corrected with monofocal negative lenses, which alter the natural process of emmetropisation. A consensus on the definition of hyperopia should be reached in order to facilitate the comparison of prevalence figures in different regions and to identify its possible aetiology.

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