Original Article

Astigmatism among schoolchildren in Mumbai, India: a large, population-based study

Mumtaz Qazi [1] and Priyanka Singh[1]

[1] Lotus College of Optometry, Juhu, Mumbai, India

ABSTRACT

Background: Astigmatism is a common refractive error. If left untreated, it may result in blurred or distorted vision. We determined the prevalence of astigmatism in schoolchildren aged 6–16 years in Mumbai, India.

Methods: A cross-sectional study was conducted using a stratified cluster random sampling method. We included primary and secondary schoolchildren aged 6–16 years. All children underwent a comprehensive eye examination. Astigmatism was characterized as having a diopter cylinder (DC) power of 0.50 or more in at least one eye, and for prevalence estimation, we reported the number of children with astigmatism. Astigmatism severity was defined as mild (≤ - 1.50 DC), moderate (- 1.50 DC to - 2.50 DC), and severe (> - 2.50 DC). Based on the axis orientation, astigmatism was categorized as with-the-rule, against-the-rule, and oblique.

Results: A total of 3151 schoolchildren with a mean (standard deviation) age of 12.1 (2.9) years were screened; boys and girls accounted for 49.22% and 50.78%, respectively. Age groups of 6–9, 10–13, and 14–16 years accounted for 51.35%, 28.53%, and 20.12%, respectively. The overall prevalence of astigmatism was 11.46%, with no significant difference between sexes ($P > 0.05$). The prevalences of astigmatism in the groups aged 6–9-, 10–13-, and 14–16 years were 5.24%, 3.49%, and 2.73%, respectively. Prevalence differed significantly among age groups ($P < 0.05$), with a trend of decreasing prevalence with increasing age. No significant association was found between age and severity of astigmatism ($P > 0.05$). The prevalences of mild, moderate, and severe astigmatism were 6.51%, 3.11%, and 1.84%, respectively. Mild astigmatism was significantly more prevalent than moderate ($P < 0.05$) or severe astigmatism ($P < 0.05$). The prevalence of astigmatism differed significantly among the three orientations of axis ($P < 0.001$). The prevalences were 9.20%, 1.68%, and 0.57% for with-the-rule, against-the-rule, and oblique astigmatism, respectively. We found a statistically significant difference in the prevalences of astigmatism based on the axis orientation between boys and girls ($P < 0.05$) and between age groups ($P < 0.001$), with a decreasing trend observed with increasing age.

Conclusions: We found a prevalence of 11.46% for astigmatism among schoolchildren aged 6–16 years in Mumbai, India. There was a decreasing trend in prevalence with increasing age, with no difference between sexes. The prevalence was the highest for mild astigmatism, followed by moderate and severe astigmatism. Prevalence differed significantly based on the axis orientation among the three subtypes, age groups, and between the two sexes, with a decreasing trend with increasing age. With-the-rule astigmatism was the most common, followed by against-the-rule astigmatism; oblique astigmatism was the least common.

KEYWORDS

ocular refraction, optometrist, ophthalmologist, children, child, frequency, prevalence, vision screening

Correspondence: Mumtaz Qazi, Lotus College of Optometry, Juhu, Mumbai, Maharashtra, India. Email: mumtaz@lcoo.edu.in. ORCID iD: https://orcid.org/0000-0002-4693-7945

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INTRODUCTION

Astigmatism, a common refractive error, is characterized by the uneven focusing of light onto the retina owing to variations in the curvature of the cornea or crystalline lens, resulting in blurred or distorted vision [1]. Globally, it is prevalent among both children and adults. Factors such as age, genetic predisposition, environmental influences, and ocular muscle dynamics contribute to the variability in astigmatism prevalence [2-4]. Astigmatism presents in different meridians, including with-the-rule, against-the-rule, and oblique, depending on the predominant meridian of optical power [5, 6]. Both corneal and lenticular irregularities contribute to the overall astigmatism [7].

If untreated, astigmatism can result in various visual issues, including eyestrain, diplopia, and reduced visual acuity. Additionally, uncorrected astigmatism has been associated with a decline in quality of life, increased risk of falls, and difficulties with nighttime driving [8, 9]. Astigmatism affects not only visual acuity, but also visual development, particularly in children. Early detection and correction are vital, as uncorrected astigmatism can lead to conditions such as amblyopia [10, 11].

Astigmatism is a common refractive error affecting both children and adults worldwide. The prevalence varies by age, ethnicity, and geography [12, 13]. Studies conducted across different regions have reported varying prevalence rates in children. For instance, research in Wuxi, China, found that 36% of preschool children aged 1–5 years had astigmatism [14], whereas in Iran, the prevalence was 16.7% among 6–12-year-old children [15].

Over half of children aged 6–17 years who failed vision screening in South India had astigmatism [16]. However, limited data are available for Mumbai. We investigated the prevalence of astigmatism in schoolchildren aged 6–16 years in this region.

METHODS

This cross-sectional study was conducted in Mumbai, India, between August 1, 2022, and February 1, 2023, to identify the prevalence of astigmatism among schoolchildren aged 6–16 years. The study adhered to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Lotus College of Optometry, Juhu, Mumbai, Maharashtra, India. Consent was obtained from school deans, and verbal consent was obtained from parents or legal guardians of the schoolchildren.

We used a stratified cluster random sampling method to ensure representative participant selection from a diverse array of schools in the region. Mumbai Schools functions as a population; we divided it into various clusters based on geographical zone and randomly selected schools from each cluster [17]. We included primary and secondary schoolchildren aged 6–16 years. We excluded children with ocular comorbidities or histories that might affect the results [15] and those with a spherical component of refraction more than + 4.00 D or - 6.00 D.

Following a detailed history-taking, visual acuity was measured under appropriate lighting conditions using a logarithm of the minimum angle of resolution (logMAR) letter chart (non-illuminated Bailey–Lovie logMAR chart; Precision Vision, Illinois, USA). Objective refraction was performed using streak retinoscopy (Keeler; Halma Co., Windsor, UK); the right eye was examined first, followed by the left eye, and the results were documented. Subjective refraction (Baliwalla and Homi Trial Set and Trial Frames; Baliwalla & Homi Pvt. Ltd., Mumbai, India) was then conducted and the final refraction with the best-corrected distance visual acuity was recorded.

All the subjective refraction steps were followed during refraction, starting from initial spherical refraction, cylinder refinement for axis, then assessment of power using a Jackson cross cylinder [18] (Baliwalla and Homi Trial Set and Trial Frames; Baliwalla & Homi), best vision sphere, +1.00 blur test, and binocular balancing using the prism dissociation method [19, 20].

All individuals underwent comprehensive ocular and visual function assessments. Pupil examination was conducted with a simple pen torch to evaluate the direct and consensual reflexes and to assess for relative afferent pupillary defects [21, 22]. The cover and alternate cover tests were performed for both distance and near vision using an occluder (Baliwalla & Homi). Additionally, binocular vision tests, including the near point of convergence [23] and near point of accommodation [24], were performed. Stereopsis was evaluated using the Titmus Fly Chart (Stereo Optical Co., Inc., Chicago, IL, USA) [25], and color vision was assessed using the Ishihara Test for Color Deficiency (Kanehara Trading Inc., Tokyo, Japan) [26]. Undilated examination of the anterior and posterior segments was performed using a slit-lamp biomicroscope (Zeiss SL 220; Carl Zeiss Meditech AG, Jena, Germany) and a direct ophthalmoscope (Keeler Ltd., Windsor, UK), respectively.

Astigmatism was characterized as having a diopter cylinder (DC) power of 0.50 or more in at least one eye, and for prevalence estimation, we determined the number of children with astigmatism. Astigmatism severity was further categorized as mild (≤ - 1.50 DC), moderate (- 1.50 DC to - 2.50 DC), and severe (> - 2.50 DC) [2]. In addition, astigmatism was categorized based on axis orientation into with-the-rule, against-the-rule, and oblique [15]. The spherical equivalent of the refractive error (SEQ) in D was determined for the study population and calculated as sphere + 1/2 cylinder [27].

Data were analyzed using IBM SPSS Statistics for Windows (version 29.0; IBM Corp., Armonk, NY, USA). The normality of the data distribution was determined using the Shapiro–Wilk test. An independent samples *t*-test, Mann–Whitney U-test, Kruskal–Wallis test, or chi-square test was used for further analysis when applicable. *P*-value < 0.05 was defined as the significance level.

RESULTS

A total of 3151 schoolchildren with a mean (standard deviation [SD]) (range) age of 12.1 (2.9) (6–16) years were screened; boys and girls accounted for 49.22% (n = 1551) and 50.78% (n = 1600), respectively. The groups aged 6–9, 10–13, and 14–16 years accounted for 51.35% (n = 1618), 28.53% (n = 899), and 20.12% (n = 634) of participants, respectively. The mean (SD) SEQ of refractive error was -1.2 (1.6) D. The prevalence of astigmatism in the total population was 11.46% (n = 361), with no significant difference between the sexes (P = 0.45); the prevalences of astigmatism in boys and girls were 5.43% (n = 171) and 6.03% (n = 190), respectively. The prevalences of astigmatism in the 6–9, 10–13, and 14–16-year age groups were 5.24% (n = 165), 3.49% (n = 110), and 2.73% (n = 86), respectively. We found a significant difference in the prevalences of astigmatism among the different age groups (P = 0.021), observing a decreasing trend with increasing age. The prevalence of astigmatism was significantly higher in the 6–9-year age group than in the 10–13 (P = 0.015) and 14–16-year (P = 0.02) age groups.

Table 1 displays the prevalences of astigmatism based on severity level, and Table 2, those based on axis orientation among sex and age groups. No significant association was found between age and severity of astigmatism (P = 0.670). The prevalences of mild, moderate, and severe astigmatism were 6.51% (n = 205), 3.11% (n = 98), and 1.84% (n = 58), respectively. Mild astigmatism was significantly more prevalent than moderate (P = 0.035) or severe astigmatism (P = 0.035). The prevalence of astigmatism differed significantly among the three orientations of axis (P < 0.001): with-the-rule, 9.20% (n = 290); against-the-rule, 1.68% (n = 53); and oblique, 0.57% (n = 18). We found a statistically significant difference in the prevalence of astigmatism based on the axis orientation between boys and girls (P = 0.032) and between age groups (P < 0.001), observing a decreasing trend with increasing age.

DISCUSSION

We found an overall prevalence of astigmatism of 11.46% among schoolchildren aged 6–16 years in Mumbai, India. The prevalence showed a significantly decreasing trend among age groups without a difference between sexes. Based on severity level, the prevalence was highest in mild astigmatism, followed by moderate astigmatism, and was lowest in severe astigmatism. In addition, the prevalence differed significantly based on the axis orientation among the three subtypes, age groups, and between the two sexes, with a decreasing trend with increasing age. The prevalence was highest for with-the-rule astigmatism, followed by against-the-rule astigmatism, and was lowest for oblique astigmatism.

The overall prevalence of astigmatism in our study was 11.46% among schoolchildren in Mumbai, India, a prevalence that differs from those reported in other studies. In a study from India [16] of 245 565 schoolchildren aged 6–17 years, 3.69% had astigmatism. Among those who failed vision screening owing to refractive errors, 50% had astigmatism. The authors indicated that high severity and unilateral involvement in astigmatism are amblyogenic and require early intervention [16]. The observed differences between the two studies could arise from differences in their aims and inclusion criteria. In a systematic review and meta-analysis [28] of population- and school-based studies in India, the population-based prevalence of astigmatism was 5.4% in children aged 0–15 years [28], a prevalence lower than the rate reported in the current study. Given the similar racial backgrounds [28], the observed discrepancy could be due to differences in the definition of astigmatism, age range of the included children, and geographical variation among the studies [28]. However, further multicenter national studies in India are required to verify this reasoning.

Table 1. Prevalence of astigmatism based on severity level among schoolchildren

Variable	≤ -1.50 DC, % (95% CI)	-1.50 DC to -2.50 DC, % (95% CI)	> -2.50 DC, % (95% CI)
Sex group			
Boys (n = 171)	3.4 (2.77 – 4.03)	1.43 (1.02 – 1.84)	0.6 (0.33 – 0.87)
Girls (n = 190)	3.11 (2.5 – 3.7)	1.68 (1.23 – 2.13)	1.24 (0.85 – 1.63)
Age group			
6 to 9 years (n = 165)	3.17 (2.56 – 3.78)	1.27 (0.88 – 1.66)	0.79 (0.46 – 1.06)
10 to 13 years (n = 110)	1.87 (1.4 – 2.34)	0.98 (0.65 – 1.31)	0.63 (0.36 – 0.9)
14 to 16 years (n = 86)	1.46 (1.04 – 1.88)	0.86 (0.54 – 1.18)	0.41 (0.19 – 0.63)

Abbreviations: DC, the cylindrical component of the refractive error (cylinder) in diopter cylinder, %, percentage; CI, confidence interval; n, number. Note: Astigmatism severity was categorized into mild (≤ - 1.50 DC), moderate (- 1.50 DC to - 2.50 DC), and severe (> - 2.50 DC) [2].

Table 2. Prevalence of astigmatism based on axis orientation among schoolchildren

Variable	With-the-rule, % (95% CI)	Against-the-rule, % (95% CI)	Oblique, % (95% CI)
Sex group			
Boys (n = 171)	4.63 (3.9 – 5.36)	0.67 (0.39 – 0.94)	0.13 (0.01 – 0.25)
Girls (n = 190)	4.57 (3.84 – 5.3)	1.02 (0.67 – 1.37)	0.44 (0.21 – 0.67)
Age group			
6 to 9 years (n = 165)	4.03 (3.34 – 4.72)	0.92 (0.59 – 1.25)	0.29 (0.1 – 0.48)
10 to 13 years (n = 110)	2.60 (2.04 – 3.16)	0.70 (0.41 – 0.99)	0.19 (0.04 – 0.34)
14 to 16 years (n = 86)	2.57 (2.02 – 3.12)	0.06 (0.02 – 0.15)	0.095 (0.015 – 0.2)

Abbreviations: CI, confidence interval; %, percentage; n, number. Note: Astigmatism was categorized based on axis orientation into with-the-rule, against-the-rule, and oblique [15].

Race-based variations in the prevalence of astigmatism have been previously documented [29-31]. In a cross-sectional school-based study of 4801 Chinese students aged 5–20 years, the overall prevalence of astigmatism (14.2%) was higher than that in our study [29], which could be explained by the difference in racial background of the populations in the two studies. Shih et al. [32] found an increasing trend in the prevalence of astigmatism among schoolchildren aged 7–18 years at two time points with a five-year interval in a nationwide survey in Taiwan, where 57.5% in 1995 and 49.00% in 2000 had no astigmatism, which was defined as astigmatism less than 0.5 DC [32]. In a cross-sectional study of 5544 schoolchildren in southern Iran, the prevalence of astigmatism was 13.47% [33], which was higher than our observed rate. The prevalence of astigmatism among 5528 schoolchildren aged 6–12 years from Shahroud, northern Iran, was 16.7% [15].

In a study of 21 415 students aged 5–13 years from Langzhong City, China [34], the authors found a high rate of astigmatism (61.70%), with the definition of astigmatism as ≥ 0.50 DC, a prevalence substantially higher than what we observed. In addition to differences in racial background, lower age could be another contributing factor to this difference, as we included schoolchildren aged 6–16 years, which was older than that in their study [34]. Tong et al. found a prevalence rate of 19.2% for astigmatism worse than or equal to 1 DC among 1028 schoolchildren aged 7–9 years [35]. This was higher than the rate observed in the current study, although we defined astigmatism as worse than or equal to 0.5 DC.

We found a decreasing trend in the prevalence of astigmatism based on the severity level, whereby mild astigmatism was the highest (6.51%), followed by moderate (3.11%) and severe astigmatism (1.84%). Likewise, Shih et al. [32] observed a decreasing trend in the prevalence of astigmatism based on severity level in a survey among schoolchildren in Taiwan that was conducted at two time points with a five-year interval: astigmatism < 1.00 D (29.9% versus 3.9%), 1–2 D (11% versus 13%), and > 3.00 D (1.3% versus 1.8%). Similar to our results, the prevalence decreased with increasing disease severity at both timepoints [32]. Wang et al. observed a decreasing trend in the prevalence of astigmatism based on the severity levels [29]. The most common type of astigmatism based on severity level in children in Langzhong City, China, was mild astigmatism [34].

Considering the axis orientation, with-the-rule astigmatism was the most common (9.2%), followed by against-the-rule astigmatism (1.68%) and oblique astigmatism (0.57%) in the current study. The prevalence of astigmatism based on axis orientation differed significantly between sexes and age groups, with a decreasing trend with increasing age in all three subtypes of astigmatism. Similarly, Shih et al. [32] found that with-the-rule and oblique astigmatism were the most and least prevalent subtypes, respectively. In contrast, they found an increasing trend in the rate of with-the-rule astigmatism and a decreasing trend in against-the-rule astigmatism; however, the rate of oblique astigmatism was stable with age [32].

Similar to our findings, Fotouhi et al. [33] found that with-the-rule astigmatism was the most prevalent, followed by against-the-rule and oblique astigmatism. Likewise, they observed a decrease in the prevalence of with-the-rule astigmatism with increasing age; however, the prevalence of against-the-rule astigmatism increased significantly, yet no difference in oblique astigmatism was found between age groups [33]. The most common type of astigmatism based on the axis orientation in children in Langzhong City, China, is with-the-rule astigmatism [34]. Similarly, Hashemi et al. observed the highest prevalence in with-the-rule astigmatism, followed by against-the-rule and oblique astigmatism [15]. As in our study, Tong et al. found that with-the-rule was more common than against-the-rule [35]. Among Chinese students aged 5–20 years, Wang et al. found that most eyes had with-the-rule astigmatism, as we observed [29].

Our results replicate those of previous studies, indicating a higher prevalence of astigmatism in younger children and suggesting a possible developmental trend in which astigmatism tends to decrease with age [15]. The overall prevalence of astigmatism in our study was comparable between the sexes; for boys and girls, it was 5.43% and 6.03%, respectively. The prevalence differed significantly between the age groups, showing a decreasing trend with increasing age. Considering the axis orientation, the prevalence of astigmatism differed significantly between sex and age groups, showing a decreasing trend with increasing age. However, we found no significant association between age groups and the prevalence of astigmatism based on severity level. In a study by Hashemi et al. [15], the prevalence was similar between the sexes and showed a decreasing trend with increasing age. The prevalence was higher in urban schools than in rural schools. They found a decrease in prevalence in 10-year-old children (13.7%) compared to 6-year-old children (21.5%), but it increased to 18.3% among 12-year-old children [15]. Tong et al. found no significant difference in the prevalence of astigmatism between sexes, ethnicities, or age groups [35].

Our study may be important for eye care providers and policymakers because it helps them create programs to identify and treat astigmatism early, prevent vision problems in the future, and enhance the visual performance of schoolchildren. Our findings underscore the significance of astigmatism as a prevalent refractive error among school-aged children in Mumbai, with implications for vision care and management strategies tailored to address the predominant types of astigmatism observed in this population. While our study is helpful in estimating the prevalence of astigmatism among 6–16-year-old schoolchildren in Mumbai, India, it has some limitations. We excluded children less than 6 years of age, those with high hyperopia or myopia and ocular comorbidities, and we did not measure accommodative convergence or accommodation along with refraction. Future studies addressing these limitations may enable a real estimation of astigmatism prevalence in our region and could help policymakers set realistic preventive programs for enhancing the visual performance of schoolchildren.

CONCLUSIONS

The overall prevalence of astigmatism among schoolchildren aged 6–16 years in Mumbai, India, was 11.46%. We observed a decreasing trend with increasing age and no difference between sexes. Considering severity level, the prevalence was higher in mild astigmatism, followed by moderate and severe astigmatism. The prevalence was significantly different among the three subtypes of axis orientation, between the two sexes, and among age groups, showing a decreasing trend with increasing age. With-the-rule astigmatism was the most common, followed by against-the-rule astigmatism; oblique astigmatism was the least common. The high rate of astigmatism reported in this study indicates that this is a significant public health issue that requires rigorous strategies from different stakeholders, including healthcare providers, education and training professionals, and parents, to prevent the consequences of astigmatism. Further studies with broad inclusion criteria and age ranges in this region are necessary to provide an accurate estimation of the prevalence of astigmatism.

ETHICAL DECLARATIONS

Ethical approval: The study adhered to the tenets of the Declaration of Helsinki and was approved by the ethics committee of Lotus College of Optometry, Juhu, Mumbai, Maharashtra, India. Consent was obtained from school deans, and verbal consent was obtained from parents or legal guardians of the schoolchildren.
Conflict of interest: None.

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