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Association of Ametropia with Academic Performance and Development of Myopia Among School Children

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[1,2,3] concept/research design, data collection, project management, takes the responsibility and accountable,[4] edit of manuscript, statistical analysis, and accountable [5]statistical analysis and manuscript writing,[6] critical revision of the manuscript and for all aspects of the work

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ABSTRACT

Objective: To evaluate the associations between ametropia, academic performance, and myopia development among schoolchildren.

Methodology: This multicenter observational cross-sectional cohort study was carried out in Ophthalmology Department at Akbar Niazi Teaching Hospital, Islamabad, as well as at Farooq Teaching Hospital and Holy Family Hospital in Rawalpindi, Pakistan, from January 2022 to June 2023. Initially, an analysis was conducted on students in grades 1 through 9 from Rawalpindi and Islamabad to assess the influence of refractive status on their academic performance on an annual basis. Additionally, a longitudinal analysis was conducted on the students to assess the trend in academic performance in relation to refractive changes over a 12-month period. The refractive status was assessed utilizing non-cycloplegic autorefractors.

Results: Total 1880 children, regardless of myopia status were analyzed (mean age: 11.2 years; 1051 males and 829 females). The analysis revealed that hyperopia prevalence was associated to low academic score in grade 1, the year students began primary school (β = −0.1, p = 0.001). In contrast, myopia prevalence was associated with high academic score in grades 6 and 8, the years when students were preparing for board examinations for primary or secondary school (β = 0.3, p = 0.04; β = 0.5, p = 0.001). The longitudinal analysis indicated that quicker myopia progression was associated with high score across all grades, after adjusting for factors including parental myopia, BMI, outdoor activities, screen, and reading times (at baseline all grades were as follow; grade 2: β = 0.04, p < 0.001; grade 3: β = 0.05, p = 0.001; grade 4: β = 0.02, p < 0.001; grade 5: β = 0.04, p < 0.001; grade 6: β = 0.05, p < 0.001).

Conclusion: Refractive errors indicated an association with academic performance among school children. Children who were in high academic performance tended to exhibit more rapid myopia development.

Keywords: Academic performance; Hyperopia; Myopia; Refractive errors.

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Introduction

Refractive error prevalence is associated to educational attainment. A study found a positive correlation between the number of years of education and myopia development.[1] Additionally, intense learning activities, such as prolonged reading, are associated to myopia development. Overall, research on association between education factors and refractive error in school children holds important implications for public health.[2]

The refractive error prevalence is significantly high among East Asians compared to other ethnic groups.[3] A significant number of individuals, including school

children, need correction for refractive errors like nearsightedness and farsightedness. VISION 2020 partners are creating models to deliver affordable optical correction and low vision aids to people in need worldwide, particularly those in underserved urban and rural areas with limited access to services. Access to these services helps secure a brighter future for visually impaired children and adults.[4] Uncorrected refractive errors account for 11.4% of blindness cases in Pakistan.[5]

Many children with uncorrected refractive errors are asymptomatic, making screening essential for early detection and timely intervention. The lack of sight-improving glasses for children has become a significant concern in recent studies.[6] Ocular screening programs for school-aged children are essential and highly beneficial. It also positively impacts children's psychosocial development. School screening programs facilitate the identification of myopia and its associated risk factors, including refractive errors.[7] These factors are environmental and genetic factors to development the myopia. Genetically, myopia may be associated with certain inheritable connective tissue disorders. Various environmental factors, such as the amount of near work performed, contribute to the progression of myopia. Near work refers to activities that require the eye's lens to accommodate and focus sharp images on retina, including reading, studying (writing and homework), watching television, playing video games, or using computers.[8]

Given the regional variation in refractive error prevalence within the education system, it is essential to carry out an in-depth study among school children in Pakistan to explore the association between academic performance and refractive errors. Furthermore, no follow-up study has yet specified the nationwide association between development the myopia and academic performance. Therefore, this study examines the associations between ametropia, academic performance, and development of myopia among schoolchildren, contributing to the formulation of strategies for enhancing academic outcomes and protecting visual health.

Methodology

This multicenter study was carried out in Ophthalmology Department at Akbar Niazi Teaching Hospital, Islamabad, as well as at Farooq Teaching Hospital and Holy Family Hospital in Rawalpindi, Pakistan, from January 2022 to June 2023 IRB no RAC & IRB-1-1/06/2023 The study adhered to the outlines of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).[9] This study was approved by Institutional Review Boards of all three institutions, and consent was attained after informing the parents of all participating children. This study analyzed two distinct cohorts of students in Rawalpindi/Islamabad, Pakistan. One cohort comprised students from grades 1 to 9 (age range 6–15 years) to assess the association between academic performance and refractive error status annually in a cross-sectional study. Another cohort included students from grades 2 to 6 (age range 7–12 years) to assess the association of academic performance in relation to refractive variations over a 12-month span. Study data was collected during hospital-based screenings and from children who reported directly to the hospitals.

The students in the study participated in an interview regarding their eye's health. The students had previously used rigid contact lenses, who had any medical treatments, conditions that could impact on vision or visual development including amblyopia or diabetes were excluded. The students examined by uniform slit lamp in a low light indoor setting using HS 5000 (Huvitz, South Korea). If students had strabismus, keratitis, cataracts, and other conditions that could lead to impaired vision or adversely impact academic performance were also excluded from this study.

Students also underwent additional refractive error measurements using non-cycloplegic autorefraction with Nidek ARK-1a (Nidek Co., Ltd., Japan). A maximum of three measurements were taken. During examination if eyes failed to align properly with visual targets were excluded from the measurements. The follow-up examinations mirrored those conducted at baseline and were carried out by same evaluator using identical equipment. The refractive status was measured twice: at baseline and follow-up. Sphere and cylinder powers were documented to determine the spherical equivalent refraction (SER) for each eye, which is the algebraic sum in diopters (D). The development of myopia was referred as changes in eye refraction, determined by comparing SER at baseline with SER at follow-up. Vision conditions were categorized as follow: (SER ≤ -0.5 D, myopia); (SER $< +0.5$ D, < -0.5 D, emmetropia); and (SER $\geq +0.5$ D, hyperopia). Myopia was additionally categorized as low (SER ≤ -0.5 D, ≤ -3 D), moderate (SER ≤ -6 D, ≤ -3 D), and high (-6 D or less).

The latest overall scores from standard board examinations, based on grades level, were utilized as evaluation of individual academic performance. All

students within equal grades level participated in the identical exam. Each student's total score of exams was documented. Each subject score for students from grades 1 to 6 were documented for analysis of subgroups. Total score and individual subject score were converted to 0–100% scale for evaluation.

Parental myopia, body mass index (BMI), daily reading, daily screen, and daily outdoor activities times are considered environmental factors influencing myopia. Data from right eye was utilized in this analysis, as 64% of studies performed analysis only one eye, and right eye being a common selection criterion.[10]

Chi square test was employed to evaluate the student's proportional variations with myopia and hyperopia across successful grades. The prevalence comparison of myopia and hyperopia was analyzed in male and female students. In cross-sectional analysis, the association between refractive status and academic performance in students from grades 1 to 9, representing the compulsory education grades, was examined following these steps. Firstly, multilinear regression was conducted to determine the association between refractive errors (hyperopia and myopia) and academic performance. Secondly, an analysis of subgroups was conducted to examine the association between score in each subject and refractive errors. Thirdly, multilinear regression was applied to evaluate the association between precise refraction of eye in students with hyperopia or myopia and academic performance.

In every regression analysis, academic performance was the dependent variable, with BMI, age, and gender factored in as covariates. The statistical tests were conducted as two-sided, with significance defined at $p < 0.05$. Every analysis was performed using SPSS v 25.

Results

The study included 2,000 students, and 88 participants were excluded because of high astigmatism, low vision, anisometropia, unreliable autorefraction values, or missing data. Additionally, 28 were excluded because of previous medical treatments, used rigid contact lenses, conditions that could impair vision and adversely affect academic performance. 4 participants were excluded for being under 6 years old or over 15 years old at baseline. Finally, 1,880 students were analyzed in the study, comprising 1,051 (55.9%) males and 829 (44.1%) females. In the follow-up cohort, 1,765 students were included at baseline, and 1,750 (99.2%) were re-examined after 12-month.

The mean SER values were as follows: for all subjects, −0.3 ± 1.0 D (ranged, −7.7 to 5.7 D); for males, −0.3 ± 0.8 D (ranged, −7.2 to 5.7 D); and for females, −0.3 ± 1.1 D (ranged, −7.7 to 5.1 D). The overall prevalence rates were 2.3% for hyperopia and 13.2% for myopia.

Table I illustrate the prevalence rates and hyperopia and myopia trend of every grade. From grade 1 to grade 9, hyperopia prevalence rate was decreased from 7.5% - 0% ($\chi^2 = 44.1$, $p < 0.001$), while myopia prevalence rate was increased from 11.5% - 90.5% ($\chi^2 = 785.1$, $p < 0.001$). Additionally, in grade 6 and 7, myopia growth rate was surged from 35.6% to 80.1%. All levels of myopia rose from grade 1 to 9: low ($\chi^2 = 356.1$, $p < 0.001$), moderate ($\chi^2 = 896.9$, $p < 0.001$), and high ($\chi^2 = 576.3$, $p < 0.001$). Females exhibited high prevalence rate of myopia compared to males ($\chi^2 = 21.1$, $p < 0.001$). However, they had similar prevalence rate of hyperopia ($\chi^2 = 1.1$, $p = 0.89$).

In grade 1, multilinear regression indicated that hyperopia students had low score compared to those with emmetropia ($\beta = -0.1$, $p = 0.01$). In grade 1, hyperopia was associated with poorer academic performance in Urdu and Math subjects ($\beta = -0.1$, $p = 0.01$; $\beta = -0.03$, $p = 0.01$; Tables 2 and 3). In grades 6 and 8, myopia was associated with strong academic performance ($\beta = 0.03$, $p = 0.04$; $\beta = 0.2$, $p = 0.001$). In grade 6, myopia students were unlikely to achieve strong academic performance in

Table I: Refractive errors trends and proportion.

Characteristics	Grades									Total	Trend (χ^2)	P value
	1	2	3	4	5	6	7	8	9			
No. of students	312	208	144	223	265	284	212	131	101	1880	-	-
Ages (yrs)	6.8	8.2	9.1	11.0	10.2	11.9	12.6	13.4	14.4	10.8	-	-
Mean (D)	-0.1	-0.1	-0.3	-0.3	-0.7	-1.0	-2.1	-2.9	-3.1	-0.5	-	-
SE (D)	0.8	0.7	0.8	0.9	1.3	1.6	2.1	2.2	2.2	2.0	-	-
Hyperopia (%)	7.5	3.8	2.8	1.4	1.0	0.9	2.4	1.5	0	1.3	44.1	.001
Myopia (%)	11.5	8.8	17.6	22.5	32.1	35.6	80.1	84.5	90.5	23.5	785.1	.001
Low myopia (%)	9.9	8.2	15.8	19.5	22.9	23.4	42.6	39.0	42.4	19.5	356.1	.001
Moderate (%)	1.7	0.7	1.9	3.0	10.3	13.9	32.2	38.6	40.5	4.8	896.9	.001
High (%)	0	0	0	0.1	0	0.4	7.4	9.1	9.7	0.3	576.3	.001

D: diopter, SE: standard error

Table II: Regression analysis of academic performance with refractive errors.

Grades	N	Hyperopia, β & p-values				Myopia, β & p-values			
		Total score	Urdu	Math	English	Total score	Urdu	Math	English
1	312	-0.1 (0.01)	-0.1 (0.03)	-0.03 (0.01)	-	-0.02 (0.31)	-0.02 (0.31)	-0.002 (0.56)	-
2	208	-0.01 (0.68)	-0.01 (0.78)	-0.01 (0.66)	-	0.02 (0.29)	0.02 (0.36)	0.02 (0.32)	-
3	144	0.05 (0.48)	0.07 (0.42)	0.02 (0.93)	0.02 (0.41)	0.03 (0.88)	0.01 (0.71)	0.004 (0.73)	-0.003 (0.77)
4	223	-0.01 (0.83)	-0.01 (0.47)	0.02 (0.66)	-0.02 (0.50)	0.02 (0.37)	0.02 (0.30)	0.02 (0.29)	0.02 (0.67)
5	265	-0.1 (0.32)	-0.1 (0.04)	-0.23 (0.27)	-0.02 (1.00)	0.02 (0.49)	0.03 (0.31)	0.02 (0.40)	0.003 (0.84)
6	284	-0.001 (1.00)	0.01 (0.89)	0.03 (0.99)	-0.08 (0.60)	0.03 (0.04)	0.03 (0.03)	0.03 (0.25)	0.04 (0.03)
7	212	0.1 (0.33)	-	-	-	0.02 (0.72)	-	-	-
8	131	-	-	-	-	0.05 (0.01)	-	-	-
9	101	-	-	-	-	-0.03 (0.59)	-	-	-

Empty cells indicate an insufficient sample for analysis.

Table III: Stratification of overall academic performance and refractive errors in regression analysis.

Grades	Hyperopia			Myopia		
	N	β	p-value	N	β	p-value
1	23	0.001	1.00	40	0.003	0.92
2	12	0.05	0.42	42	-0.02	0.68
3	6	-	-	52	-0.03	0.09
4	8	-0.03	0.94	90	0.02	0.29
5	6	-	-	135	-0.02	0.46
6	5	-	-	181	-0.02	0.29
7	7	-0.38	0.88	182	-0.003	0.88
8	4	-	-	120	-0.02	0.20
9	1	-	-	100	-0.03	0.03

Urdu and English subjects compared to those no myopia (β = 0.03, p = 0.03; β = 0.04, p = 0.03). In other grades, refractive errors did not show an association with academic performance (Tables II and III).

Additionally, the data was stratified by refractive status to analyze the association between academic performance and eye refraction in hyperopia and myopia students. Interestingly, in grade 9, low refractive values in myopia students had significant better academic score (β = −0.03, p = 0.02). This suggests that students with high myopia (<−6 D) tend to have high academic score compared to those with low or moderate myopia (>−6 D).

Of the 1,765 participants who were followed. At baseline, 1,750 emmetropic or myopic students were analyzed to mitigate the influence of hyperopia on academic performance. In grade 2 students, the regression indicates that faster myopia progression of -2.0 D over 12 months was associated to a 4% enhancement in academic performance by end of grade 5 (β = 0.04, p < 0.001). With grade 3 at baseline, -2.0 D raise in myopia progression over 12 months was linked to 5% improvement in academic performance by end of grade 6 (β = 0.05, p = 0.001). For students in grade 4, faster refraction progression (-2.0 D over 12 months) was associated with a 2% increase in scores (β = 0.02, p < 0.001). Additionally, for grade 5 students, a faster myopia progression of -2.0 D over 12 months was linked to a 4% raise in academic performance by end of grade 7 (β = 0.04, p < 0.001). Also, accelerated myopia progression was positive correlated with improved academic performance in grade 6 (β = 0.05, p < 0.001). Table IV

Table IV: Overall academic performance and myopia progression in regression analysis

Baseline grades	Follow-up grades	N	β	p-value
2	4	55	0.04	.0001
3	5	28	0.05	.001
4	6	1565	0.02	.0001
5	7	50	0.04	.0001
6	8	35	0.05	.0001

The questionnaire was completed by the parents of 1,733 students, resulting in a 99% response rate. After adjusting for covariates from the questionnaire including parental myopia (both maternal and paternal), BMI, average daily reading time, average daily screen time, and average daily outdoor activity, the association in myopia progression and academic performance remained significant (at baseline grade 2: β = 0.04, p < 0.001; at baseline grade 3: β = 0.05, p < 0.001; at baseline grade 4: β = 0.02, p < 0.001; at baseline grade 5: β = 0.04, p < 0.001; at baseline grade 6: β = 0.05, p < 0.001).

Discussion

This study conducted a comprehensive analysis of association in refractive errors and academic performance

among schoolchildren. The study demonstrates a relationship in academic performance and refractive status in schoolchildren. In grade 1, there is an association in hyperopia prevalence and low academic performance in Urdu and math subjects. Emmetropization begins between 1 and 7 years of age, with students typically having mild hyperopia earlier starting school, which can impact their writing, reading, and classroom concentration.[11,12] In grades 6, 8, and 9, students with myopia tended to achieve high academic score, which may be attributed to the intensified study demands for entrance exams at the conclusion of grade 9. A prior study found that engaging in near-distance activities can lead to an average refractive shift of −0.63 D every year in 6 to 17 years aged students.[13] This study found that students of 6 grade with myopia had a positive correlation with high academic performance in Urdu and English subjects, possibly due to reading and writing demands of language studies.

Based on the follow-up analysis, academic performance was strongly positively correlated with changes in refraction over time among students across all grades with emmetropia or myopia. After adjusting for parental myopia, BMI, outdoor activities, screen and reading times, students with high academic performance showed a greater prevalence and quicker progression of myopia.

This analysis reveals that myopia prevalence in grade 1 students (11.5%, mean age 6.8 years) is high than what was documented in an earlier study (≤ 5% for both genders, age 6 years).[14] Furthermore, the study revealed that myopia prevalence in grade 7 (80.1%, average age 12.6 years) was high compared to previous reports by Li et al (63.3% at age 12) and Grzybowski et al (60% at age 12).[15,16] These findings may suggest a recent raise in myopia prevalence. In line with previous studies, females exhibited a high prevalence of refractive errors (including myopia) as compare to males, which may be linked to shorter axial lengths and steeper corneas.[17] As a result, myopia addressing and preventing might be difficult in females compared to their male counterparts.

This study limitations must be considered when evaluating its findings. Refractive errors were assessed using noncycloplegic autorefraction, subsequently through subjective refraction. Measuring refractive errors absence of cycloplegia may lead to overestimating myopia or underestimating hyperopia. As a result, certain participants in the study may have been misclassified as myopic. Factors related to academic performance, such as parental educational and intelligence quotient (IQ) were not included in this analysis. These findings warrant additional analysis with adjustments for these potential factors. The approach for evaluating academic performance appears to depend on single standardized exam given at end of year.

Conclusion

Academic performance is associated to progression of myopia and ametropia. The hyperopia prevalence is associated with low academic score in grade 1, whereas myopia is associated to strong academic score in grades 6, 8, and 9. Schools and parents are urged to prioritize providing suitable correction for hyperopia students to mitigate possible learning challenges.

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