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The influence of intraocular pressure and accommodation amplitude on refractive status in school-age children



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ABSTRACT

Introduction: Refraction is the ability of the eye to refract light, which is divided into 3 categories of refractive status (RS), namely emmetropia, myopia, and hypermetropia. Increasing age in school-age children is also accompanied by the development of intraocular pressure (IOP) and accommodation amplitude (AA) values, which are assumed to affect retinal sensitivity (RS). Therefore, this study aims to investigate the effects of partial and simultaneous interactions between age, intraocular pressure (IOP), and age-related macular degeneration (AA) on retinal sensitivity (RS) in school-age children.

Methods: This cross-sectional study utilized 236 eyeballs from children aged ≤ 18 years who consented to participate and completed all eye examinations at the Al-Ikhlâs Singosari Orphanage in Malang. Variables included age, IOP, AA, and RS converted into spherical equivalent (SE). Data analysis employed partial and simultaneous regression tests.

Result: Partially, increased age, IOP, and decreased AA influenced myopia (6.6%, 33.3%, and 19.1%, respectively), while reduced age, increased IOP, and increased AA influenced hypermetropia (14.3%, 47.2%, and 12.2%). Simultaneously, these variables affected myopia RS by 0.6% and hypermetropia RS by 2.6%, though not significantly.

Conclusion: Age, IOP, and AA show effects on myopia and hypermetropia RS both partially and simultaneously, but the influence is small and insignificant.

Keywords: refractive status, intraocular pressure, accommodation amplitude, school-age children.

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INTRODUCTION

Refraction is the eye's ability to bend light, measured both clinically objectively and subjectively. Refractive disorders occur when light entering the eye does not focus correctly on the retina. Refractive disorders are categorized into myopia, hypermetropia, and astigmatism^{2,3}. Myopia, or nearsightedness, occurs when the focal point of light falls in front of the retina, causing distant objects to appear blurry. In contrast, hypermetropia is characterized by the inability to focus on nearby objects without accommodation, with the image focusing behind the retina. Astigmatism causes blurred or distorted vision due to irregular focusing of light on the retina³.

Refractive disorders are common in both children and adults, with astigmatism being the most prevalent (14.9%), followed by myopia (11.7%) and

hypermetropia (4.6%). In Southeast Asia, astigmatism is particularly widespread⁵. In Indonesia, myopia is the most common refractive disorder among school-age children⁶. Uncorrected refractive errors can negatively impact children's academic and extracurricular performance.⁷

Intraocular pressure (IOP) refers to the pressure within the eyeball, influenced by aqueous humor (AH)⁸. Excess AH can elongate the eyeball and thicken the lens, impacting RS. Normal IOP ranges from 10 to 21 mmHg⁹. Elevated IOP can result from excessive aqueous humor (AH) production or blocked aqueous humor (AH) drainage.¹⁰

Accommodation is the eye's ability to adjust its refractive power by altering the shape and size of the lens. This process reduces the depth of the anterior chamber, influenced by the zonular fibers and ciliary muscles, allowing light to focus precisely on the retina. Accommodation

amplitude (AA) is calculated using Hofstetter's formula, with an average value of $18.5 - (0.30 \times \text{age in years})$ ¹². Deviations in axial ametropia (AA) are associated with refractive errors, such as reduced AA in myopia and excessive AA in hypermetropia.¹³

The interplay of IOP and AA in influencing RS is worth exploring, especially among school-age children. Limited studies in Indonesia and globally make this topic a significant concern. This research aims to provide insights into the roles of IOP and AA in affecting RS in school-age children, potentially guiding refractive error prevention and screening efforts.

METHODS

Study Design

This observational study employed a cross-sectional design. Data were collected

from secondary sources, involving eye examinations conducted by the Department of Ophthalmology at Saiful Anwar Hospital and Brawijaya University from July to August 2023 at the Al-Ikhlâs Singosari Orphanage Islamic Boarding School in Malang. The protocol for this study has been approved by the Health Research Ethics Commission of the Faculty of Medicine, Brawijaya University, based on the Helsinki guidelines.

Population and Sampling

The study applied purposive sampling among school-age children at the orphanage, adhering to inclusion and exclusion criteria. The minimum sample size was calculated using Slovin's formula, requiring at least 76 children or 152 eyes. Inclusion criteria included cooperative children aged ≤ 18 years who consented to participate and completed all eye examinations. Exclusion criteria involved children with eye abnormalities or red-eye conditions.

Variables and Instruments

Independent variables were age, IOP, and AA, while the dependent variable was RS, categorized into myopia (low: $-0.25D$ to $-3.00D$, moderate: $-3.25D$ to $-6.00D$, and high: $> -6.00D$) and hypermetropia (low: $+0.25D$ to $+3.00D$, moderate: $+3.25D$ to $+6.00D$, and high: $> +6.00D$). Instruments included the iCare rebound tonometer (model SW-500), directed at the child's eyes for IOP measurement using mmHg units, the RAF Ruler for AA measurement using diopter units, and the Canon RK-F2 auto refractometer for RS assessment using spherical and cylindrical units, then converted into spherical equivalent (SE) using diopter units.

Data Analysis

Data were managed using Microsoft Excel and analyzed using SPSS Version 26. Normality was assessed using the Kolmogorov-Smirnov test, followed by tests for multicollinearity and heteroscedasticity. Regression analysis, both partial and simultaneous, was performed to evaluate the effects of variables on RS.

Table 1. The characteristics patient

Data	Myopia (n = 130)	Hypermetropia (n = 96)
Gender		
Male (n,%)	80 (61.5)	56 (58.3)
Female (n,%)	50 (38.5)	40 (41.7)
Age (years) (Mean\pmSD)	10.34 \pm 1.673	10.31 \pm 1.585
6 (n,%)	-	2 (2.1)
7 (n,%)	10 (7.7)	6 (6.3)
8 (n,%)	14 (10.8)	4 (4.2)
9 (n,%)	14 (10.8)	11 (11.5)
10 (n,%)	18 (13.8)	22 (22.9)
11 (n,%)	40 (30.8)	33 (34.4)
12 (n,%)	26 (20.0)	12 (12.5)
13 (n,%)	8 (6.2)	6 (6.3)
IOP (mmHg) (Mean\pmSD)	16.12 \pm 2.587	16.41 \pm 2.338
10 (n,%)	2 (1.5)	-
11 (n,%)	2 (1.5)	-
12 (n,%)	4 (3.1)	1 (1.0)
13 (n,%)	2 (1.5)	2 (2.1)
14 (n,%)	26 (20.0)	15 (15.6)
15 (n,%)	33 (25.4)	27 (28.1)
16 (n,%)	12 (9.2)	17 (17.7)
17 (n,%)	12 (9.2)	6 (6.3)
18 (n,%)	4 (3.1)	2 (2.1)
19 (n,%)	16 (12.3)	16 (16.7)
20 (n,%)	12 (9.2)	8 (8.3)
21 (n,%)	3 (2.3)	-
22 (n,%)	1 (0.8)	-
23 (n,%)	1 (0.8)	-
24 (n,%)	-	2 (2.1)
AA (Diopters) (Mean\pmSD)	13.32 \pm 2.568	13.50 \pm 3.156
6 (n,%)	-	2 (2.1)
7 (n,%)	3 (2.3)	1 (1.0)
8 (n,%)	2 (1.5)	8 (7.3)
9 (n,%)	1 (0.8)	1 (1.0)
10 (n,%)	4 (3.1)	3 (3.1)
11 (n,%)	23 (17.7)	13 (13.5)
12 (n,%)	13 (10.0)	6 (6.3)
13 (n,%)	32 (24.6)	13 (13.5)
14 (n,%)	8 (6.2)	3 (3.1)
15 (n,%)	22 (16.9)	22 (22.9)
16 (n,%)	12 (9.2)	15 (15.6)
17 (n,%)	4 (3.1)	4 (4.2)
19 (n,%)	1 (0.8)	1 (1.0)
20 (n,%)	5 (3.8)	5 (5.2)
Degree Classification		
(Mean \pm SD)	-0.864 \pm 0.814	0.520 \pm 0.541
Low (n,%)	126 (96.9)	95 (99.0)
Moderate (n,%)	4 (3.1)	1 (1.0)
High (n,%)	-	-

Note: n = number of eyeballs. The most data were found in children aged 11 years (73 eyes), with an IOP of 15 mmHg (60 eyes), and an AA of 13 Diopters (45 eyes).

RESULTS

Data Characteristics

A total of 246 eyes were included in this study. However, 20 eyes were excluded from the analysis stage due to several factors, including 10 eyes with missing data on IOP and age and 10 eyes with

normal refractive status. Thus, there were 226 eyes, comprising 130 myopic eyes and 96 hypermetropic eyes. The diagnosis of myopia and hypermetropia was based on the SE value from an objective examination by an eye specialist using the ARK tool.

The characteristics of the study subjects

Table 2. Partial Test of t-Statistic Negative SE

Data	Coefficients				
	Unstandardized Coefficient		t	sig	95% CI
	B	SE			
Cons	-1.041	1,601	-0.650	0.517	-4.210 – 2.128
Age	0.066	0.162	0.408	0.684	-0.255 – 0.387
IOP	0.333	0.505	0.659	0.511	-0.667 – 1.332
AA	-0.191	0.412	-0.464	0.643	-1.007 – 0.625

Note: Reference value has a statistical effect if t count > t table and is significant if sig < 0.05; B = Beta Regression Coefficient; SE = Standard Error; CI = Confidence Interval; Cons = Constanta; IOP = Intraocular Pressure; AA = Accommodation Amplitude.
a = Dependent Variable (negative SE).

Table 3. Partial Test of t-Statistic positive SE

Data	Coefficients				
	Unstandardized Coefficient		t	sig	95% CI
	B	SE			
Cons	-2.311	1.616	-1,430	0.156	-5.521 – 0.898
Age	-0.143	0.159	-0.897	0.372	-0.460 – 0.174
IOP	0.472	0.550	0.858	0.393	-0.621 – 1.564
AA	0.122	0.132	0.918	0.361	-0.141 – 0.385

are shown in Table 1. The number of subjects with myopia and hypermetropia in boys was the largest, with percentages of 61.5% and 58.3%, respectively. In children with myopia, the average age was not significantly different from that of hypermetropia (10.34±1.673 years and 10.31±1.585 years), with a minimum value of 6 years and a maximum of 13 years. The age of the largest children with myopia and hypermetropia was relatively the same, specifically in children aged 11 years, with 40 eyeballs (30.8%) and 33 eyeballs (34.4%) affected. Furthermore, the distribution of IOP was also analyzed, with an average IOP that was not significantly different between myopia and hypermetropia (16.12±2.587 mmHg and 16.41±2.338 mmHg), ranging from a minimum of 10 mmHg to a maximum of 23 mmHg. The highest distribution of IOP was observed at an IOP value of 16 mmHg in both myopia and hypermetropia, specifically in 33 eyes (25.4%) and 27 eyes (28.1%), respectively.

The study of AA values was also conducted, with an average AA value of 13.32 ± 2.568 years in myopia and 13.50 ± 3.156 in hypermetropia, which were not significantly different. However, the distribution of the highest AA values was quite different, specifically in myopia, with an AA value of 13 diopters, and hypermetropia, with a value of 15 diopters (24.6% and 22.9%, respectively). Myopia

and hypermetropia were classified into low, moderate, and high levels, with the majority of data (126 eyes and 95 eyes, representing 96.9% and 99%, respectively) falling within the low myopia and low hypermetropia categories.

In partial testing of each variable against negative SE, it was found that the SE value in myopia refraction status decreased by 104.1%. Furthermore, a 1% increase in the SE value in myopic eyes would be accompanied by a 6.6% increase in age, a 33.3% increase in IOP, and a 19.1% decrease in axial length (AA), which would be insignificant (Table 2). This suggests that each increase in negative SE value may be attributed to increasing age, higher IOP, or a decrease in AA value, as indicated by the percentage above.

Meanwhile, in positive SE, the SE value in hypermetropia refraction status will decrease by 213.1%. Furthermore, a 1% increase in SE value will be accompanied by insignificant changes, including a 14.3% decrease in age, a 47.2% increase in IOP, and a 12.2% increase in AA (Table 3). This suggests that each higher or increasing positive SE value may be due to a younger age, increased IOP, or an increased AA value, as indicated by the percentage above.

The results of the determination coefficient analysis test showed that the R Square value was 0.006. These results indicate that the variables of age, IOP, and

AA can account for an influence of 0.6%, with the remaining approximately 99.4% being explained by other variables not studied. This finding is also in line with the p-value of 0.05, which indicates that the regression model is not statistically significant and has a minimal influence.

Meanwhile, the results of the determination coefficient analysis test in the appendix indicate that the R-squared value is 0.026. These results suggest that the variables of age, IOP, and AA can account for an influence of 2.6%, with the remaining 97.4% being explained by other variables not studied. This finding is also consistent with the p-value of 0.05, which indicates that the regression model is not statistically significant and has a minimal influence.

DISCUSSION

The effect of age on refractive status was found to be that for every 1% increase in SE value, it was accompanied by a 6.6% increase in age in myopic eyes and a 14.3% decrease in age in hypermetropic eyes. However, this difference was not statistically significant. These results are in line with previous meta-analyses, which explained that there was a decrease in refractive value of 9.7% per year for every year of age increase (P < 0.0001), with the Asian race occupying the most significant percentage (42.2%, P < 0.0001).¹⁴ Another

study by Joseph and colleagues in 2023 showed that the prevalence of myopia increased with age with an increase from 1.57% at ages 5-9 years to 3.13% and 4.8% at ages 10-14 years and 15-18 years.¹⁵ The study is in line with the results of this study where the most significant percentage of myopia was 40 eyes at age 11 (30.8%) and 26 eyes at age 12 (20.0%).

The effect of IOP on refractive status was found to be that for every 1% increase in SE value, it was accompanied by a 33.3% increase in IOP in myopic eyes and a 47.2% increase in hypermetropic eyes. However, this difference was not statistically significant. This finding aligns with a cross-sectional study in China, which suggested that an increase in IOP is associated with an increase in myopia severity. IOP also peaked at the age of 9 years (17.53 ± 2.86).¹⁶ However, this is in contrast to the recent meta-analysis, which explains that there is no correlation between IOP and the dioptric power of the eye in children under <17 years, as well as research in Samarinda in patients with glaucoma which shows no relationship between refractive status and IOP.¹⁷

The effect of AA on refractive status was found to be that for every 1% increase in SE value, it was followed by a decrease in AA of 19.1% in myopic eyes and an increase of 11.2% in hypermetropic eyes. However, this difference was not statistically significant. This finding aligns with research conducted by Oneta in several junior high schools in Padang City. The correlation strength was -0.795, indicating that the higher a person's myopia, the smaller the AA value will be. This study examined monocular AA in both the left and right eyes.¹⁸ The results of this study are also supported by Dewi (2020), which shows that AA has no statistical effect on SE in monocular eyes.¹⁹

The effect of age, IOP, and AA on refractive status was found to be 0.6% for myopia and 2.6% for hypermetropia, with the remaining 99.4% and 97.4% influenced by other variables not studied. There has been no research to support these results because this is the first study to examine the effect of all three simultaneously on the refractive status of myopia and hypermetropia. However, there is research that shows that increased IOP and AA can occur in myopia that continues to

develop.²⁰

Other factors also influence the refractive status of school-age children, including gender, outdoor activities, myopia or hypermetropia in the elderly, increasing age towards the age of 20 years, time spent on near vision, vitamin D, and sleep duration.²¹ A study conducted on 15,316 school children in ethnic groups showed a strong relationship between myopic children and both parents who had binocular myopia with an average SE of -2.33D (Odds ratio = 2.83). Bivariate analysis conducted on students in Palembang showed results that supported previous studies with significant values on the relationship between myopia in children with parents who had myopia.²² Myopia can be inherited as an autosomal dominant, autosomal recessive, or x-linked trait. Sex-linked inheritance is very rare. More often, autosomal recessive inheritance occurs in people with myopia, especially in oriental races.²³

Environmental factors also play a role in the refractive status of children. Looking at close distances for extended periods, such as reading, writing, and using digital devices, are risk factors for the development of myopia. Engaging in outdoor activities can help reduce the risk of myopia.²⁴ A longitudinal study conducted by Shah confirmed a negative relationship between outdoor time and myopia. The study found that the incidence of myopia among children aged 10 to 15 years who frequently engaged in indoor activities decreased during the 3- to 9-year age range.²⁵

Nutritional factors are also thought to play a role, such as vitamin D. Vitamin D levels have been found to be lower in people with myopia compared to those without myopia. This was associated with the finding of an increase in axial length and the prevalence of myopia in children aged 6 to 18 years. However, there is no strong evidence to explain the mechanism of myopia in individuals with vitamin D deficiency.²⁶

Several studies have demonstrated that children with refractive errors tend to have lower academic performance compared to their peers with normal vision. For example, interventions correcting refractive errors have been shown to significantly improve academic scores, suggesting that vision

correction has a positive influence on learning.²⁷⁻²⁹ Children with uncorrected refractive errors often struggle to copy from the blackboard or participate fully in classroom activities, which further hinders their educational progress and social.³⁰

This study reveals several advantages and limitations. This study is the first to discuss the simultaneous influence of age variables, intraocular pressure, and amplitude on refractive status, analyzed with both negative and positive spherical equivalent (SE) values. Furthermore, this study involved children in Islamic boarding schools, which are often found in orphanages, whose activity exposure was slightly different compared to children in public schools. This study is a community-based study that can describe field conditions more accurately compared to hospital-based or clinical studies. However, this study also has several limitations, including a relatively small sample size that involves only one data collection center/location. Gender was not included as a covariate factor in the study to examine its relationship with the results because of the presence of several missing data points.

Additionally, the amplitude of accommodation in binocular eyes was excluded due to the disparity in the number of samples between monocular eyes. Other confounding variables such as parental genetic factors, prolonged use of digital devices, and other relevant factors were not analyzed because this is an orphanage school where the genetic identification of the parents cannot be carried out, the use of digital tools cannot be detected because this school implements a direct face-to-face learning system, both without the use of digital tools, both during school activities and in the dormitory. Further research is needed on a large scale, involving various data collection centers, to confirm the genetic factors and to employ different study designs, such as cohort studies, to track changes in subjects' habits.

CONCLUSION

There was an increase in SE value of 1% for every 6.6% increase in age, an increase in IOP of 33.3%, a decrease in AA of 19.1% in myopic eyes, and a reduction in age of

14.3%, an increase in IOP of 47.2%, and an increase in AA of 12.2% in hypermetropic eyes. Age, IOP, and AA together only had an effect of 0.6% on myopic refractive status and 2.6% on hypermetropic refractive status. As a suggestion, further research is needed on a large scale, involving various data collection centers and different study designs, such as cohort studies, to follow the changes in subjects' habits. Other variables can be included in the survey that are suspected of influencing refractive status disorders. Health workers should pay attention to age, intraocular pressure, and accommodation amplitude during the examination of refractive status in children, even though the results may not be significant.

DISCLOSURES

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Ethical Consideration

This study was approved by The Ethics Committee, Faculty of Medicine, Universitas Brawijaya, with approval number 114/EC/KEPK-S1-PD/05/2024.

Conflict of Interest

None.

Author Contribution

All of the authors are involved in conceiving, designing, and supervising the manuscript. RMR conducted the study and analyzed the data. All authors prepare the manuscript and agree for this final version of the manuscript to be submitted to this journal.

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