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Original Research Article

# To study the association of refractive errors, intraocular pressure with systemic blood pressure and BMI in the age group (11-20 years) in comparison with controls of similar age and gender group

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## Abstract

**Background:** Refractive errors, eye pressure (IOP), blood pressure, and body weight (BMI) are all closely connected and can affect both vision and overall health—especially during adolescence, a period of rapid growth. With more screen time and less outdoor activity, myopia is on the rise and often linked to higher IOP and BMI, though research shows mixed results. In places like Odisha, where low BMI is common, undernutrition may impact both eye development and systemic health, highlighting the need for region-specific studies.

**Aims and Objective:** To evaluate the association of refractive errors and intraocular pressure (IOP) with systemic blood pressure (BP) and body mass index (BMI) in adolescents aged 11–20 years, and compare findings with age- and sex-matched emmetropic controls.

**Materials and Methods:** This comparative cross-sectional study was conducted at a tertiary eye care center in Odisha. A total of 264 participants (134 cases with refractive errors and 130 controls) aged 11–20 years were enrolled. Visual acuity, refraction, IOP, systemic BP, pulse rate, and anthropometric data were collected. Statistical analyses included t-tests, chi-square tests, and two-way ANOVA to assess intergroup differences and associations.

**Results:** There was no significant difference in age or height between cases and controls. However, cases had significantly higher BMI ($p < 0.001$), body weight ($p = 0.010$), and diastolic BP ($p = 0.042$). Pulse rate was significantly lower in cases ($p = 0.004$). The prevalence of overweight and obesity was higher among cases, whereas underweight status was more common in controls. IOP was slightly higher in females and positively correlated with BMI and diastolic BP, particularly in myopic individuals. Pulse rate and DBP showed age- and gender-based variations, reinforcing systemic physiological influences on ocular parameters.

**Conclusion:** Adolescents with refractive errors, particularly myopia, demonstrated higher BMI and Diastolic Blood Pressure (DBP) with lower pulse rates, indicating possible autonomic and vascular dysregulation. These systemic associations highlight the need for integrated screening strategies addressing both ocular and systemic health during adolescence, especially in nutritionally vulnerable populations like those in Odisha.

**Keywords:** Refractive errors, Myopia, Intraocular pressure, Blood pressure, BMI, Adolescents, Odisha, Systemic association.

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## 1. Introduction

Refractive errors, intraocular pressure (IOP), systemic blood pressure (BP), and body mass index (BMI) are interrelated physiological parameters that significantly influence ocular and systemic health. This is particularly relevant during adolescence, a critical period characterized by rapid physical, hormonal, and behavioural changes. Among these, refractive errors such as myopia, hyperopia, and astigmatism are becoming increasingly prevalent, especially myopia, due to urbanization, excessive near work, and reduced outdoor exposure. IOP, which helps maintain the structural integrity of the eye, can be altered by systemic conditions like hypertension and diabetes. Elevated IOP is frequently associated with myopia and may increase the risk of glaucoma. Similarly, systemic blood pressure plays an essential role in ocular perfusion; while hypertension can lead to hypertensive retinopathy, hypotension may compromise

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optic nerve function. BMI, a marker of nutritional and systemic status, has been implicated in both elevated BP and IOP, with obesity often linked to increased ocular risks and low BMI associated with developmental insufficiencies.[1]

Despite a growing body of literature suggesting interrelationships between these variables, findings remain inconsistent. Myopia is frequently reported in conjunction with higher IOP and BMI, yet conflicting evidence challenges these associations.[1,2] Multivariate analyses suggest complex physiological interactions, especially during puberty, when axial elongation and hormonal fluctuations affect both ocular and systemic parameters. The Indian adolescent population, particularly in states like Odisha, presents a unique demographic profile with a high prevalence of low BMI.[3] This warrants special attention, as undernutrition during growth phases may influence systemic BP, ocular pressure, and the development of refractive errors, reinforcing the need for region-specific investigations.[4]

The rationale for this study stems from the need to clarify these associations in an adolescent cohort from Odisha, where environmental, nutritional, and genetic influences may distinctly impact ocular health. The primary aim is to assess the association of refractive errors and IOP with systemic BP and BMI in adolescents aged 11–20 years compared to age-matched controls. The primary objective is to evaluate the influence of systemic blood pressure and BMI on refractive errors. The secondary objective is to compare intraocular pressure and refractive error patterns between paediatric and adolescent groups and their age-matched controls to better understand potential risk factors and guide preventive ophthalmic care.

## 2. Materials and Methods

### *2.1. Study design and setting*

A comparative cross-sectional study was conducted at a tertiary eye care center to evaluate the association of refractive errors and intraocular pressure (IOP) with systemic blood pressure (BP) and body mass index (BMI) among adolescents. The study population included participants aged 11 to 20 years, categorized into cases (individuals with refractive errors) and age- and sex-matched controls (without significant refractive errors).

### *2.2. Participants*

Participants were recruited from outpatient ophthalmology clinics, schools, and community outreach programs.

### *2.3. Inclusion criteria*

Adolescents aged 11–20 years, without prior ocular pathology, surgery, or systemic diseases affecting BP or BMI, and willing to participate.

### *2.4. Exclusion criteria*

History of glaucoma, ocular trauma, systemic illness (e.g., diabetes, cardiovascular disease), or medications affecting BP or IOP.

### *2.5. Sample size and ethical consideration*

The sample size was estimated using previous study data, ensuring 80% power and a 95% confidence interval. An initial target of 208 was expanded to 264 (134 cases and 130 controls) to enhance subgroup analysis. Ethical approval was obtained from the Institutional Ethics Committee (IEC No. KIIT/KIMS/IEC/1157/2023), and the study adhered to the Declaration of Helsinki.

### *2.6. Clinical assessment and data collection*

1. Visual acuity and refraction: Distance visual acuity was assessed using a Snellen chart at 6 meters under standard lighting. Refractive status was determined using retinoscopy, refined by subjective refraction, and recorded as spherical equivalent (SE). Visual acuity results were converted to logMAR for analysis.
2. Intraocular pressure (IOP): IOP was measured using Goldmann applanation tonometry (14-20years) or non-contact tonometry (11-13years) after instilling topical anaesthetic.
3. Systemic blood pressure and pulse rate: BP was measured with a standard mercury sphygmomanometer using the auscultatory method, with the subject seated and arm at heart level. Pulse rate was recorded after five minutes of rest by palpating the radial or carotid artery.
4. Body mass index (BMI): Height and weight were measured using a stadiometer and calibrated scale. BMI was calculated as weight (kg) divided by height in meters squared and categorized using age- and sex-specific norms.

### *2.7. Statistical analysis*

Quantitative variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. The independent Student's t-test was used for comparing continuous variables, and the chi-square test for categorical variables. Two-way ANOVA was applied for subgroup comparisons. A p-value $< 0.05$ was considered statistically significant. Data were analysed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA).

## 3. Results

Comparison of age, height, weight, pulse rate, Systolic blood pressure (SBP), Diastolic blood presssure (DBP), Body mass index (BMI), and Mean arterial pressure (MAP) as presented in **Table 1**, the comparison of demographic and systemic parameters between the case and control groups revealed several significant findings. There was no statistically significant difference in age (p = 0.885) or height (p = 0.961) between the groups, indicating successful matching. However, cases showed significantly higher body weight (p = 0.010), diastolic blood pressure (DBP) (p = 0.042), and body mass index (BMI) (p = 0.001) compared to controls. On the other hand, controls exhibited a significantly higher pulse rate (p = 0.004). No significant group differences were observed in systolic blood pressure (SBP) (p = 0.192) or mean arterial pressure (MAP) (p = 0.166). Statistically significant differences in BMI (p < 0.001), DBP (p = 0.042), and pulse rate (p = 0.004) between cases and controls suggest meaningful associations with refractive errors. These findings are detailed in **Table 1**.

**Table 1:** Comparison of all demographics and vitals parameters between cases and control with p-value

| | Group | Mean | Std. Deviation | p-value |
|---|---|---|---|---|
| Age | Case | 15.13 | 2.824 | 0.885 |
| | Control | 15.08 | 2.761 | |
| Height | Case | 150.44 | 10.713 | 0.961 |
| | Control | 150.38 | 10.045 | |
| Weight | Case | 43.032 | 10.178 | 0.01 |
| | Control | 39.972 | 8.961 | |
| Pulse rate | Case | 80.1 | 10.158 | 0.004 |
| | Control | 84.43 | 13.974 | |
| SBP | Case | 104.49 | 12.413 | 0.192 |
| | Control | 106.29 | 9.873 | |
| DBP | Case | 79.19 | 8.782 | 0.042 |
| | Control | 69.23 | 8.751 | |
| BMI | Case | 22.8 | 3.5 | 0.001 |
| | Control | 20.9 | 2.9 | |
| MAP | Case | 82.381 | 9.076 | 0.166 |
| | Control | 80.915 | 8.014 | |

BMI comparison as detailed in **Table 2**, the distribution of body mass index (BMI) categories differed significantly between the case and control groups (p < 0.001). The IAP classifies BMI in children aged 5-18 using age- and sex-specific percentiles. Underweight is below the 5th percentile, normal ranges from the 5th to below the 85th percentile, overweight starts at an adult-equivalent BMI of 23 kg/m², and obesity at 27 kg/m². Although the majority of participants in both groups fell within the normal BMI range, this was more prevalent among controls (76.2%) compared to cases (69.4%). Notably, the proportion of overweight (21.6% vs. 12.3%) and obese individuals (6.7% vs. 0.8%) was higher in the case group, suggesting a possible association between increased BMI and refractive errors. In contrast, underweight status was more commonly observed among controls (10.8%) than cases (2.2%). These findings emphasize the potential link between higher BMI and the presence of refractive errors during adolescence, as shown in **Table 2**.

**Table 2:** BMI comparison the p-value and chi-square value were calculated using the Chi-square test of independence to evaluate the association between BMI categories and refractive error group.

| BMI | | Case | Control | p-value |
|---|---|---|---|---|
| Normal | Count | 93 | 99 | <0.001 |
| | % within Group | 69.40% | 76.20% | |
| Obese | Count | 9 | 1 | |
| | % within Group | 6.70% | 0.80% | |
| Overweight | Count | 29 | 16 | |
| | % within Group | 21.60% | 12.30% | |
| Underweight | Count | 3 | 14 | |
| | % within Group | 2.20% | 10.80% | |

The pattern in **Figure 1** indicates a significant association between higher BMI and the presence of refractive errors, particularly myopia. The relative scarcity of obese individuals in the control group further supports the hypothesis that increasing body mass may contribute to the development or progression of refractive errors.

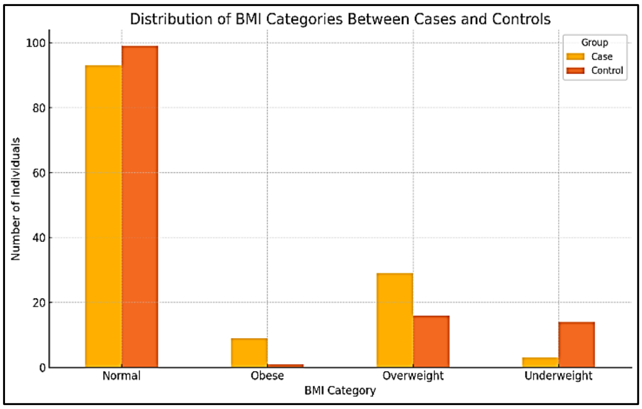


**Figure 1**:

As shown in **Table 3** pulse rate varied significantly by group (p = 0.006) and age (p < 0.001). Controls had consistently higher rates in younger groups, with the largest difference in the 13-16 group (89.53 vs. 80.10 bpm). In the 17-20 group, Cases had a slightly higher rate (80.77 vs. 74.97 bpm). Overall significance was confirmed (p < 0.001), indicating influence from both age and group.

**Table 3:** Dependent variable: Pulse rate

| Group | Case Mean | Case Std. Deviation | Control Mean | Control Std. Deviation | p-value w.r.t group | p-value w.r.t age group | p-value Overall |
|---|---|---|---|---|---|---|---|
| 11–12 | 79.61 | 12.896 | 87.16 | 14.355 | 0.006 | <0.001 | <0.001 |
| 13–16 | 80.1 | 8.067 | 89.53 | 13.868 | | | |
| 17–20 | 80.77 | 11.003 | 74.97 | 8.571 | | | |

**Table 4:** Dependent variable: DBP

| Group | Case Mean | Case Std. Deviation | Control Mean | Control Std. Deviation | p-value w.r.t group | p-value w.r.t age group | p-value Overall |
|---|---|---|---|---|---|---|---|
| 11–12 | 69.48 | 7.81 | 66 | 8.63 | 0.024 | <0.001 | 0.001 |
| 13–16 | 70.95 | 9.17 | 65.12 | 7.45 | | | |
| 17–20 | 72.74 | 8.2 | 74.79 | 7.43 | | | |

**Table 3**: Pulse rate comparison p-value (case vs. control) indicates whether refractive error status (case vs. control) significantly affects pulse rate within each age group. p-value (age effect) evaluates whether pulse rate varies with age, regardless of refractive status, identifying age as an independent factor. “p-value overall” examines the combined effect of age and refractive status on pulse rate across all groups, revealing whether both variables together have a significant influence. The p-values for "case vs. control" were calculated using the independent samples t-test (Student’s t-test). The p-values for "age effect" and overall p-value were calculated using two-way ANOVA to assess the influence of age groups and refractive errors on the measured parameter diastolic blood pressure (DBP) comparison.

In this study, systolic blood pressure (SBP) showed no statistically significant difference between the case and control groups ($p = 0.192$), indicating it was not a distinguishing factor in refractive error status. Unlike diastolic pressure, SBP did not vary meaningfully with age or group. Its lack of association suggests that SBP may not contribute significantly to the development or presence of refractive errors in adolescents.

As mentioned in **Table 4**, children in the case group had notably higher diastolic blood pressure than controls, especially in the 11–12 age range. Blood pressure also varied with age, showing a clear developmental influence. These patterns suggest that both age and health status may be shaping blood pressure differences.

**Table 4**: Diastolic blood pressure (DBP) comparison p-value (case vs. control) indicates the significance of the difference in diastolic blood pressure (mmHg) between cases and controls within each age group. “p-value (age effect)” shows whether diastolic pressure varies significantly across age categories, regardless of refractive status. “p-value overall” reflects the combined effect of age and refractive error status on diastolic pressure across all groups, indicating whether their interaction is statistically significant. The p-values for "case vs. control" were calculated using the independent samples t-test (Student’s t-test). The p-values for "age effect" and overall p-value were calculated using two-way ANOVA to assess the influence of age groups and refractive errors on the measured parameter.

Diastolic blood pressure (DBP) in Cases, no significant differences by age, gender, or overall ($p > 0.05$), though minor gender variations exist. In controls, DBP shows significant differences by age ($p < 0.001$), gender ($p = 0.007$), and overall ($p = 0.021$), with a marked male-female difference in the 11-12 age group.

Intraocular pressure (IOP) IOP values are slightly higher in females. No significant differences in IOP R ($p > 0.05$). IOP shows significant gender ($p = 0.011$) and overall differences ($p = 0.018$), with higher values in females, especially in older age groups. Age has no significant effect. **Figure 2** shows higher BMI parallels higher right-eye IOP across the sample. Emmetropic controls cluster around normal BMI with mid-range pressures, whereas myopic cases fan out toward heavier BMI and elevated IOP. This divergence indicates that the BMI-IOP link, while present overall, is more pronounced in the myopes.

In **Figure 3**, individuals with myopia (cases) show a broader spread of diastolic blood pressure values, with many exceeding 75 mmHg and displaying higher intraocular pressure (IOP). In contrast, emmetropic controls tend to cluster between 60–70 mmHg and have lower IOP levels. This pattern suggests that elevated diastolic pressure may be linked to increased IOP, possibly due to greater aqueous humor production or reduced outflow. The association appears stronger in the myopic group, indicating a more pronounced vascular influence on IOP regulation in these individuals.

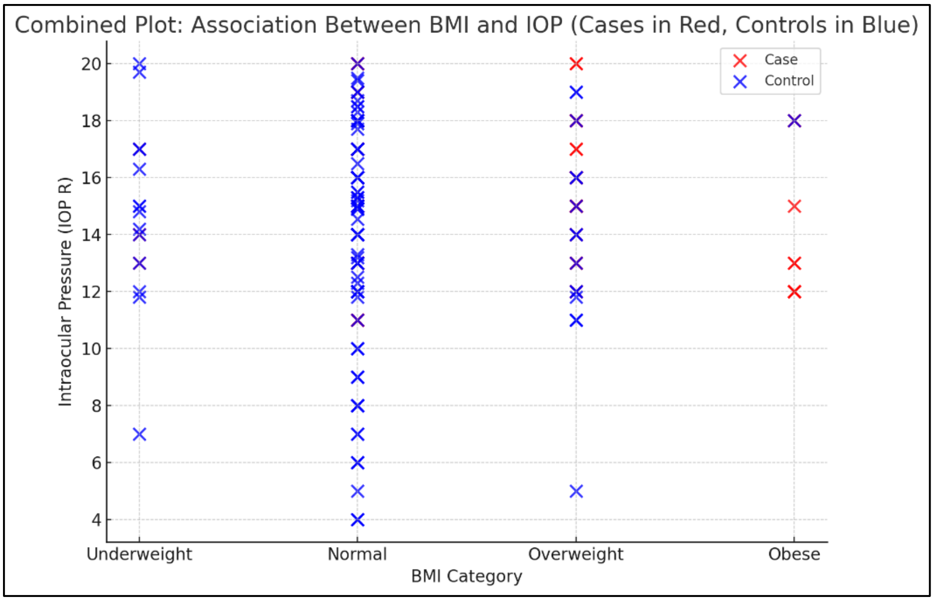


**Figure 2:** Scatter plot of IOP vs. BMI (Cases and Controls)

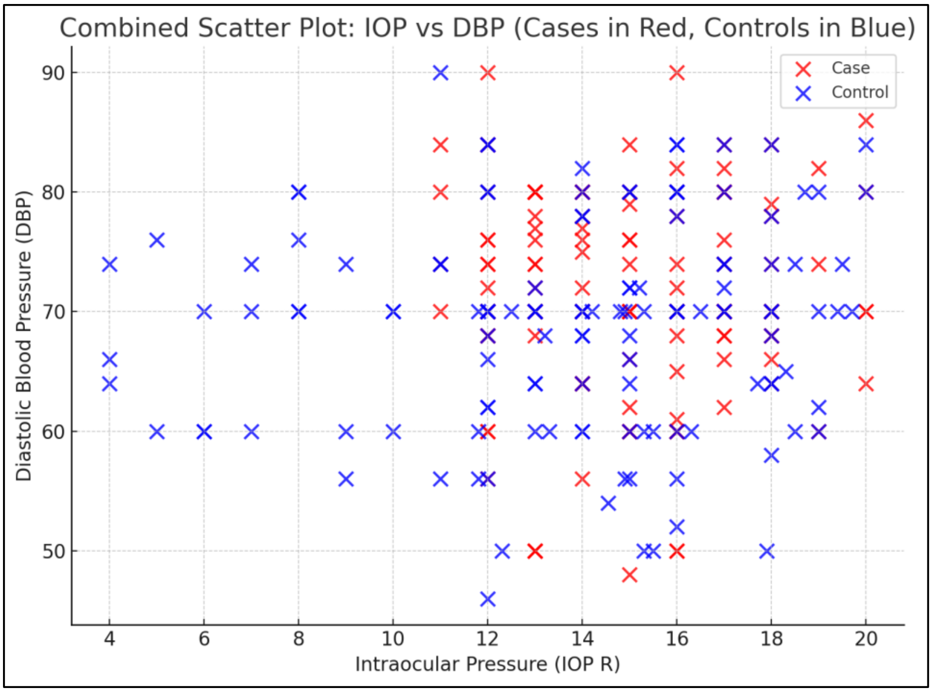


**Figure 3:** Scatter plot of IOP vs. Diastolic BP (Cases and Controls)

### *3.1. Pulse rate trends*

Among the case group, pulse rate remained relatively stable across age and gender, with no statistically significant differences ($p > 0.05$). In the control group, however, pulse rate increased significantly with age ($p < 0.001$). Female controls showed higher pulse rates during early adolescence, but gender and overall group comparisons did not reach statistical significance. These results reinforce a clear association between refractive error status and systemic parameters such as BMI, diastolic blood pressure, and pulse rate, with myopic individuals more likely to present with elevated DBP and altered cardiovascular profiles.

Acceptance right & left eye comparison acceptance R and L show significant overall differences ($p = 0.011$ and $p = 0.010$), with gender as a key factor. In the 13-16 age group, males had substantially lower acceptance values than females for both R (-3.441 vs. -1.478) and L (-3.509 vs. -1.276), indicating a marked accommodative imbalance. Greater variability in male responses suggests a wider range of accommodative responses in this group. Additionally, the significant gender difference in Acceptance L in the 11-12 group ($p = 0.026$) highlights early gender-based visual performance differences. These findings suggest that accommodative response patterns vary significantly by gender, particularly in early to mid-adolescence.

## 4. Discussion

Refractive errors, particularly myopia, are increasing globally, necessitating evaluation of systemic parameters such as age, height, weight, pulse rate, systolic blood pressure (SBP), and mean arterial pressure (MAP). In the present dataset, age ($p = 0.885$) and height ($p = 0.961$) did not differ significantly between cases and controls. While axial elongation is associated with age, environmental factors like near work and reduced outdoor activity are major contributors. Although height correlates with axial length, consistent associations with refractive errors are lacking. A significant difference in weight ($p = 0.010$), with higher values in cases, supports the finding that increased weight is associated with elevated intraocular pressure (IOP), a potential contributor to myopia. Obesity, a risk factor for hypertension, may contribute to both systemic and ocular pathophysiology.

Significantly lower pulse rates in cases ($p = 0.004$) may reflect autonomic dysfunction, affecting ocular perfusion and myopia progression. Previous studies by Akova-Budak et al have reported reduced pulse rates in myopic children, linking them to altered cardiovascular regulation. Some evidence also suggests that low birth weight is associated with hyperopia and high pulse rate, while higher birth weight correlates with myopia, indicating early metabolic influences.[2] A study by Li M, et al and Du W et al showed BMI–myopia association mediated by pulse rate has been described. Reduced sympathetic activity may drive both lower pulse rates and axial elongation, consistent with the current data.[3,5]

SBP showed no significant overall difference ($p = 0.782$) but varied by age ($p < 0.001$), with lower SBP in cases, especially older adolescents. While some studies link myopia to slightly elevated SBP and IOP, our findings suggest otherwise. A study by Wong TY et al showed high SBP may narrow retinal vessels, whereas lower SBP might facilitate axial elongation.[4] Other researchers like Bai WL et al and He Y et al have similarly observed lower SBP in younger myopes. These findings imply SBP could influence myopia by modulating ocular perfusion and choroidal blood flow resistance.[6,7] Ikuno et al. concluded that choroidal thickness decreases with age and increasing myopia/axial length, supporting the idea that choroidal structure and perfusion are important in the development of refractive error.[8]

Diastolic BP differed significantly by group ($p = 0.024$), age ($p < 0.001$), and overall ($p = 0.001$), with younger myopes showing higher DBP. Prior studies by Yang DY et al have reported similar patterns, associating high DBP with increased IOP and axial elongation. High DBP has also been linked to narrower retinal vessels and reduced choroidal perfusion.[9] While MAP did not show statistically significant differences overall ($p = 0.075$), it was elevated in younger cases and decreased in older adolescents. Other studies by Mitchell P et al have described MAP's role in retinal vessel narrowing and myopia progression, and its association with poorer acuity.[10] These vascular shifts likely contribute to early-onset myopia, with possible adaptation in late adolescence.

BMI was strongly linked to refractive error status ($p < 0.001$). The "obesity paradox," a study by Takagi H, Umemoto et al which describes lower mortality in overweight but not obese individuals, aligns with this study, where overweight (21.6%) and obesity (6.7%) were more prevalent in cases than controls.[11] Other authors such as Anderson LN et al emphasized the misclassification risk of BMI,[12] supported here by the higher proportion of normal-BMI individuals among controls (76.2% vs. 69.4%). As studied by WHO expert consultation lower BMI cutoffs for Asians are recommended due to higher body fat at lower BMIs.[13] A study by Hubbard RE et al showed frailty in underweight individuals, noted in other studies, is reflected in our dataset, with a higher proportion of underweight controls (10.8% vs. 2.2%).[14] Adolescents with myopia often have higher BMI due to sedentary lifestyles, reduced outdoor activity, and increased screen time. Higher BMI is linked to metabolic changes that may promote axial elongation, contributing to myopia. Reduced time outdoors limits exposure to natural light, which normally inhibits eye growth via dopamine release in the retina. Additionally, myopic individuals are more likely to engage in prolonged near work—such as reading and computer use—due to academic demands and behavioural tendencies. These factors form a cycle where increased near work and less outdoor exposure both contribute to higher BMI and myopia progression.

Height was not significantly associated with myopia overall ($p = 0.204$), but age-wise differences were significant ($p < 0.001$). Growth spurts may trigger axial elongation, a trend mirrored in our data, with taller individuals aged 17–20 years in the case group. Weight differences were notable in younger groups ($p = 0.003$ for 11–12 years), suggesting early metabolic impact. As studied by Peled A et al a J-shaped BMI–myopia curve has been described, and it has been reported that myopia risk increases by 1% per 1 $kg/m^2$ rise in BMI.[15] The role of birth weight and obesity in axial elongation and refractive error development is further supported.[2]

No significant IOP difference was seen by age ($p = 0.635$), gender ($p = 0.114$), or overall ($p = 0.909$), although females consistently had slightly higher IOP. IOP is a key factor in glaucoma, and similar gender-based trends have been noted in other populations. Pulse rate also showed no overall differences across age ($p = 0.915$), gender ($p = 0.390$), or group ($p = 0.337$), but patterns emerged with higher rates in 13–16-year-old females, equalizing by age 17–20. This trend is attributed to autonomic and hormonal changes. In controls, pulse rate differed significantly by age ($p < 0.001$), with gradual declines seen across adolescence, reflecting cardiovascular and autonomic maturation.

In the present study, a clear association was observed between intraocular pressure (IOP), body mass index (BMI), blood pressure (BP), and refractive error, particularly myopia. Myopic individuals tended to have higher IOP values than emmetropic controls, although this difference was not statistically significant. BMI was significantly elevated in the myopic group, indicating that increased body weight may contribute to ocular changes associated with refractive errors. A positive trend was noted between higher BMI and increased IOP, especially among cases, suggesting a metabolic influence on intraocular dynamics. Diastolic blood pressure (DBP) was significantly higher in myopic individuals, particularly in younger adolescents, while systolic blood pressure (SBP) was consistently lower in cases, supporting the idea of altered ocular perfusion in myopia. Although mean arterial pressure (MAP) did not differ significantly, it was elevated in younger cases, pointing toward underlying microvascular changes. Scatter plot analysis revealed that elevated DBP was associated with increased IOP, a relationship more evident in myopes than controls. This suggests that high BP may increase aqueous humor production or impair its outflow, thereby raising IOP and contributing to axial elongation. Additionally, lower pulse rates observed in myopic adolescents may reflect autonomic dysfunction affecting ocular blood flow regulation. Overall, these findings underscore the significant interplay between systemic vascular and metabolic parameters in the development and progression of refractive errors during adolescence.

## 5. Limitations

This study was conducted in a single clinical and school-based population, limiting its generalizability to broader adolescent groups across diverse geographic or socioeconomic settings. The cross-sectional design restricts causal inference between systemic parameters and refractive errors. Birth weight and axial length—important factors in myopia development—were not recorded. The use of BMI alone may misclassify metabolic status, lacking body fat or waist circumference data. Diurnal variations in BP and IOP were not controlled. The study relied on self-reported history for exclusion criteria, which may introduce bias. Environmental factors such as screen time and outdoor activity were also not quantified, which may influence refractive status.

## 6. Conclusion

This study highlights a significant association between refractive errors in adolescents and systemic parameters such as BMI, pulse rate, and diastolic blood pressure. Myopic individuals exhibited higher BMI and DBP values, along with lower pulse rates, suggesting autonomic and metabolic influences on ocular physiology. Although IOP differences were not statistically significant, females consistently showed slightly higher values, supporting hormonal contributions. MAP trends indicated early vascular changes in younger myopes. Age-related height and weight variations also appeared more pronounced in myopic groups, reflecting developmental risk periods. Gender-based accommodative differences further suggest visual performance disparities. Overall, systemic health appears intricately linked with refractive development, emphasizing the need for an integrated clinical approach in adolescent eye care.

## 7. Source of Funding

None.

## 8. Conflict of Interest

None.

## 9. Ethical Number

Ethical No.: KIIT/KIMS/IEC/1157/2023.

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