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# Development and progression of myopia in emmetropic children in Turkey

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## ABSTRACT

**Aims**: To investigate the development and progression of myopia in emmetrope school-aged children in Turkey.

**Methods**: This retrospective study included emmetrope children aged 6-18 who attended the ophthalmology clinic for regular eye and refractive examinations between 2010 and 2021. Individuals were examined at least twice for six months period. Myopia progression was calculated as the difference between the baseline and the last visit spherical equivalent refractive (SER) values. Individuals were further categorized to determine the age-specific myopia development and progression as 6-11, 12-16, and 17-18 age groups based on the school periods of the country. According to the change in SER values, individuals were classified into those who remain emmetrope and those who develop myopia.

**Results**: A total of 738 eyes of 369 children (222 female, 147 male) with a mean age of 9.4±2.98 (6-18) years were included in the study. The mean follow-up time of patients was 45.62±26.36 (6-130) months. The baseline mean SER value was -0.01±0.10 D (range: -0.375 and +0.375) and -0.44±0.8 (range: -5.00 and +0.375) at the final visit. The overall mean progression was -0.12±0.25 D/year (range: -2.21 and +0.36). 234 eyes (31.75%) developed myopia, and annual SER change was -0.38±0.31 D/year ($p<0.001$). 79 (35.7%) of females and 38 (25.9%) of males developed myopia with a statistical significance ($p<0.006$). There were 163 children between 6-11 years, 169 children between 12-16 years, 37 children between 17-18 years, and 41 (25.2%), 69 (40.8%), and 7 (18.9%) patients of age groups developed myopia, respectively ($p=0.15$).

**Conclusion**: The development and progression of myopia is more common in 12-16 ages and females. Myopia prevention recommendations should be carefully advised to predisposed age populations and females to reduce myopia progression.

**Keywords**: Emmetrope, myopia, development of myopia, progression of myopia, myopia in children

## INTRODUCTION

Refractive error is one of the most common causes of vision loss, and myopia is becoming an epidemic because of its increasing prevalence all over the world. The worldwide prevalence of myopia and high myopia is envisaged to be 52% (almost 5 billion) and 10% (almost 1 billion) by 2050. Myopia may develop in early childhood, late teens, or adulthood.[1,2] Epidemi of myopia is defined in East and Southeast Asia, which has a prevalence in young adults of almost 80-90%.[3] Early onset of myopia has been reported to evolve more myopic refractive error or high myopia later in life.[4] High myopia may link to pathological myopia, in which choroidal, retinal, and scleral changes cause uncorrectable vision loss.[5] Despite the high prevalence in Asia countries, it was reported as almost 18% in 18-20 year-olds in European countries.[6,7] A much higher prevalence (%49.7) was reported in 12-year-old children from Sweeden.[8]

As studies on the incidence of myopia are essential to observe differences between countries and populations, the current study aims to assess the incidence and progression of myopia in school-aged children. Furthermore, the data on refractive error and the variability between gender and age were obtained from children living in Turkey.

## METHODS

This retrospective study was conducted in accordance with the Declaration of Helsinki with written permission from the Zonguldak Bülent Ecevit University Non-interventional Clinical Researches Ethics Committee (Date: 06.04.2022, Decision No:2022/07). The study was carried out in Devrek State Hospital, Zonguldak, Turkey. 369 individuals

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aged 6 to 18 years and only with the diagnosis of 'emmetrope' at their first visit (taken as a baseline) were included in the study. Based on the World Health Organization (WHO) definition, we defined emmetropy as spherical equivalent refractive (SER) between <+0.50 D and >-0.50 D.[1] Patients examined at least twice with six months intervals between 2010-2021 years were evaluated. Myopia progression was calculated as the difference between the baseline and the last visit between SER values. Individuals were further categorized to determine the age-specific myopia development and progression as 6-11, 12-16, and 17-18 age groups based on the school periods of the country. According to the change in SER values, individuals were classified into those who remained emmetrope and those who developed myopia. The best corrected visual acuity was 1.0 for all patients under the correction of refractive status. Patients with other ocular diseases like uveitis, trauma, strabismus, and retinal diseases were excluded from this study.

### Statistical Analysis

Descriptive and statistical analyzes were performed using IBM SPSS Statistics 21. Demographic characteristics and clinical data were expressed as mean, standard deviation, frequency, or percentage. The Kolmogorov-Smirnov test was evaluated for the normal distribution test of continuous data. Since the data were unsuitable for normal distribution, the Mann-Whitney U test was used for independent groups. Wilcoxon Signed Rank test was used for related samples, and the Kruskal Wallis test was used for multiple categorical data. The Chi-Square test is also used for suitable data. P value of 0.05 or less was considered statistically significant.

## RESULTS

A total of 738 eyes of 369 children (222 female, 147 male) with a mean age of 9.4±2.98 (6-18) years were included in the study. The mean follow-up time of patients was 45.62±26.36 (6-130) months. No anisometropic patients were found during follow-up. 234 eyes of 117 patients (31.8%) developed myopia whose annual SER change was -0.38±0.31 D/year (Table 1). The mean SER value changed from -0.04±0.11 D (range: -0.375 and +0.375) to -1.35±0.87 (range: -0.50 and -0.5) during mean 49.67±21.76 (7.3-106) months follow-up of myopia developed group. Statistical significance existed between the baseline and last SER values (p<0.001). Although the first and last SER values were -0.001±0.09 D (range: -0.375 and +0.375), -0.02±0.17 D (-0.375 and +0.375) of the 'remained emmetrope' group during the 43.74±28.07 (6-130) months follow-up period, the results revealed a statistical significance (p<0.001).

**Table 1.** Evaluation of the number of patients who developed myopia and remained emmetrope based on gender

| | Total of patients | Female | Male |
|---|---|---|---|
| Number of patients | 369 | 222 | 147 |
| Developed myopia | 117 (31.8%) | 79 (35.7%) | 38 (25.9%) |
| Remained emmetrope | 252 (68.2%) | 143 (64.3%) | 109 (74.1%) |
| p value | | 0.006* | |

(*): Chi-Square test was used.

79 (35.7%) of females and 38 (25.9%) of males developed myopia, and there was statistical significance regarding the gender of patients (p<0.006) (Table 1).

The annual SER change of 234 eyes that develop myopia was -0.38 ±0.31 D (range: -0.03 and -2.21), and 504 eyes that remained emmetrope was 0.007±0.05 D (range: -0.36 and +0.37) (p<0.001) (Table 2)

The baseline mean SER value was -0.01±0.10 D (range: -0.375 and +0.375), -0.44±0.8 (range: -5.00 and +0.375) at the final visit, and the overall mean progression was -0.12±0.25 D/year (range: -2.21 and +0.36) of all the patients (Table 3).

**Table 2.** Evaluation of the number of eyes that developed myopia and remained emmetrope, follow-up periods, baseline, final and annual change of spherical refractive equivalent (SER) values

| | N (eyes) | Follow-up period (months) | Baseline SER values | Final SER values | P value | Annual SER progression |
|---|---|---|---|---|---|---|
| Developed myopia | 234 (31.8%) | 49.67 ± 21.76 (7.3-106) | -0.04 ± 0.11 (Range: -0.375 and +0.375) | -1.35 ± 0.87 (Range: -0.50 and -0.5) | <0.001* | -0.38 ± 0.31 (Range: -0.03 and -2.21) |
| Remained emmetrope | 504 (68.2%) | 43.74 ± 28.07 (6-130) | -0.001 ± 0.09 (Range: -0.375 and +0.375) | -0.02 ± 0.17 (Range: -0.375 and + 0.375) | <0.001* | 0.007 ± 0.05 (Range: -0.36 and +0.37) |
| p value | | <0.001** | <0.001** | <0.001** | | <0.001** |

Results indicate as mean ± standard deviation. (*): Wilcoxon signed rank test, (**): Mann Whitney U test

**Table 3.** Follow-up period, baseline, and final mean spherical refractive equivalent (SER) values and myopia progression based on age, and gender

| | Number of patients | Follow-up period (months) | Baseline SER values | Final SER values | P value | Annual SER progression |
|---|---|---|---|---|---|---|
| Total | 369 | 45.62 ± 26.36 (6 - 130) | -0.01± 0.10 (Range: -0.375 and +0.375) | -0.44 ± 0.8 (Range: -5.00 and +0.375) | <0.001** | -0.12 ± 0.25 (Range: -2.21 and +0.36) |
| **Age groups** | | | | | | |
| 6-11 | 163 (44.1%) | 66.86 ± 26.50 (10.5 - 130) | -0.005 ± 0.07 (Range: -0.375 and +0.375) | -0.34 ± 0.77 (Range: -4.00 and + 0.375) | <0.001** | -0.05 ± 0.11 (Range: -0.55 and + 0.21) |
| 12-16 | 169 (45.9%) | 42.74 ± 24.1 (6 - 111) | -0.01 ± 0.1 (Range: -0.375 and +0.375) | -0.56 ± 0.84 (Range: -5.00 and +0.375) | <0.001** | -0.14 ± 0.27 (Range: -2.21 and +0.36) |
| 17-18 | 37 (10%) | 32.48 ± 18.24 (6 - 70.9) | -0.03 ± 0.11 (Range: -0.375 and +0.25) | -0.31 ± 0.62 (Range: -2.50 and +0.25) | <0.001** | -0.14 ± 0.27 (Range: -1.64 and +0.30) |
| p value | | <0.001* | =0.001* | <0.001* | | <0.001* |
| **Gender** | | | | | | |
| Females | 222 (60.2%) | 46.21 ± 25.83 (6 - 130) | -0.02 ± 0.1 (Range: -0.375 and +0.375) | -0.50 ± 0.81 (Range: -3.75 and +0.375) | <0.001** | -0.14 ± 0.26 (Range: -2.21 and +0.36) |
| Males | 147 (39.8%) | 44.72 ± 27.17 (6 - 128) | -0.002 ± 0.1 (Range: -0.375 and +0.375) | -0.35 ± 0.77 (Range: -5.00 and +0.375) | <0.001** | -0.1 ± 0.22 (Range: (-1.55 and +0.15) |
| p value | | =0.321*** | =0.004*** | <0.001*** | | =0.003*** |

Results indicate as mean ± standard deviation. (*): Kruskal Wallis Test, (**): Wilcoxon Signed Rank Test, (***): Mann Whitney U test

The mean age of the patients was 9.57±2.6 (6-18) of that developed myopia and 9.32±3.1 (6-18) of that remained emmetrope (p=0.51) (Table 4).

**Table 4.** Demographic characteristics of patients who developed myopia and remained emmetrope

| | Developed Myopia | Remained Emmetrope | p value |
|---|---|---|---|
| Number of patients (%) | 117 (31.8%) | 252 (68.2%) | |
| Age (min-max) | 9.57 ± 2.6 (6-18) | 9.32 ± 3.1 (6-18) | 0.51 |
| Female (%) | 78 (67.5%) | 143 (56.7%) | 0.006* |

Results indicate as mean ± standard deviation. (*): Chi-Square Test

When evaluated according to age, the refraction values were found to be more myopic at the last visit compared to the baseline in all groups. There were 163 children between 6-11 years, 169 children between 12-16 years, 37 children between 17-18 years, and 41 (25.2%), 69 (40.8%), and 7 (18.9%) of age groups developed myopia, respectively (p=0.15). Evaluation of myopia progression based on age revealed no statistical significance (Table 5).

**Table 5.** Analyses of the number of patients who developed myopia and remained emmetrope based on age

| Age groups | 6-11 ages | 12-16 ages | 17-18 ages |
|---|---|---|---|
| Number of patients | 163 (44.1%) | 169 (45.9%) | 37 (10%) |
| Developed myopia | 41 (25.2%) | 69 (40.8%) | 7 (18.9%) |
| Remained emmetrope | 122 (74.8%) | 100 (59.2%) | 30 (81.1%) |
| p value | | 0.15 | |

## DISCUSSION

This study's results indicate that myopia's incidence and progression in school-aged children varied with age and gender. Most of the individuals remained emmetrope (68.2%), and there was not a statistical difference between the developed myopia and remained emmetrope patients regarding age, but there is regarding gender. Females were more prone to developing myopia.

The incidence and progression of myopia have been evaluated in numerous studies. Annual cumulative incidence of myopia has been found more in younger age groups and among females in literature.[9,10] There has still been conflict about the onset of myopia. Fan et al.[11] and Zhou et al.[12] reported a progressive increase in incident myopia with age. Although a statistical difference was not found between age groups regarding myopia development, the 12-16 age group was more prone to develop myopia in our study. The possible reason for this finding could be the difference in follow-up time between the age groups.

With higher incidence and prevalence as reported, girls appear to be at greater risk than boys in our country. Although the conflict of gender dominance in myopia, a similar finding has been reported in the literature.[11,12] A tendency to read, write, and spend more significant time indoors of girls was reported in India. Therefore, they associated the high rates of myopia with these reasons for girls.[13] Moreover, studies show that myopia is more common but progresses more slowly in school-age girls, and the frequency is higher in boys at advanced ages.[14,15] In our study, there was a significant difference between the genders regarding myopia progression. Girls were more prone to have progression of myopia.

The present study revealed a similar annual progression of myopia values (-0.38±0.31) with those in Europe (-0.55 D), Caucasian children (aged 6 to 15 years) living in Australia (-0.31 to -0.41D), in East Asian countries like China and Singapore (-0.31 to -1.2 D) and the USA (-0.34 D to -0.50 D).[9-11,13,16] Donovan et al.[17] published a meta-analysis including 2194 participants in total; children wearing single-vision spectacles with an average age of 9.3 had a progression of -0.52 D/year (%95 CI -0.39 to -0.72 D) myopia in Europe and -0.82 D/year (%95 CI -0.71 to -0.93 D) per a year in Asia. In the ATOM1 study, 400 children aged 6-12 years with spherical equivalents of -1.00 and -6.00 D were followed for two years, and -1.20±0.69 D/2 years myopic change was detected in the non-treated atropine placebo group (n=200).[18] Wong et al.[19] reported the median progression rate of myopia as -0.16 D/year and 62% of children with myopia progressed in London, UK. In our previous study aiming to investigate the relationship between increased digital screen time and the development and progression of myopia during the COVID-19 pandemic, we found the mean annual change in spherical equivalent refractive error (SER) as -0.97±0.66 D in urban area school-aged children in Turkey.[20] The education system, location, lifestyle, and ethnicity variations among different population groups could explain the variations in myopia progression among different countries.

The limitations of this study are involving a citywide population, and it may only reflect some of the country, especially due to the known difference in myopia between urban and rural regions. In addition, the retrospective nature and non-cycloplegic refractive measurements may cause bias. Besides, this study did not evaluate the other potential factors, such as time spent outdoors, parenteral myopia, and time spent near work. Further studies involving separate data with the potential related to various factors, such as exposure to light levels/time outdoors, are required in our country.

## CONCLUSION

The development and progression of myopia in school-aged Turkish children is comparable to the world. This finding of the greater progression in females emphasizes the need for regular follow-ups with short intervals and the application of anti-myopia strategies to control myopia progression. Given the potential role of geographic location on myopia progression, information on the pattern of progression of myopic refractive error across different age groups in Turkish children could help clinicians choose appropriate myopia prevention strategies.

## ETHICAL DECLARATIONS

**Ethics Committee Approval:** The study was carried out with the permission of Zonguldak Bülent Ecevit University Non-interventional Clinical Researches Ethics Committee (Date: 06.04.2022, Decision No:2022/07).

**Informed Consent:** Because the study was designed retrospectively, no written informed consent was obtained from patients.

**Referee Evaluation Process:** Externally peer-reviewed.

**Conflict of Interest Statement:** The authors have no conflicts of interest to declare.

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**Author Contributions:** All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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