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*Original Article*

# Frequency of Refraction Errors among School-age Children in Ankara, Turkey: A Cross-Sectional Study

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**Abstract** Uncorrected refractive errors are the most frequent cause of visual impairment in school-age children. The present study sought to evaluate frequency of refraction disorders in school-age children at different socio-cultural levels in Ankara/Turkey. This cross-sectional study was carried out on 1729 children 7-14 years of age. Frequency of refractive errors were determined as 10.8% (n=186) myopia, 3.8% (n=66) hyperopia and 26.3% (n=455) astigmatism. Multiple regression analysis revealed that age (OR:1.23, p<0.001), positive family history of myopia (OR:2.36, p<0.001), number of siblings (OR:0.73, p=0.001) and maternal working status (OR:0.32, p=0.002) were significantly associated with myopia in children. Frequency of myopia as a cause of refractive errors was increased compared with the other developed countries. Regular eye screening programs in school-aged children should be essential practices to prevent vision loss.

**Key words** Children; Eye examination; Frequency; Refractive errors

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## Introduction

Refractive errors such as myopia and hyperopia are visual impairments, the correction of which leads to potentially high costs. Such visual corrections are defined as a critical reason for public health and economic burden.[1] World Health Organization (WHO) "Vision 2020: The Right to Sight" has adopted the correction of refractive errors, which are the most important preventable causes of visual impairment, as a primary target to eliminate all preventable and treatable blindness.[2] For this reason, screening programs in school-age children are of importance in terms of long-term health conditions across the population.[3] The school-age ocular screening programs increase the chance of early diagnosis of visual impairment risk factors such as amblyopia, diplopia facilitating amblyopia and refractive errors in children.[4]

Uncorrected refractive errors are the most frequent cause of visual impairment in school-age children in either industrial or developing countries throughout the world.[5] The interaction of many factors such as genetics and the environment, socio-economical level, and outdoor activities may contribute to the development of refractive errors.[6] Refractive errors in childhood may result in insufficient and low performance at school but if not detected and treated appropriately may progress to permanent vision loss.[7]

Many studies have been carried out on children at various age groups in different ethnic groups regarding refractive errors. While the frequency of myopia was 24.5% in a study carried out in students between the ages of 12-17 in the USA from 1971-1972, it was 34.8% in a study carried out between the years of 1999-2004.[8] In two studies carried out in Australia, the frequency of myopia was 1.4% in the children at the age of 6,[9] and it was reported as 5.1% in the children at the age of 12.[5] The frequency of myopia in children originating from East Asia as a sub-group in the 12-age groupwas reported as 41.6%.[5] The frequency of myopia was found at a low rate such as 1.2% in a broad-based study which involved children between the ages of 5-15 in Nepal.[10] While the frequency of myopia was reported at a lower rate of 1.4% in the rural area of India,[11]and it was 7.4% in the urban area.[12] In certain studies carried out in East Asia countries, the frequency of myopia was found to be above 35% in the children of different age groups.[13,14]

This study evaluated the frequency of ocular pathologies leading to visual impairment such as decreased visual acuity, refractive defects and diplopia in school-age children at different socio-cultural levels in Ankara/Turkey. Additionally, we also sought to identify possible risk factors and demographic features unique to children with myopia.

## Methods

### *Study Design*

This study was a cross-sectional study intended to determine the frequency of vision problems such as amblyopia, refractive errors, diplopia and colour blindness in the school-age children ages 7-14.

### *Questionnaire*

A questionnaire included questions regarding socio-demographic characteristics of the parents and their children and an eye health history of the children was completed by their parents. Parent approval about participation in the research study was obtained in order to fill out the survey including questions about their educational levels, working status, number of children, conditions of others who have an eye disorder in the family, whether the child had previously undergone an eye examination, school success, and the time that the child spends on the television/ computer. Body mass index (BMI) values of participants were calculated based on the formula of BMI=weight/height² ($kg/m^2$).

### *Definitions*

In order to ensure a complete and valid comparison with other studies, certain definitions were clarified. *Myopia* was defined as a spherical equivalent (SE) refraction having 0.5 diopter (D) or lower values in one or both eyes. We categorised myopia as mild (-0.5 D to -3.0 D), moderate (-3.1 D to -6.0 D), and high (worse than -6.0 D). *Hyperopia* was defined as SE refraction's having +2.0 diopter or higher values in one or both eyes. Hyperopia was categorised as mild (+2.0 D to +3.9 D), moderate (+4.0 D to +5.9 D) and high (≥ +6.0 D). *Astigmatism* was defined as cylindrical defect's being ≥0.75 D in one or both eyes. A difference more than 2 lines between eyes in Snellen charts and best corrected visual acuity of each eye lower than 0.6 were considered amblyopia.

### *Population and Samples*

This cross-sectional study was carried out on primary and secondary school-age children in Ankara between the dates of 1st May-1st December 2010. 1729 of 2000 students who were included in the study (86.45%) fulfilled the criteria

for the parental consent and inclusion into the study. Participants from different socio-cultural levels were included in the study in a randomised manner. Students who were diagnosed with mental retardation, congenital anomaly, ocular opacity and retinal disease and the students of whom consents of their parents were not obtained were excluded from the study. The students were taken into the examination room by their class number. Data from the questionnaire form which was prepared to determine the socio-demographic information of all participants and their previous eye health conditions were recorded.

### *Examinations*

The refractive errors of all of the eyes were measured without cycloplegia. Measurement of all of the patients was repeated using Plusoptix S08 refractometers. For measurements with the Plusoptix S08, the examiner adjusted the mobile camera to the face of the patient at a distance of 1 m, and at the end of the measurement, the refractive data indicated in green on the monitor were taken as the baseline. Refractive measurements of the patients were performed by investigators under the same conditions, each device being used by the same investigator. All of the measurements were repeated at least 3 times and the average values of the obtained results were recorded in order to be used in the study.

### *Devices Used in the Study*

Plusoptix S08 (Plusoptix GmbH, Nuremberg, Germany) works based on the eccentric photorefraction method. As it performs the measurements from a distance of 1 m, it gives a relaxation of accommodation. Especially in children, its main advantages are that it does not cause a feeling of fear due to the lack of physical contact and it assists in the detection of anisometropia without accommodation difference due to its capability of the binocular measurement. The device also detects the pupil size and inter pupiller distance (IPD) values during refraction measurement.

### *Statistical Analysis*

While evaluating the data obtained from the study, the package program SPSS 15.0 for Windows (Chicago-USA) was used. Descriptive statistical methods were given in numbers and percentages for categorical variables and as mean ± standard deviation or median (minimum - maximum) for continuous variables. Refractive errors were accepted as primary outcome, whereas gender, age, BMI, parental educational levels, parental working status, the existence of refractive errors in the family, time spent watching TV-computer and number of siblings were accepted as predictors. The conformity of data to a normal distribution was analysed using Kolmogorov-Simirnov test. Chi-square test was used for categorical variables. Spearman correlation analysis was used to evaluate the correlation between factors. The statistical significance was accepted at $p<0.05$. Multiple logistic regression analysis was applied to detect the impact of independent variables on the refractive errors.

### *Ethical Approval*

The parents of school-children were informed and their written consent regarding the study was obtained. The necessary ethical committee approval for the study was received from the Gulhane Military Medical Academy (GMMA) Local Ethics Committee and the required permission was obtained from Ankara Provincial Directorate of National Education. The research adhered to the principles of the Declaration of Helsinki.

## Results

The mean age of the participants was 9.43±2.06 years (7-14 years) and 47.8% (n=827) of the students were males. The refractive error evaluation carried out on the children was examined in terms of the presence of myopia, hyperopia, and astigmatism in at least one eye. As a result of this evaluation, the frequency of refractive error was determined as 10.8% (n=186) myopia, 3.8% (n=66) hyperopia and 26.3% (n=455) astigmatism. The frequency of myopia-astigmatism was 4.6% (n=80). In the evaluation carried out by considering the presence of amblyopia in at least one eye, the frequency of amblyopia was determined as 8.8% (n=152). When refractive errors and amblyopia rates were evaluated in terms of gender, no statistically

**Table 1** Distribution of the frequency of refractive defects and amblyopia by gender (n=1729)

| Gender | Myopia n (%) | Hipermetropia n (%) | Astigmatism n (%) | Ambliyopia n (%) |
|---|---|---|---|---|
| Male | 82 (9.9) | 38 (4.6) | 228 (27.6) | 76 (9.2) |
| Female | 104 (11.5) | 28 (3.1) | 227 (25.2) | 76 (8.4) |
| Total | 186 (10.8) | 66 (3.8) | 455 (26.3) | 152 (8.8) |

significant difference was found (p>0.05) (Table 1).

Students who were examined in terms of refractive errors were analysed regarding the independent variables including gender, age, BMI, parental educational level, parental working status, the presence of eye disease in the family, time spent on the TV/computer and number of siblings. An analysis of the children having myopia in terms of the independent variables was specified in Table 2. The only significant difference in terms of age was found in those who have hyperopia as compared with those who do not have hyperopia (8.86±1.92/9.45±2.06; p=0.023). A significant difference in terms of BMI (17.88±2.93/17.36±2.77; p=0.001) and average time spent on the TV-computer (3.02±1.48/2.80±1.44; p=0.005) was found in those who have astigmatism as compared with those who do not have astigmatism.

In the study, the relationship between the educational status of the parents and the frequency of myopia of the children was analysed. When the maternal educational level of the children with myopia was compared with the maternal educational level of the children without myopia; the results were as follows: (0-8 years) 60.8/57%, (9-12 years) 36.6/34.7%, (≥12 years) 2.7/8.3% (p=0.025) (Table 2). When the relationship between the frequency of myopia of the children and the working status of the parents was analysed, it was found that there was a significant relationship between the children with myopia and the working status of both mother and father (p<0.001, p=0.024, respectively) (Table 2). Furthermore, a positive correlation was detected between the parental educational level and the children who had undergone an eye examination before (r=0.073, p=0.020; r=0.089, p<0.001).

Myopia and hyperopia defect rating carried out by considering the SE values for both eyes is specified in Table 3. The distribution of the frequency of myopia and hyperopia by the age groups is shown in Figure 1 and Figure 2 (p<0.001 and p=0.015, respectively). In the distribution of the frequencies of astigmatism and amblyopia by the

**Table 2** Socio-demographic characteristics of the students evaluated in terms of myopia (n=1729)

| **Parameters** | **Myopia** | | **p*** |
|---|---|---|---|
| | **Myopia (+) n (%)** | **Myopia (-) n (%)** | |
| Gender | | | |
| Female | 104 (11.5) | 798 (88.5) | 0.279 |
| Male | 82 (9.9) | 745 (90.1) | |
| Mother working (+) | 10 (5.4) | 228 (14.8) | **<0.001** |
| Father working (+) | 172 (92.5) | 1482 (96) | **0.024** |
| Mother education | | | |
| 0-8 years | 113 (60.8) | 880 (57.0) | |
| 9-12 years | 68 (36.6) | 535 (34.7) | **0.025** |
| >12 years | 5 (2.7) | 128 (8.3) | |
| Father education | | | |
| 0-8 years | 78 (41.9) | 583 (37.8) | |
| 9-12 years | 79 (42.5) | 609 (39.5) | 0.082 |
| >12 years | 29 (15.6) | 351 (22.7) | |
| Refractive disorders in the family (+) | 102 (54.8) | 530 (34.3) | **<0.001** |
| | **mean±SD** | **mean±SD** | **P**** |
| Age (year) | 10.35±2.06 | 9.32±2.03 | **<0.001** |
| BMI (kg/m$^2$) | 18.32±2.76 | 17.39±2.81 | <0.001 |
| TV-PC time (hour/day) | 2.88±1.42 | 2.86±1.46 | 0.862 |

*: Student t-test; **: Chi-Square test.

Myopia (+): with myopia; Myopia(-): without myopia.

age groups, no significant difference was found (p>0.05).

Parents were surveyed regarding whether their children had undergone eye examinations before and 45.8% of the children (n=792) had never gone through an eye examination. When the current eye health information of the children was asked to the parents, although 78% (n=1349) notified that their children had no eye problem, 14% (n=242) stated that their children used eyeglass, 2.8% (n=48) stated that their children had amblyopia, 0.3% (n=5) stated that their children had colour blindness, 0.5% (n=9) indicated that their children had diplopia and 4.4% (n=76) stated that their children had other eye diseases in the past. The eyeglass usage rates of the children in which refractive errors and amblyopia were detected during the examination are specified in Figure 3.

Of the parents, 36.6% (n=632) at least one of them had an eye health related problem. Eye pathologies which also include myopia, hyperopia, astigmatism, dyschromatopsia, and colour blindness were found in 17.8% of the mothers (n=307), in 16.5% of the fathers (n=286) and in 12.9% of the siblings. A positive relationship was found between those whose family members have had eye health problems and students having refractive error in terms of myopia (r=0.132, p<0.001) and astigmatism (r=0.048, p=0.045). The total duration that the children spent on the TV and/or computer averaged 2.86±1.45 (0-7 hours) per day.

In a multiple logistic regression analysis carried out, a significant association with age (OR:0.91, CI 95%; 0.86-0.97, p=0.004), BMI (OR:1.08, CI %95; 1.04-1.13, p<0.001) and average duration spent on the TV-computer (OR:1.09, CI 95%; 1.01-1.18, p=0.020) was found in the students diagnosed with astigmatism and a significant association was found in students diagnosed with hyperopia in terms of age as part of the independent variables (OR: 0.83, CI 95%; 0.72-0.97, p=0.020). Multiple regression analysis revealed that age (OR:1.23, p<0.001), positive family history (OR:2.36, p<0.001), number of siblings (OR: 0.73, p=0.001) and maternal working status (OR:0.32, p=0.002) were significantly associated with myopia in children (Table 4).

**Table 3** Right and left eye evaluation by the severity of the myopia and hyperopia defect (n=1729)

| Parameters | Right eye n (%) | Left eye n (%) |
|---|---|---|
| Healthy | 1515 (87.6) | 1519 (87.9) |
| Mild myopia (-0,5 D to -3,0 D) | 128 (7.4) | 122 (7.1) |
| Moderate myopia (-3,1 D to -6,0 D) | 35 (2) | 36 (2.1) |
| High myopia (> -6,0 D) | 2 (0.1) | 2 (0.1) |
| Mild hyperopia (+2,0 D to +3,9 D) | 43 (2.5) | 40 (2.3) |
| Moderate hyperopia (+4,0 D to +5,9 D) | 5 (0.3) | 9 (0.5) |
| High hyperopia (≥ +6,0 D) | 1 (0.1) | 1 (0.1) |

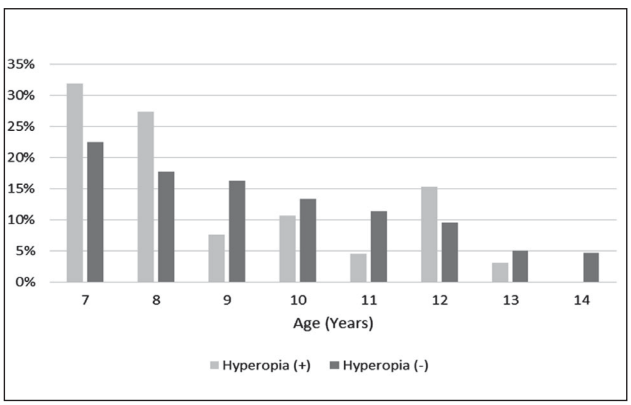


**Figure 2** Distribution of the frequency of hyperopia by the age groups.

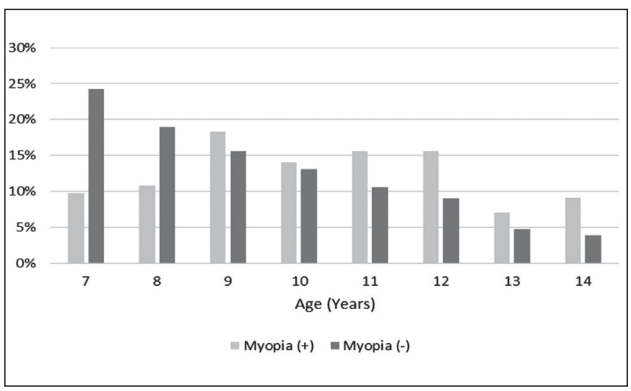


**Figure 1** Distribution of the frequency of myopia by the age groups.

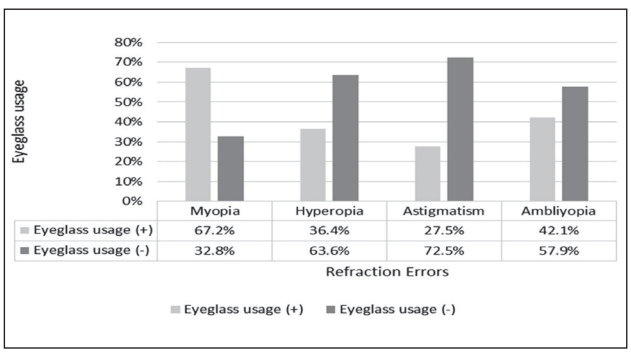


**Figure 3** Eyeglass usage rates of the children in which refraction errors and amblyopia were detected.

## Discussion

Refractive errors are responsible for more than half of the vision impairments in the populations researched.[14,15] These visual impairments are significant without differentiating age, gender or ethnicity throughout the world. It is important to establish a diagnosis by means of early and rapid diagnosis methods and to ensure healthy vision ability by means of suitable treatment methods.[15,16] The prevalence of refractive errors can differ by race and geographical region,[14,15] gender,[15,17] age[15,17] and parent training level.[18] In our study, the frequency of amblyopia was 8.8% whereas myopia was determined as 10.8%, hyperopia as 3.8% and astigmatism as 26.3% from all refractive errors.

In the studies carried out in the Far East countries, myopia (≥ -0.50 D) was affecting 36.8% of the children at the age of 13; 53.9% of the children at the age of 17, hyperopia (≥ +2.00 D) was affecting the children at the rate of approximately 1% in all age groups and astigmatism (≥ -0.75 D) rates were affecting 25.3% of all children in the study carried out by He et al in which 2454 total children participated.[19] Saw et al determined the myopia rate as 24.7% at the age of 7 and 49.7% at the age of 9 (approximately two folds greater than at age of 7).[20] In two different studies carried out in the Middle East, myopia was determined at the rate of 1.7%, hyperopia at the rate of 20.5% and astigmatism at the rate of 19.6% in an investigation carried out in children at the age of 6 by Jamali et al.[21] The frequency of myopia was determined as 4.3%, the frequency of hyperopia as 5.4% and the frequency of astigmatism as 11.5% by Rezvan et al in the school-age children ages 6-17.[22] In a study carried out in Northern Ireland, refractive error at ages 6-7 was compared with the age group 12-13; myopia was determined at the rate of 2.8% / 17.7% and hyperopia as 26% / 14.7%.[23] Whereas in Europe, the myopia rate was determined as 11% in 13-year-old children in Poland,[24] and the frequency of myopia (45%) was found to be higher in the same age group in Sweden.[25] In our study, the myopia rates were 4.6% in 7-year-old children and 22.1% in 14-year-old children. The hyperopia rate was 5.3% in the 7-year-old children and 2.4% in 13-year-old children. Hyperopia was not found in children at the age of 14. When we compared refractive error frequencies that we found with the other countries, our myopia rate was not as high as the Far East, and our hyperopia rate was not as high as the European countries.

**Table 4** Multiple regression analysis of the independent variables affecting myopia in children (n=1690)

| | B | OR (CI 95%) | p |
|---|---|---|---|
| Age (year) | 0.212 | 1.23 (1.13-1.34) | **<0.001** |
| Gender | 0.164 | 1.17 (0.85-1.63) | 0.322 |
| BMI (k/m$^2$) | 0.057 | 1.05 (0.99-1.12) | 0.063 |
| TV-PC time (hour/day) | -0.039 | 0.96 (0.86-1.07) | 0.492 |
| Family history (+) | 0.860 | 2.36 (1.70-3.26) | **<0.001** |
| Sibling numbers | -0.306 | 0.73 (0.61-0.88) | **0.001** |
| Mother education | | | |
| 9-12 years vs. 0-8 years | 0.634 | 1.88 (0.62-5.66) | 0.259 |
| >12 years vs. 0-8 years | 0.696 | 2.00 (0.67-5.92) | 0.208 |
| Father education | | | |
| 9-12 years vs. 0-8 years | 0.486 | 1.62 (0.97-2.70) | 0.062 |
| >12 years vs. 0-8 years | 0.422 | 1.52 (0.94-2.46) | 0.086 |
| Mother working (+) | -1.126 | 0.32 (0.16-0.65) | **0.002** |
| Father working (+) | -0.631 | 0.53 (0.27-1.01) | 0.056 |

The spherical equivalency (spheric+cylinder/2) was used in the definition of refractive errors in terms of consistency with the other studies. However, this formulation might lead to faults especially in the patients where the primary problem is high astigmatism in the evaluation of refractive errors.[23] For instance, the SE value was (-0.50) in the eye in the measurement of (+0.50/-2.00), and the main problem was considered as myopia even though it was astigmatism. For this reason, refractive error ratios which are a little bit higher than average might have been found.

There can be many reasons for achieving different results in terms of refractive errors among the different countries. The foremost among them is racial differences. It is considered that the environmental exposure and lifestyle changes play a role even though the factors that increase the genetic sensitivity cannot be clearly explained.[26] Another reason for the differences between the countries is that there are different refractive error descriptions in the studies. Robinson et al found the frequency of myopia in children at the age of 6 as 6% when they considered myopia as -0.25 D on the horizontal meridian and as 1.8% when they determined the margin as -1.00 D in the study that they carried out by the non-cycloplegic refraction method.[27] In the Avon Longitudinal Study of Parents and Children, however, the expression "likely to be myopic" was used as the definition and -1.50 D was accepted as the margin. Accordingly, the frequency of myopia was found as 1.5%.[28] In our study, we took as the baseline the margins used in the "Refractive Error Study in Children"[29] protocol

which was most commonly used in previous publications. Compared with the myopia prevalence of children in developed countries, the relatively high myopia prevalence in school-children living in developing countries may arise from the deficiency of public screening interventions during childhood.

In a study carried out by Gao et al, it was found that the eyeglass usage rates in rural area schools are lower than urban area schools.[6] Another important finding that we established was other refractive errors were lower in children diagnosed with myopia and lower eyeglass usage rates in amblyopia. This finding may depend on the fact that wearing eyeglasses is humiliating among students. To cope with this fallacy and to ensure eyeglass usage in necessary cases seems possible by educating the children, their families and their teachers about its importance in preventing other refractive errors and potentially blindness.

It is stated that refractive errors are also related to the educational level and social status of the parents.[18,30] In our study, a negative significant relationship was found between myopia and the educational level of the mothers and the working status of the parents. We estimate that the parents who are working and the mothers who have high educational level take their children to a regular eye examination and give more value to protective eye health precautions. We could not find a significant relation between the refractive errors and gender. There are also studies which demonstrate that girls are in the majority of the children with myopia,[11,14] as well as other research studies having parallel findings with our study in terms of the gender difference.[22,31]

The existence of refractive error history in the family was defined as another independent risk factor. Kaur et al researched the frequency of myopia in three generations (grandparents, parents, and children). It was found that most of the parents who had myopia also had grandparents with myopia. Although the frequency of myopia increases from the older generations to younger generations, no relationship was found between this increase and the myopia of the parents and children.[32] In a study carried out by Jones et al, it was found that parental myopia is a high risk factor in the development of myopia in children.[33] In our study, the presence of the refractive error history in a family increased the development of myopia in children approximately 2.5 times (OR=2.362). These results underline the importance for the students whose families have refractive error history to receive eye health services in terms of preventive care.

The relationship between the children's outdoor playing activities and the frequency of myopia are examined in recent studies. In a study carried out by Dirani et al, a negative significant relationship was found between the increase in the average time spent in the outdoor activities and myopia. This negative significant relationship also continued between the total period spent while doing physical exercise and the development of myopia.[34] In a study carried out on students 12 years of age by Rose et al, however, lower myopia rates were found in the students who were doing outdoor activities (Physical Exercise and leisure time).[35] In a study carried out in students ages 7-12 by Wu et al a significant relationship was found between the TV watching time and myopia.[36] In the analysis that we performed in our study, higher BMI values were found in children with myopia as compared with the children without myopia. These results make us consider that the students in our study group do not spare enough time for sportive and physical outdoor activities, and they spend their leisure time doing activities which cause damage to their eye health such as watching TV, PC games.

## Study Limitation

The major limitation of the study is not that it is a study that is based on population distribution, but that it is a study that is based on demographic characteristics at schools. The differences between rural and urban region schools were researched with questions regarding the socio-economic level. The use of cycloplegic and mydriatic agents could not be applied since the research was designed as a comprehensive field study.

## Conclusion

The frequency of myopia within the refractive errors was determined moderately high compared with the other developed countries although it was determined as lower than the Far Eastern countries. It was remarkable that the eyeglass usage rate in the refractive error groups other than myopia was not high. Study results indicate that refraction errors in children may differ based on demographics and public health policy should be rearranged in terms of visual screening programs. Visual disorders occurring in childhood may persist to adulthood and become a significant barrier to achieve educational goals and pursue certain career paths through an individual's life. The performance of regular eye screening programs, mainly in

the regions with low socio-economic development will potentially prevent vision losses later in life. Meanwhile, effective interventions could provide healthy neurodevelopmental improvements during the childhood period.

## Declaration of Interest

None

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