# THE PREVALENCE OF MYOPIA IN SCHOOL-AGE CHILDREN IN SLOVAKIA AND THE COVID-19 PANDEMIC

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## SUMMARY

**Aims:** The aim of the authors' study was to determine the prevalence of myopia and premyopia in children and adolescents attending primary school in a village in the north of Slovakia in the period before and after the peak of the Covid-19 pandemic.
**Material and methods:** Changes in the spherical equivalent and axial length of the eyes were measured in 2019 and 2022 in a group of 47 children and adolescents within the age range of 7–12 years at the time of first measurement. In all the individuals, refraction was measured using an automatic keratorefractometer without the use of cycloplegic eye drops, and axial length was measured with an optical biometer. Refraction was also measured using an automatic keratorefractometer after using cycloplegic eye drops.
**Results:** We recorded a significant change in the mean spherical equivalent (1.02 ±1.16 D vs. 0.72 ±1.29) and the axial length of the eyes (23.05 ±0.72mm vs. 23.30 ±0.74mm) when comparing the measurements from 2019 to 2022. The probands manifested a myopic refractive shift of -0.30 D throughout the entire cohort (-0.24 D in boys and -0.38 D in girls), and the mean axial length increased by 0.2 mm in the entire cohort (by 0.3 mm in boys and 0.2 mm in girls). The percentage of myopic and premyopic eyes increased (4.3% vs. 8.5% a 31.9% vs. 48.9%).
**Conclusion:** We noted a decrease in the spherical equivalent and increase in the axial length of the eyes after the Covid-19 pandemic compared to the period before the pandemic in Slovak school-aged children. During this period, the prevalence of myopia and premyopia increased.
**Key words:** Covid-19, myopia, childhood

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## INTRODUCTION

Myopia currently constitutes a significant health and socio-economic problem. Worldwide it is the most common cause of deterioration of vision, and its incidence is increasing globally. It is predicted that 49.8% of the world's population will be suffering from myopia by 2050, and that 9.8% of people will suffer from high myopia [1]. In the majority of cases this concerns a benign disorder, which can be corrected by glasses, contact lenses or a refractive surgical procedure. However, more severe forms of myopia are associated with the risk of sight-threatening complications such as myopic maculopathy, subretinal neovascularization, cataract, retinal detachment and glaucoma. In the publication Updates on Myopia, the authors stated that pathological myopia develops in 25% of cases of high myopia (SE<-6D), and that half of these cases result in loss of sight at a more advanced age [2].

The incidence of myopia has pronounced geographical, ethnic and generational differences, with the maximum incidence in certain urban regions of East Asia. By contrast, the lowest incidence appears to be in Africa. In the group of 12-year-old children there is a fundamentally higher incidence of myopia in certain regions of East Asia (47.7–62%) in comparison with other regions (6–20%). A similar situation applies with regard to older

children and young adults, although in the group of older adults the differences are not so pronounced [1-5]. The prevalence of myopia in Slovakia is not known, since there is an absence of professional studies dealing with the prevalence of myopia; however, it is assumed that there are many cases of undiagnosed myopia.

Myopia is considered to represent a highly hereditary disorder. Although a significant influence of genes is described in the origin of myopia, the proportion of genes alone does not explain the rapid worldwide increase in the prevalence of myopia, and also does not explain the dramatic differences in the prevalence of short-sightedness within the same ethnic groups. The main environmental risk factors in the onset and progression of myopia are considered to be close-up work and insufficient time spent in natural outside light.

In an endeavor to prevent the spread of the Covid-19 disease, most countries introduced strict anti-epidemic measures. As a consequence of the closure of schools, children's eyes were excessively exposed to digital screens, close-up activity became more intensive and outside activities were limited. This change of lifestyle during the Covid-19 pandemic influenced the incidence and progression of myopia [6].

## MATERIAL AND METHOD

Myopia is defined as a condition in which the spherical equivalent of the refractive error of the eye is ≤ -0.5 D, in which the accommodation of the eye is relaxed. Premyopia is a condition in which the spherical equivalent of the child is ≤ +0.75 and > -0.5 D, and at the same time the combination of initial refraction, age and other risk factors represents a probable development of myopia. Cyclopentolate eye drops (Cyclogyl 1%, Alcon) were used in order to ensure cycloplegia.

The children examined in the study attended a primary school in a village in the north of Slovakia. The entire cohort comprised 47 subjects (96 eyes), who underwent the first examination in May 2019 (1st measurement), with a subsequent follow-up examination in May 2022 (2nd measurement). A condition for inclusion of a proband in the cohort was an informed consent form signed by the legal guardian of the child.

The ophthalmological examination consisted of a number of stages. In the first, measurement of refraction was conducted with the aid of an automatic keratorefractometer (Shin-nippon, Accuref-K 9001), without the use of cycloplegic drops. Refraction was evaluated with the aid of spherical equivalent (SE = spherical diopter +1/2 cylindrical diopter). Subsequently the axial length of both eyes was measured with the aid of an optical biometer (IOL Master, Zeiss). The resulting value of eye length in millimeters was calculated as the mean of five consecutive measurements. Following on from this, cyclopentolate drops (Cyclogyl 1%, Alcon) were applied to patients three times consecutively within five-minute intervals. At the end, refraction was measured with an automatic keratorefractometer 45 minutes after the last application of cyclopentolate drops. The prevalence of myopia was stipulated on the basis of the number of myopic eyes. For the statistical analysis of the data, we used the program SYSTAT 13. In all the used tests, we considered values of the level significance at $p \leq 0.05$ to be statistically significant.

## RESULTS

The entire cohort consisted of 47 probands (96 eyes), of whom 23 were boys (48.9%) and 24 were girls (51.1%). The average age of all the subjects was 9.7 ± 1.8 years, in which boys 9.2 ± 1.8 and girls 10.2 ± 1.6 years.

At the time of the first measurement (May 2019), the mean value of spherical equivalent (SE) throughout the entire cohort was 1.02 ± 1.16 D, for all boys 0.96 ± 1.01 D and for all girls 1.09 ± 1.31 D. The mean values of SE in both years are summarized in Table 1. The mean value of spherical equivalent in May 2022 (second measurement) within the entire cohort was 0.72 ± 1.29 D; for boys 0.72 ± 1.06 D and for girls 0.71 ± 1.49 D. In a comparison between the years 2019 and 2022, the difference in the mean value of SE throughout the entire cohort was -0.3 D; for boys -0.24 D and for girls -0.38 D. No significant differences were recorded between right and left eyes.

The mean spherical equivalent of all measurements in both years without the use of cycloplegic eye drops was -0.125 (-0.75 – 0.187) D, and with the use of cycloplegic eye drops 0.875 (0.50 – 1.25) D. Overvaluation of myopia without the use of cycloplegia would correspond to a value of 1 D ($p < 0.0001$).

Mean axial length (AL) of eyes in 2019 for all the examined subjects was 23.1 ± 0.72 mm, in 2022 AL was 23.3 ± 0.75 mm. AL increased by 0.2 mm throughout the entire cohort; by 0.3 mm in boys and by 0.2 mm in girls. Mean AL of eyes in boys and girls in the individual measurements is presented in further detail in Table 2. In a comparison of the values between the right and left eye, no significant difference was found in the axial length of eyes. In the group of all subjects in both years of measurement, a significant negative correlation was determined between axial length of the eye and spherical equivalent, which is illustrated in Graph 1.

In 2019, throughout the entire cohort 4.3% of eyes were within the band of myopia and 31.9% of eyes within the band of premyopia. In 2022 the percentage of myopic eyes had increased to 8.5%, and premyopic eyes to 48.9%.

## DISCUSSION

The prevalence of myopia in the pediatric population in Slovakia is not known. To date no data have been published relating to the incidence of myopia in this country. The geographically closest data originate from long-term studies conducted by authors from Plzeň, Czech Republic, who investigated the seasonal variability of axial length of eyes. In this study the average age of the participants was 12.2 years. The mean axial length of eyes upon the first

**Table 1.** Comparison of spherical equivalent between 2019 and 2022

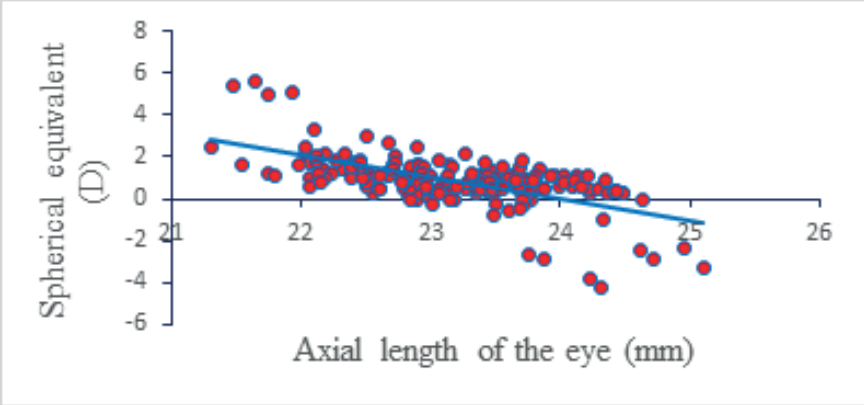
| | | | BOYS and GIRLS | | | BOYS | | | GIRLS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2019 | 2022 | p | 2019 | 2022 | p | 2019 | 2022 | p |
| N (%) | | | 47 (100) | | - | 23 (48.9) | | - | 24 (51.1) | 24 (51.1) | - |
| SE (D) | Both eyes | x̄±SD | 1.02 ±1.16 | 0.72 ±1.29 | < 0.0001 | 0.96 ±1.01 | 0.72 ±1.06 | 0.0001 | 1.09 ±1.31 | 0.71 ±1.49 | < 0.0001 |
| | | M (IQR) | 1,0 (0.50–1.50) | 0.75 (0.50–1.13) | | 1.06 (0.63–1.38) | 0.88 (0.38–1.25) | | 1.00 (0.50–1.63) | 0,63 (0,50–1.13) | |

*N – number of subjects in the group, SE – spherical equivalent, – arithmetic mean, SD – standard deviation, M – median, IQR – interquartil range*

**Table 2.** Comparison of axial length between 2019 and 2022

| | | | BOYS and GIRLS | | | BOYS | | | GIRLS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2019 | 2022 | p | 2019 | 2022 | p | 2019 | 2022 | p |
| N (%) | | | 47 (100) | | - | 23 (48.9) | | - | 24 (51.1) | 24 (51.1) | - |
| AL (mm) | Both eyes | x̄±SD | 23.05 ±0.72 | 23.30 ±0.74 | < 0.0001 | 23.26 ±0.76 | 23.56 ±0.77 | < 0.0001 | 22.85 ±0.62 | 23.05 ±0.62 | < 0.0001 |
| | | M (IQR) | 23.11 (22.52–23.50) | 23.36 (22.70–23.81) | | 23.39 (22.85–23.71) | 23.70 (22.99–24.14) | | 22,85 (22.40–23.40) | 23.04 (22.62–23.47) | |

*N – number of subjects in the group, AL – axial length axial length, – arithmetic mean, SD – standard deviation, M – median, IQR – interquartil range*




**Graph 1.** Correlation of axial length and spherical equivalent between 2019 and 2022. Spearman's coefficient ρ = -0.447; p = <0.0001. A significant negative correlation was found between the axial length and spherical equivalent in all subjects in measurements of both years

measurement in April 2016 was 23.230 mm in children without myopia and 23.397 mm in children with myopia. In October 2019 the mean axial length of eyes in the same group of myopic children was 23.612 mm, and 23.401 mm in the same group of non-myopic children. The authors also drew attention to the protective effect of sporting activities and the negative impact of working with a computer on excessive growth of the eye [7, 8]. During the Covid-19 pandemic, several measures were introduced worldwide in order to prevent the spread of the disease. Quarantine, closure of schools and home schooling led to a radical change of the everyday routine of both children and their parents. During the pandemic the school featured in our study was completely closed for a number of times, in total for the length of approximately 7 months, and during this period education took place in the form of online teaching. Teaching with the aid of digital devices pronouncedly extended the children's time spent in front of a digital screen. Studies focusing on the use of digital screens in connection with the onset of myopia have determined that the risk of onset and progression of myopia increases by a multiple of 1.26 with each hour per day spent in front of a digital screen [9, 10]. Excess accommodation upon protracted close-up work and the observation of close fixed targets without refocusing to distance increases the risk of onset of myopia. In children who used projectors and televisions for online teaching, the progression of myopia was slower than in those who studied with the aid of mobile telephones and tablets. The distance from the television and projectors is usually more

than 1 meter, whereas in the case of mobile telephones and tablets it is less than 0.5 meters [10, 11].

Following the outbreak of the Covid-19 pandemic in our region, people were repeatedly placed in home quarantine, outside activities were restricted, children did not have to walk or travel to and from school, and did not attend out of school activities or meet in groups. Exposure to natural outside light is an important protective factor in the prevention of myopia [2]. Multiple studies conducted on school-age children have demonstrated that an increased length of time spent outside, with a duration of 40 to 80 minutes per day, leads to a significant reduction of the incidence of myopia [13-16]. Natural daylight has a markedly different intensity and spectral composition in comparison with artificial light. The effect of clear natural outside light during the day leads to a release of dopamine and a subsequent retardation of the growth of the eyes by means of the protective effect of the D2-dopamine receptors [17-22]. Refocusing also has a positive effect during time spent in an outside environment, since this is applied more in an exterior than an interior setting. Two hours per day (or 14 hours per week) spent in natural outside light is considered sufficient in order to prevent myopia [2].

Over the time frame of three years, we recorded a statistically significant decrease of mean spherical equivalent and a statistically significant increase of mean axial length of the eyes in our cohort. At the same time, an increase in the prevalence of myopia (by 4.2%) and premyopia (by 17.0%) was observed in 2022 in comparison with 2019.

Several population studies have dealt with the increase in the incidence of myopia in connection with the Covid-19 pandemic [9, 23-26]. The majority of these studies originate from China. The results of the study conducted by Caia et al. from the beginning of the period of the pandemic, when schools in China were closed, indicated a monthly increase in the axial length of the eye by 35% in comparison with the situation before the outbreak of the pandemic (0.046 mm vs. 0.033 mm/month, $p = 0.003$) [9].

Habitual changes of children during the Covid-19 pandemic and their effect on the progression of myopia were examined by Xu et al. in their study on a sample of more than one million schoolchildren aged 7–18 years, who attended a number of different schools within the Zhejiang province in China. They compared the results of measurements from the years 2019 and 2020. The prevalence of myopia increased from 52.9% to 59.4%, and high myopia from 4.1% to 5.0%. The progression of myopia over a period of six months worsened from -0.23 D to -0.343 D, and the incidence of myopia increased from 8.5% to 13.6% [25]. However, the main limitation of the study was the measurement of refraction without the use of cycloplegia. The application of cycloplegics causes a pronounced change of both objective and subjective refraction [27]. In our study the mean difference in spherical equivalent between cycloplegic and non-cycloplegic refraction was 1 D.

In a cross-sectional study conducted by Wang et al. in an eastern province of China on more than one hundred thousand children, the prevalence of myopia in the years 2019–2020 was compared with the period from 2015 to 2019. The prevalence of myopia increased during this period by a multiple of 1.4–3.0. Before the pandemic the largest change was in the spherical equivalent in the group of children aged 9 to 13 years, whereas during the pandemic the age limit shifted downwards, with the largest change in spherical equivalent recorded in children aged 6 to 8 years [24]. A 2.5-fold increase in the incidence of myopia during the pandemic was recorded also by Zhang et al. in a group of 6 to 8-year-old children [23].

Of European studies, the influence of the pandemic on myopia has been investigated by authors from England, Spain and Russia. In England, Shah et al. evaluated the influence of the pandemic on bilateral deterioration of central visual acuity in children of pre-school age. In a comparison over a seven-year period, after the pandemic they recorded a reduction of visual acuity in children, which may indicate an increasing incidence of myopia [28].

In Spain spherical equivalent before and after the period of the pandemic was compared in 39 children with an average age of 10.79 ± 2.83 years. The measurements were conducted only in the right eyes, and the mean change of spherical equivalent in the pre-pandemic period (2018 to 2019) was -0.37 ± 0.43 D compared to -1.12 ± 0.70 D during the pandemic one year later ($p < 0.001$) [29]. A decrease in spherical equivalent in connection with the Covid-19 pandemic was recorded in 5 to 7-year-old-children also in a study conducted by the Spanish authors Alvarez-Peregrina et al. [30].

Bikbov et al. investigated a cohort of 471 children aged 7 to 19 years, who were examined at the beginning of the pandemic, before the closure of schools in Russia, and again following the reopening of schools in Russia (on average after 1.41 ± 0.33 years). The effect of home schooling on the axial length of the eye was relatively small and was demonstrated only in the group of younger children aged less than 9.6 years [31].

The results of our own study point to a rising trend in the prevalence of myopia in school-age children in this rural region. Worldwide studies indicate a lower prevalence of myopia in children in rural regions in comparison with children living in urban environments. In Slovakia there is a lack of statistical data on the incidence of myopia, and for this reason it would be necessary to conduct further measurements on a larger sample of subjects, taking into account sex, age, geographical, ethnic and other factors.

## CONCLUSION

We recorded a decrease of spherical equivalent and an increase in axial length of eyes in school-age children from a rural region of Slovakia following the Covid-19 pandemic in comparison with the period preceding the pandemic. During this period the number of myopic and premyopic eyes increased. Parents, teachers and health workers should contribute to the introduction of regimen measures in order to prevent a further increase in the incidence and progression of myopia

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