



Refraction in Preschool Children in Kazanlak, Bulgaria

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Abstract

Introduction: The refractive state of the eye changes as the eye's axial length increases and the cornea and lens flatten. In general, eyes are hyperopic at birth, become slightly more hyperopic until the age of 7, which at this point we see a myopic shift toward plano until the eyes reach their adult dimensions, usually by about the age 16.

Aim: To determine the prevalence of refractive error in preschool children aged 3 - 6 in the city of Kazanlak, Bulgaria.

Materials and methods: A cross-sectional study was conducted in a kindergarten based school within the city of Kazanlak, Bulgaria. Out of 15 kindergarten schools, 10 chose to participate in the study. The children underwent non-mydriatic refraction screening using a Plus-Optix S12c mobile camera. Myopia, hyperopia and astigmatism were defined as being a spherical equivalent (SE) ≤ -0.50 D, $SE \geq +2.00$ D and cylindrical diopters ≤ -1.00 D.

Results: A total of 596 children were screened. Out of these 596 children; 526 were with ametropia (470 hypermetropia, 46 myopia) and 50 had astigmatism. Strabismus was found in 12 children, with a further 8 children suffering from amblyopia and finally 8 children were also found to be diagnosed with anisometropia. In 8 cases there were no results due to opacities or due to the small size of the pupil.

Conclusion: The prevalence of refractive error in preschool children is similar to that found in other research in the field. While most cases fall into the category of emmetropia or mild hypermetropia, most of the children had never been to an ophthalmologist. A mandatory checkup should be issued for all children below the age of seven.

Keywords

refraction, children, plus-Optix, screening

INTRODUCTION

Full term newborn babies are generally hypermetropic at birth, whereas preterm infants are myopic. Their myopia is closely related to their birth weight and usually turns hypermetropic by week 52.^{1,2} Studies report that at least 95% of children have hyperopia $< +3.25$ D, astigmatism $< +1.50$ D, and anisometropia < 1.50 D.³

The eye starts the process of emmetropization in the years after birth.⁴ The term emmetropization refers to the

process in the developing eye in which the refractive power of the anterior segment and the axial length of the eye adjust to reach emmetropia. The refractive state of the eye changes as the eye's axial length increases and the cornea and lens flatten. In general, eyes which are hyperopic at birth, become slightly more hyperopic until the age of seven, which at this point we see a myopic shift toward plano until the eyes reach their adult dimensions, usually by about age 16 years. Changes in refractive error vary widely, but if myopia is present before the age of ten, there is a

higher risk of eventual progression to myopia of 6.00 D or more. Astigmatism is common in infants and often regresses. The reduction in astigmatism that occurs in many infant eyes and the decreasing hyperopia that occurs in eyes after the age of 6–8 years are examples of emmetropization.⁵

This process of refractive development does not necessarily end in emmetropia and may lead to other refractive errors. Studies suggest that mild hyperopia is the natural state of refractive development in children and that emmetropia during childhood carries the risk of subsequent progression to myopia.⁶

AIM

To determine the prevalence of refractive error in preschool children aged 3–6 years in the city of Kazanlak, Bulgaria

MATERIALS AND METHODS

Study design

A cross-sectional study was conducted in kindergarten based schools in the city of Kazanlak, Bulgaria. This study is part of a charity programme aimed at providing free and accessible refraction screening for pre-schoolers in Bulgaria.

Study Population

The study is part of a larger programme providing auto-refraction in different cities in Bulgaria. Our study focuses on kindergartens in Kazanlak, Bulgaria. Out of 15 kindergarten schools, 10 chose to participate in the study. A total of 634 children participated in the examinations. Of these, 611 were given parental consent to participate in the survey. Due to unforeseen circumstances, 15 were absent during the examination, leaving 596 children aged 3–6 years who completed the examination.

Kazanlak is a Bulgarian town within the Stara Zagora Province, located approximately in the middle of the plain with the same name. It covers an area of 36 square kilometres, with a population of 44760 at the end of 2017.

Ethics statement

The Study was approved by the Ethics Committee of Traкия University Hospital. The research was conducted in accordance with the Declaration of Helsinki. The nature and possible consequences of the study were explained at each kindergarten. After the headmasters of the kindergarten schools had agreed to participate, the details of the examination were explained to the parents and guardians prior to the examination. Written informed consent was

obtained from each parent/guardian and the children provided verbal consent on the day of the examination.

Examination

A trained team consisting of two ophthalmologists conducted the examination from August 2017 to November 2018. The children underwent non-mydratic refraction screening using the Plus-optix S12c Mobile camera. Autorefractometer readings of three consecutive measurements were obtained and the average was computed automatically in each eye. Each child was reexamined until three measurements fell within 0.50 diopters (D) if any two measurements varied by >0.50 D.

Definition

Spherical power and cylindrical power were measured. The cylindrical power was presented in negative notations and the spherical equivalent (SE) was calculated, which equalled the spherical power plus half of the cylindrical power. Data from both eyes were included in the current study. Myopia was defined as $SE \leq -0.50$ D, emmetropia was defined as $-0.50 < SE < +0.50$ D, mild hyperopia was defined as $+0.50 \leq SE < +2.00$ D, and hyperopia was defined as $SE \geq +2.00$ D. Astigmatism was defined as cylindrical diopters ≤ -1.00 D. To classify the types of astigmatism (≤ -1.00 D), with-the-rule (WTR) astigmatism was defined as negative cylinder axes from 1° to 15° or from 165° to 180° , against-the-rule (ATR) astigmatism as negative cylinder axes between 75° and 105° , and oblique astigmatism as axes from 16° to 74° or from 106° to 164° . The definitions of the classification of astigmatism were chosen to facilitate comparison within other studies.

Statistical analysis

The comparisons of the mean values of age, SE, and cylinder power between boys and girls were made with an independent sample t-test. Chi-squared analysis was used to compare the gender differences between children. Analysis of variance (ANOVA) was used to compare SE and cylinder power among age groups and Bonferroni correction was used for post hoc analysis. Prevalence and 95% confidence interval (CI) was calculated for different refractive categories. Chi-squared analysis was used to compare the prev-

Table 1. SE in screened children by age, $p=0.672$

Age	N	Mean	Std. Deviation	Skewness	Kurtosis
3 years	154	0.93	1.27	-0.634	3.985
4 years	146	1.06	1.01	-0.341	2.305
5 years	142	1.05	1.11	-0.329	4.035
6 years	146	.95	1.13	-0.257	2.559

absence of refractive errors among age groups and gender groups. A p value of less than 0.05 was considered statistically significant. Statistical analysis was performed using SPSS 22.0.

RESULTS

A total of 596 children were screened. Of these, 526 children were found to have ametropia (470 hypermetropia, 46 myopia), and 50 had astigmatism. Strabismus was discovered in 12 children, amblyopia in 8, anisometropia in 8. In 8 cases there were no results due to opacities or small size of the pupil.

The mean age was 4.49 years (SD, 1.13). The mean SE for 3 to 6 years old children was 1.00 D (SD 1.13), with a range from -4.25 D to +5.0 D sph. (Tables 1,2). There was no statistically significant difference between groups based on age or gender. Bonferroni correction for post hoc analysis test found no difference between age groups. Independent sample t test found no difference based on gender, although there was slight prevalence of higher hypermetropia in females age 3 and 6 and in boys age 4 and 5.

The mean cylinder for 3-to-6-year-old children was -0.37 D (SD 0.47), with a range from 3.0 D to +0.0 D. (Tables 3, 4) There was no statistically significant difference between groups based on age or gender. Bonferroni correction for post hoc analysis test found no difference between age groups. Independent sample t test found no difference based on gender, with females having slightly higher values at ages 3, 4 and 5.

Table 2. SE in screened children by gender, $p=0.866$

Gender	Age	N	Mean	Std. Deviation	Skewness	Kurtosis
Male	3 years	72	0.82	1.46	-1.141	3.844
	4 years	80	1.14	0.95	-0.134	1.614
	5 years	66	1.21	0.96	1.473	4.424
	6 years	62	0.77	0.96	-1.905	3.116
Female	3 years	82	1.03	1.06	0.798	1.286
	4 years	66	0.96	1.09	-0.450	2.766
	5 years	76	0.92	1.21	-0.971	3.062
	6 years	84	1.09	1.22	0.193	1.815

Table 3. Cylinder in screened children by gender, $p=0.931$

Age	N	Mean	Std. Deviation	Skewness	Kurtosis
3 years	154	-0.41	0.54	-2.338	6.140
4 years	146	-0.35	0.43	-2.479	8.790
5 years	142	-0.33	0.45	-2.833	11.124
6 years	146	-0.38	0.44	-1.859	4.446

Table 4. Cylinder in screened children by gender, $p=0.197$

Gender	Age	N	Mean	Std. Deviation	Skewness	Kurtosis
Male	3 years	72	-0.37	0.47	-2.673	8.839
	4 years	80	-0.27	0.25	-0.416	-0.965
	5 years	66	-0.30	0.33	-2.328	9.099
	6 years	62	-0.45	0.49	-1.285	1.195
Female	3 years	82	-0.45	0.59	-2.118	4.807
	4 years	66	-0.44	0.56	-2.012	4.434
	5 years	76	-0.36	0.53	-2.689	9.075
	6 years	84	-0.33	0.40	-2.529	9.842

Table 5 shows the frequency of different refractive errors in different age groups, and Fig. 1 shows the distribution of different refractive categories in each age group. The leading refractive error was mild hypermetropia, followed by hypermetropia, emmetropia and myopia. There was a statistically significant difference between genders, with hypermetropia and emmetropia being prevalent in females ($p=0.001$). There was no difference in the age groups, with myopia being slightly more frequent in the 6-year-old group.

Table 5. Frequency of SE refractive status

Age	Refractive Status	Frequency	%	95% CI
3 years	Emmetropia	22	14.3	0 - 0.08
	Mild hypermetropia	104	67.5	1.02 - 1.22
	Hypermetropia	16	10.4	2.83 - 3.41
	Myopia	12	7.8	-2.73 - -1.13
4 years	Emmetropia	12	8.2	-0.08 - 0.12
	Mild hypermetropia	106	72.6	1.03 - 1.16
	Hypermetropia	18	12.3	2.63 - 3.11
	Myopia	10	6.8	-1.81 - -0.83
5 years	Emmetropia	14	9.6	-0.01 - -0.08
	Mild hypermetropia	100	68.5	1.03 - 1.17
	Hypermetropia	18	12.3	2.65 - 3.34
	Myopia	10	6.8	-2.14 - -0.75
6 years	Emmetropia	14	9.3	0 - 0.11
	Mild hypermetropia	102	68.0	1.02 - 1.15
	Hypermetropia	16	10.7	2.61 - 3.38
	Myopia	14	9.3	-1.83 - -1.06

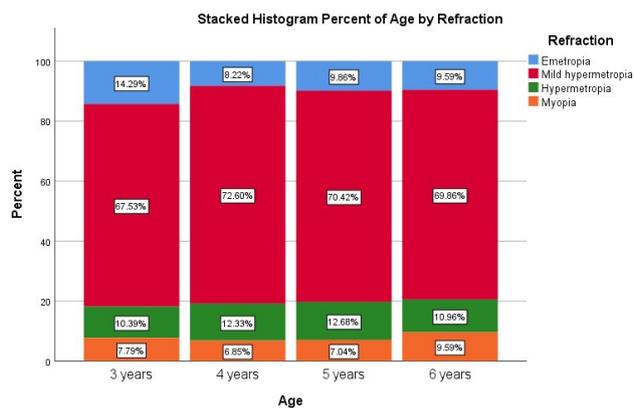


Figure 1. Age specific distribution of the refractive status.

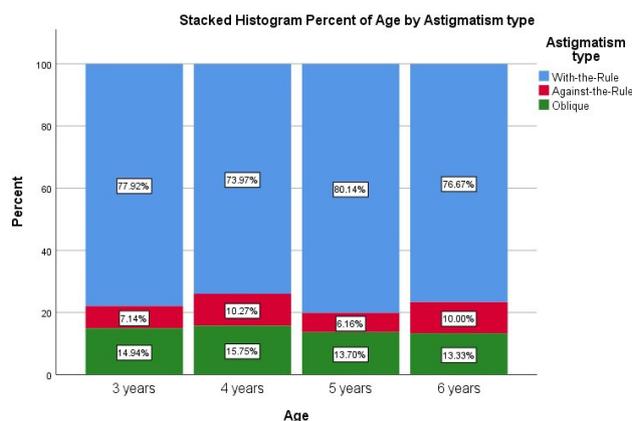


Figure 2. Age specific distribution of the astigmatism type.

Table 6 presents the frequency of astigmatism in different age groups, and Fig. 2 shows the distribution of different astigmatism types in each age group. Astigmatism was present in 8.4% of all children, with 78.0% being the with-the-rule type, 10% against-the-rule type, and 12% were the oblique type. Females were twice as likely to have astigmatism ($p=0.001$), with it being more often oblique ($p=0.013$).

Table 6. Frequency of the astigmatism type

Age	Frequency	%	95% CI
3 years	WTR	120	77.9 -0.53 – -0.33
	ATR	11	7.1 -0.72 - 0.04
	Oblique	23	14.9 -0.54 – -0.17
4 years	WTR	108	74.0 -0.43 – -0.27
	ATR	15	10.3 -0.56 – -0.20
	Oblique	23	15.8 -0.56 – -0.10
5 years	WTR	117	80.1 -0.44 – -0.25
	ATR	9	6.2 -0.37 – -0.07
	Oblique	20	13.7 -0.46 – -0.18
6 years	WTR	115	76.7 -0.45 – -0.28
	ATR	15	10.0 -0.65 – -0.17
	Oblique	20	13.3 -0.69 – -0.22

The age group was not a significant factor although the 4-year-olds were less likely to have astigmatism.

The children with hypermetropia and myopia were statistically significantly more likely to have astigmatism ($p<0.001$). The children with astigmatism had higher hyperopic power 3.25 D (SD 0.55) versus 2.94 D (SD 0.61). The prevalence of mild hypermetropia in children with astigmatism was significantly lower (44%) than those without (72.5%)

During the screening, the parents were asked if the child had visited an ophthalmologist before. Out of the 80 previously diagnosed conditions, 56 (70%) were due to parents suspecting an existing problem. A similar trend was noted by Ibrionke et al., who suggested parental concerns about general developmental problems are associated with some types of refractive error. Due to the potential consequences of uncorrected refractive errors, children whose parents have expressed concerns regarding development should be referred for an eye examination with cycloplegic refraction to rule out significant refractive errors.⁷

A statistically significant number of refractive errors were undiagnosed ($p<0.001$), with half of the children with hypermetropia and a third of those with myopia never having visited an ophthalmologist. This finding was most prominent within the 4-year-old age group. There were 12 cases of strabismus, all of which were previously diagnosed and 4 cases of amblyopia, only 2 of which were diagnosed. This was similar to the findings of Marinov et al. in their research in Plovdiv, Bulgaria⁸ and Chernodrinska et al. in Sofia, Bulgaria⁹. Marsh-Tootle et al. acknowledged national efforts to reduce preventable vision loss from amblyopia are hampered because children are not available for screening and because providers miss many opportunities to screen vision at pre-school age.¹⁰

DISCUSSION

Refractive error

Refractive errors in preschool children aged 3-6 years have been studied by different researchers but there have been very few such studies in Bulgaria.

Studies suggest that 56% of the causes for reduced vision in children are due to refractive error.¹¹

Giordano et al. in their study in Baltimore, USA found myopia of 1.00 D or more in 0.7% of white children, 5.5% in African-American children and hyperopia of +3 D or more in 8.9% of white children and 4.4% in African-American children. The prevalence of emmetropia was seen in 35.6% of white children and 58.0% of African-American children. Of the children, 5.1% would have benefited from spectacle correction, however, only 1.3% had been prescribed correction.¹² This differs from our findings: we recorded 10.49% emmetropia, out of all screened children 34.23% would have benefited from spectacle correction and only 13.42%

had been prescribed one.

Similar studies found hyperopia present in 7.7% of children and myopia present in 7.4%, with hyperopia being associated with female gender, whilst myopia was more common in children whose fathers had received higher levels of education.¹³

According to Kleinstein et al., overall 9.2% of the children are myopic, 12.8% are hyperopic, and 28.4% are astigmatic, with myopia having the highest prevalence in the Asian ethnicity and hyperopia in whites.¹⁴

Similar studies in Iran found the prevalence of hyperopia, myopia, astigmatism, and anisometropia to be 20.5, 1.7, 19.6, and 2.2%, respectively.¹⁵

Fan et al. found a mean cylinder of -0.65 D and with-the-rule astigmatism was predominant (53%) in preschool children in China.¹⁶ We also report the with-the-rule astigmatism as predominant – 77.17%.

Studies suggest that in Eastern countries there is a prevalence of myopia – 11.0% and astigmatism – 8.6%, with hyperopia and anisometropia 1.4% and 0.6%, respectively. Most astigmatism (>95%) found was with-the-rule astigmatism: cylinder axes between 1° and 15° or 165° and 180° .¹³ Wu et al. supported their findings, citing 36.9% prevalence of myopia and 36.3% of astigmatism, correlating them with female gender and urban living.¹⁸

In a similar study Wen et al. found the prevalence of myopia, hyperopia, and astigmatism in children to be 1.20%, 25.65%, and 6.33%, respectively. Most astigmatism found was with-the-rule type – 4.33%.¹⁹

Afsari et al. found the overall prevalence of spherical equivalent (SE) and cylindrical anisometropia ≥ 1.0 D were 2.7% and 3.0%.²⁰

Studies in Bulgaria have found astigmatism to be prevalent in the school group (7-14 years of age) reaching 35.2%.²¹ Similar studies show that hypermetropia is prevalent in children – 49.24%, myopia – 6.17%, astigmatism – 24.71%, amblyopia – 5.02%, strabismus – 3.47%.^{22,23}

Currently in Bulgaria there is no active national screening strategy despite existing articles on the subject.²⁴ This increases the burden on primary care physicians. According to Marinov et al. refractive error was present in 26.9% of screened children, with only 10 having been previously examined.⁸ A similar study shows an alarmingly low number of preschool children screened in Sofia.⁹

Limitations: The spherical error and cylindrical power measurements of the handheld auto-refractometer and the table-mounted refractometer have a significant correlation.²⁵ The main limitation of our study, however, is the lack of cycloplegia. Due to the strong accommodation in young children the possibility of a false myopic shift exists which might be a source of bias and hyperopia is underestimated. A study by Zhang L. et al suggests modest differences between children with and without mydriasis, expecting they would not have a large impact on the results.²⁶ According to studies from 2010 and 2013, plusoptiX S08 has high sensitivity for the detection of myopia, astigmatism, and anisometropia compared to cycloplegic retinos-

copy.^{27,28} Despite this the results from this study should be interpreted with caution.

According to a study performed by J. Bloomberg and D. Suh plusoptiX had low sensitivity for detecting strabismus $\leq 20(\Delta)$. The authors postulate that sensitivity for detecting amblyogenic risk factors can be improved by combining the use of this instrument with a cover or stereo test.²⁹

CONCLUSION

Our study found most of the screened children between the ages of 3 to 6 to be mildly hyperopic and there cylindrical diopter was found to be stable, which is consistent with findings of other similar studies.^{19,26,30}

The prevalence of refractive error in preschool children we found in the study is similar to those in other such research. Most cases fall in the category of emmetropia or mild hypermetropia, with a slight increase in myopia in the 6 year old age group. The prevalence of astigmatism remained stable between the ages of 3 to 6. The main concern remains that a large portion of children have never been to an ophthalmologist. A mandatory checkup should be issued for all children at the age of three.

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Рефракция у детей дошкольного возраста из города Казанлак, Болгария

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Резюме

Введение: Рефракционное состояние глаза изменяется по мере увеличения осевой длины глаза, а роговица и хрусталик уплощаются. У новорожденных глаза, как правило, гиперметропичные, к семи годам они становятся чуть более гиперметропичными и к этому времени рефракция начинает смещаться в сторону нормальной, пока глаза не достигают размеров взрослого, обычно к 16 годам.

Цель: Определить частоту рефракционной ошибки у детей дошкольного возраста от 3 до 6 лет в городе Казанлак, Болгария.

Материалы и методы: Кросс-секционное исследование было проведено в детских садах в городе Казанлак, Болгария. Из 15 садов 10 решили принять участие в анкете. Дети прошли немидриатический скрининг рефракции с помощью мобильной камеры Plus-Optix S12c. Близорукость, дальновзоркость и астигматизм определялись сферическим эквивалентом (SE) $\leq -0,50$ D, SE $\geq +2,00$ D и цилиндрическими диоптриями $\leq -1,00$ D.

Результаты: Было обследовано 596 детей. Из этих 596 детей у 526 была аметропия (у 470 гиперметропия, у 46 – миопия) и у 50 установлен астигматизм. Косоглазие было обнаружено у 12 детей, ещё 8 страдали амблиопией и ещё у 8 была диагностирована анизометропия. В 8 случаях не было результатов из-за непрозрачности или небольшого размера зрачка.

Заключение: Распространённость рефракционной ошибки среди детей дошкольного возраста аналогична той, которая установлена в других исследованиях в этой области. Хотя большинство случаев попадают в категорию эметропии или умеренной гиперметропии, большинство детей никогда не посещали офтальмолога. Обязательное профилактическое обследование должно быть введено для всех детей в возрасте до семи лет.

Ключевые слова

рефракция, дети, plus-Optix, скрининг
