Original article

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ANALYSIS OF REFRACTIVE ERRORS IN CHILDREN AGED UP TO 15 YEARS

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Investigation of refractive anomalies is especially important in the pediatric population, because they can be the cause of amblyopia and strabismus, if detected late.

We analyzed the refractive anomalies of children aged up to 15 years who were examined in the Office of the Orthoptics and Pleoptics - Department of Ophthalmology - Clinical Center Niš during a five-year period (2006-2010) in relation to sex, age of respondents, type and amount of refractive anomalies. The study included the determination of visual acuity, eye refraction, motility, convergence, cover test, biomicroscopy and direct ophthalmoscopy.

Among the 620 children, without organic damage to the eye, there were 292 males and 328 females. Hyperopia was found in 54.11%, myopia in 2.98%, astigmatism in 42.91%, primarily hyperopic astigmatism in 28.47%.

Hyperopia and hyperopic astigmatism-related refractive anomalies are the most common in this sample of children. The importance of timely and adequate correction of refractive anomalies in children to prevent amblyopia and strabismus is emphasized. *Acta Medica Medianae 2013;52(2):33-40.*

Key words: *refractive anomalies, myopia, hyperopia, astigmatism*

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Introduction

Eye refraction is the ratio between the refractive power of the eye and its length, without the participation of the accommodation (1). Emmetropic eye (emmetropia) implies a relationship between the length and refractive power of the eye that affects the light rays coming from a distance to break and cut in the macula without the participation of accommodation (2) to enable the creation of crisp, clear image of the observed object.

Refractive anomalies (ametropia) arise when relationship between the length and refractive power of the eye is disrupted. They include: nearsightedness (myopia), farsightedness (hyperopia) and astigmatism (astigmatismus) (2).

Myopia is a refractive anomaly in which the refractive power is too strong or the length of the eye is too large for the existing power of refraction, so that parallel light rays coming from infinity, after refraction through a dioptric apparatus of the eye without the use of accommodation, cut in front of the retina, where image of the observed object is created (3).

In contrast to myopia, in hyperopia the refractive power is too weak or the length of the eye is too small, so that the image of the observed objects is created behind the retina.

Astigmatism (As.) is the occurrence of unequal refraction in one and the same eye (3). In regular astigmatism, the parallel light rays coming from infinity do not intersect at one point after refraction, but form two focal lines which are not in the same plane, perpendicular, and determine the axis of astigmatic system (1,4): one corresponding to the strongest and other to the weakest curved meridian of the cornea which are called principal meridians. Depending on whether more refraction occurs in vertical or horizontal meridian, astigmatism may be direct - more refraction in the vertical meridian (astigmatismus directus) and reverse - more refraction in horizontal meridian (astigmatismus inversus). If, however, the direction of the principal meridians is oblique, it is oblique astigmatism (astigmatismus obliquus) (5). Astigmatism in which one principal meridian is emmetropic and the other ametropic (hyperopic or myopic) is simple and is called astigmatismus simplex. If ametropia of same type and different strength occurs in both principal meridians, it is astigmatismus compositus. On the other hand, if principal meridians

have different refraction (myopic in one and hyperopic in the other), it is mixed astigmatism (astigmatismus mixtus) (3). Refractive power of the eye is expressed in diopters (D) (4). Height of refractive anomaly is determined by retinoscopy or refractometry (2).

Aim

The aim of our study was to analyse refractive anomalies of children aged up to to 15 years who were examined in the Office of the Orthoptics and Pleoptics - Department of Ophthalmology - Clinical Center Niš during a five-year period (2006-2010) in relation to sex, age of respondents, the type and amount of refractive anomalies.

Materials and methods

We performed retrospective analysis of refractive anomalies of children aged up to 15 years, without organic damage to the eye, who were examined in the Office of the Orthoptics and Pleoptics - Department of Ophthalmology - Clinical Center Niš during a five-year period (2006-2010). The study included the determination of subjective visual acuity using optotypes (with thumbnails for the younger children of preschool age with a distance of 3m, and for the older children of preschool and school-aged children with Pflüger's E-hooks, indirect method), then objective refraction of the eye (retinoscopy or refractometry in cicloplegyc and mydriasis, depending on the age of children with Sol. Homatropine 2% for school children or Sol. Atropine 0.5% and 0.25% for pre-school children), motility, convergence, cover test, biomicroscopy and direct ophthalmoscopy. The results are presented in tables.

Results

We analyzed the refractive anomalies of 620 children aged 1 - 15 years, 292 males: 328 female. The majority of the examined children aged 7-9 years (31.77%) were predominantly females (52.90%), with 47.10% of males. Distribution of examined children by sex and age is presented in Table 1. Analysis of all refractive anomalies depending on the age is presented in Table 2, as well as the percentage distribution of refractive errors for each individual aged group Table 3. For astigmatism, refractive anomalies were taken in which the difference of refractive power of both principal meridians was greater than 0.75D. For oblique astigmatism, axis with inclination of 16º to 74º and from 106º to 164º were taken.

From a total of 1240 eyes, hyperopia was found in n=671 eyes (54.11%), myopia in n=37 (2.98%), astigmatism in n=532 eyes (42.91%), and furthermore: hypermetropic astigmatism in 353 (28.47%), myopic astigmatism in 88 (7.10%) and mixed astigmatism in 91 eyes (7.34%). In all age groups, the most common refractive anomaly was hyperopia, myopia was the least represented, except for the age group 13-15 years, where the aggregate astigmatism (hyperopic + myopic + mixed) was more common than hyperopia.

Refractive anomalies were specifically analyzed and presented in tables in relation to the amount of refractive anomalies and age of children (Table 4 for hyperopia and Table 5 for myopia).

The most common category is low hyperopia up to + 3.0D n=491 eyes (73.18%). Of the 37 eyes with myopic refraction, low myopia up to -3.0D was found in 26 eyes (70.27%).

Astigmatism is particularly shown in tables as follows: As. hypermetropicus (Table 6), As. myopicus (Table 7) and As. mixtus (Table 8).

In hyperopic astigmatism, in the highest percentage (87.5%), the height of astigmatism (difference between refractive power of principal meridians) was <3D, distributed as follows: 51.8% with the height of hyperopia in one meridian +3.0D, 26.9% from +3.25 to +6.0D, 7.6% from +6.25 to +9.0D, 0.9% from +9.25 to + 12.0D and 0.3% with hyperopia ≥ + 12.25D. Astigmatism ≥ 3D was present in 12.5%, and the highest percentage (10.2%) was in the height of hyperopia in one meridian up to +3.0D.

In myopic astigmatism, the highest percentage of the astigmatism was <3D (75%): with myopia in one meridian up to –3.0D (42.1%); from –3.25 to –6D (18.2 %); from –6.25 to –9.0D (7.9%), from – 9.25 to – 12.0D (4.5%) and with myopia ≥–12.25D (2.3%). Astigmatism ≥3D was present in 25%, distributed as follows: myopia in one meridian up to -3D (11.4%) and higher myopia in one meridian(13.6%).

In mixed astigmatism, myopia in one meridian from –0.25 to –1.5D was found in 59.34% (in 49.45% hiperopia in the second meridian was <+3.0D, and in 9.89% ≥+3.0D), in 26.38% myopia in one meridian was from -1.75 to -3.0D (in 24.18% hiperopia in the second meridian was <+3.0D, and in 2.20% ≥+3D); in 7.69% myopia in one meridian was from –3.25 to –4.50D (in 6.59% hiperopia in the second meridian was <+3.0D, in 1.1% ≥+3D), while in a slightly smaller percentage (6.6%) was the astigmatism with myopia in one meridian ≥– 4.75D and hyperopia in the second meridian <+3.0D.

In Table 9, the frequency of direct, inverse and oblique astigmatism was shown for each age group separately. The most common was the direct astigmatism (81.39%), and almost equally represented were the inverse (9.21%) and oblique astigmatism (9.40%).

Table 1. Distribution of children by sex and age

Age	Sex n (%)		∑ n (%)
(year)	Male	Female	
1-3	52	50	102 (16.45%)
4-6	91	80	171 (27.58%)
7-9	87	110	197 (31.77%)
10-12	45	62	107 (17.26%)
13-15	17	26	43 (6.94%)
∑	292(47.10%)	328 (52.90%)	620 (100%)

Table 2. Refractive errors depending on age

Age (year)	Refractive errors					∑
	Hyperopia	Myopia	As. Hyperopic	As. Myopic.	As. Mixtus	
1-3	140	5	42	11	6	204
4-6	188	6	124	13	11	342
7-9	203	7	119	31	34	394
10-12	102	11	54	23	24	214
13-15	38	8	14	10	16	86
∑ %	671 (54.11%)	37 (2.98%)	353 (28.47%)	88 (7.10%)	91 (7.34%)	1240 (100%)
			532 (42.91%)			

Table 3. Representation of each refractive errors for each age group separately

Age (year.)	Refractive errors										∑	
	Hyperopia		Myopia		As. Hyperop.		As.Myopic		As.Mixtus			
	n	%	n	%	n	%	n	%	n	%	n	%
1-3	140	68.63	5	2.45	42	20.59	11	5.39	6	2.94	20	100
4-6	188	54.97	6	1.75	124	36.26	13	3.80	11	3.22	342	100
7-9	203	51.52	7	1.78	119	30.20	31	7.87	34	8.63	394	100
10-12	102	47.66	11	5.14	54	25.23	23	10.75	24	11.22	214	100
13-15	38	44.19	8	9.30	14	16.28	10	11.63	16	18.61	86	100

Table 4. Hyperopia in D depending on age of children

Age (year)	Hyperopia (D)					∑	
	+0.25 to +3.0	+3.25 to +6.0	+6.25 to +9.0	+9.25 to +12.0	+12.25 to +15.0	n	%
1-3	74	59	7	0	0	140	20.90
4-6	137	42	7	2	0	188	28.02
7-9	163	29	9	1	1	203	30.25
10-12	83	14	5	0	0	102	15.20
13-15	34	3	0	1	0	38	5.66
∑	491(73.18%)	147(21.90%)	28(4.17%)	4(0.60%)	1(0.15%)	671	100

Table 5. Myopia in D depending on age of children

Age (year)	Myopia (D)					∑	
	-0.25 to -3.0	-3.25 to -6.0	-6.25 to -9.0	-9.25 to -12.0	-12.25 to -15.0	n	%
1-3	2	1	1	0	1	5	13.51
4-6	2	0	1	3	0	6	16.22
7-9	5	2	0	0	0	7	18.92
10-12	9	1	0	1	0	11	29.73
13-15	8	0	0	0	0	8	21.62
∑	26(70.27%)	4(10.81%)	2(5.41%)	4(10.81%)	1(2.70%)	37	100

Table 6. Hyperopic astigmatism depending on age

Age (year)	Hiperopia on one meridian (D)										
	E to+3.0		+3.25to+6.0		+6.25to+9.0		+9.25to+12.0		+12.25to+15.0		Σ
	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	
	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	
1-3 d	11	6	15	2	4	0	0	0	0	0	38
1-3 I,k			4*								4*
4-6 d	52	6	30	2	10	1	2	0	0	0	103
4-6 I,k	3*6#	2*	5*4#		1#						10*11#
7-9 d	65	11	15	2	5	0	1	0	1	0	100
7-9 I,k	7*2#	4#	3*1#		2*						12*7#
10-12 d	25	6	10	0	4	1	0	0	0	0	46
10-12I,k	3#	1#	4#								8#
13-15 d	7	0	3	0	1	0	0	0	0	0	11
13-15I,k	2#		1#								3#
∑ d	160	29	73	6	24	2	3		1		298
∑ I,k	10*13#	2*5#	12*10#		2*1#						26*29#
∑	183	36	95	6	27	2	3		1		353
%	51.8%	10.2%	26.9%	1.7%	7.6%	0.6%	0.9%		0.3%		100%

RD: refractive power difference between the two principal meridians (D)
d: direct astigmatism
I: * Inverse astigmatism, k: # oblique astigmatism

Table 7. Myopic astigmatism depending on age

Age	Myopia in one meridian (D)										
(year)	E to-3.0		-3.25to-6.0		-6.25to-9.0		-9.25to-12.0		-12.25to-15.0		Σ
	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	
	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	<3.0	≥3.0	
1-3 d	2	2	2	0	0	0	3	0	2	0	11
1-3 I,k											
4-6 d	4	2	2	2		0	0	0	0	1	11
4-6 I,k	1*				1*						2*
7-9 d	10	0	6	1	4	2	0	0	0	1	24
7-9 I,k	2*3#		2*								4*3#
10-12d	5	3	4	1	1	1		0	0	0	15
10-12 I,k	3*	1#			1#	2#	1#				3*5#
13-15d	3	2	0	0	0	1	0	0	0	0	6
13-15I,k	3*1#										3*1#
∑d	24	9	14	4	5	4	3		2	2	67
∑I,k	9*4#	1#	2*		1*1#	2#	1#				12*9#
∑	37	10	16	4	7	6	4		2	2	88
%	42.1%	11.4%	18.2%	4.5%	7.9%	6.8%	4.5%		2.3%	2.3%	100%

RD: refractive power difference between the two principal meridians (D)
d: direct astigmatism
I: * Inverse astigmatism, k: # oblique astigmatism

Table 9. Representation of direct, inverse and oblique astigmatism for each age group separately

Age	Astigmatism			∑
(year)	direct	inverse	oblique	
1-3	53(89.83%)	6(10.17%)	0	59(100%)
4-6	123(83.12%)	12(8.11%)	13(8.78%)	148(100%)
7-9	153(83.15%)	16(8.70%)	15(8.15%)	184(100%)
10-12	75(74.26%)	8(7.92%)	18(17.82%)	101(100%)
13-15	29(72.50%)	7(17.50%)	4(10.00%)	40(100%)
∑	433(81.39%)	49(9.21%)	50(9.40%)	532(100%)

Table 8. Myopia and hyperopia in D with mixed astigmatism according to age

Age	Myopia in one and hyperopia in second meridian (D)										
(year)	-0.25 to-1.50		-1.75 to-3.0		-3.25 to-4.50		-4.75 to-6.0		-6.25 to-7.50		
	mII		mII		mII		mII		mII		Σ
	<+3.0	≥+3.0	<+3.0	≥+3.0	<+3.0	≥+3.0	<+3.0	≥+3.0	<+3.0	≥+3.0	
1-3 d	2	2									4
1-3 I,k	2*										2*
4-6 d	4	1	4								9
4-6 I,k			1#	1#							2#
7-9 d	13	3	9		2				2		29
7-9 I,k	1#	2#	2#								5#
10-12 d	7	1	1			1	4				14
10-12 I,k	4*1#		1*1#	1#	2#						5*5#
13-15 d	8		2		2						12
13-15 I,k	3*		1*								4*
Σ d	34	7	16		4	1	4		2		68
Σ I,k	9*2#	2#	2*4#	2#	2#						11*12#
Σ	45	9	22	2	6	1	4		2		91
%	49.45	9.89	24.18	2.20	6.59	1.10	4.40		2.20		100%

mII: Hyperopia in second meridian
d: direct astigmatism
I: * Inverse astigmatism, k: # oblique astigmatism

Discussion

Investigation of refractive anomalies is of particular importance in pediatric population, because they are the most common cause of amblyopia and strabismus, if detected late. It is important to timely determine the existence, amount and the difference of refractive anomalies in both eyes in these patients, who are in vulnerable population, with well established screening of preschool and early school aged children.

Refraction of the eye changes through life. During the growth of the eye, the process of emmetropization normally occurs i.e. harmonization of refractive and axial parameters and formation of emmetropic relations within normal biological variation. Hyperopia, from +3.0D to +4.0D at birth, decreases during the preschool period to +0.50D, emmetropy or even converges to myopia (2).

For the development of refractive anomalies primarily genetic factors are responsible, up to 86% in terms of myopia and hyperopia, and 50% in terms of inheritance of the total or 60% of corneal astigmatism (Hammond CJ, et al. (2001)). In addition to genetic factors, for the development of refractive anomalies, other - non-genetic factors are important (SM Saw, 2003). In the case of myopia, those are: close work, TV watching, computer work, working conditions (Cvetković, 1995), general state of the organism, the activity of the endocrine system, weakened accommodation, bulbomotor and eyelid muscle activity, uncoordinated relationship of intraocular pressure and rigidity of sclera (Sheedy, JE, et al. (2003)), education (Diran, M, et al. (2008)), urbanization (Morgan, et al. (2005)) and others, while in the other hand the astigmatism is connected with: lack of coordinated development of fibrous layer of the eye, the position and shape of the lens, an anomaly of development posterior pole of the eye (the insertion of hair papilla, coloboma of the optic nerve and surrounding choroid) (Cvetković, 1995), pressure of the eyelids and bulbomotor, intraocular pressure effects, the effects of surgery, diseases of the eye, adnexa, genetic syndromes associated with abnormalities of the eyelids and the like (6).

According to the results obtained in 620 children (in 1.240 examined eyes) hyperopia was present in 54.11%, myopia in 2.98%, astigmatism in 42.91% (hyperopic in 28,47%, myopic in 7.10% and mixed in 7.34%). Hyperopia and hyperopic astigmatism are the most common refractive anomalies, which is in accordance with results and other authors (7-16). Some differences in the percentage distribution of refractive anomalies in certain authors may be explained by the different age structure, geographical/racial background of the children, working methodology.

According to the amount of refractive anomalies low hyperopia up to +3.0D (73.18%) was the most prevalent in all age groups of children, which is also in accordance with the results of other authors (17,18,13). High hyperopia over +8.0 or +10.0D are otherwise rare, with only 0.18% having the refraction higher than +10.0D (2).

The frequency of occurrence of astigmatism in the overall population and among refractive anomalies vary from one author to another, usually because of differences in definition of (clinical) astigmatism. Astigmatism relatively rarely manifests as isolated refractive anomaly. Over 4/5

of all astigmatism occurs in combination with hyperopia/myopia, more common in females (6:4) and can be changed in the course of life (2).

We observed, in our work, a gradual decline in the representation of hyperopia and hyperopic astigmatism with aging of children. These results agree with the results of other authors who recorded negative prevalence of hyperopia with age (10,15,19), as well as those who recorded a decline in the percentage of the hyperopic astigmatism with age (20). In contrast to hyperopic, increase in percentage of myopic and mixed astigmatism, in our work, relates to aging of children and is associated with myopisation of the eye with age. Shih et al. (2004) record an increase in percentage of myopic, and decline of mixed astigmatism with age (20).

In the analysis of astigmatism, there is a significant difference of the refractive powers of both principal meridians of the eye of the children, which in our sample was usually <3D (with hyperopic astigmatism in 87.5%, and myopic astigmatism in 75% of respondents). Gong et al. (2004) also found only a small percentage of astigmatism ≥3D (21). In mixed astigmatism, the majority of children were with a height of myopia in one meridian to -1.5D and hyperopia height of less than +3.0D in the second meridian. In all astigmatism cases (hyperopic, myopic, and mixed) direct astigmatism was the most common, which matches the findings of other authors (20,22). Direct representation of astigmatism in our sample decreases with age in children. Shih YF (2004) provides an increase in direct astigmatism, the decrease of the inverse, while the oblique astigmatism is generally stable with age, in children (20).

Myopia is a refractive anomaly the least represented in our study (2.98%). The prevalence of myopia shows a wide geographic variation. Mild to moderate myopia occurs in about 25% of the population of Europe and North America, only about 5% of the population in Africa, and even 61% in Asia (23). The prevalence of myopia in adolescents in the recent decades has increased and is 10-25% and 60-80% in industrialized societies of the West and the East (24). It is estimated that 1.6 billion people worldwide have myopic refractive anomaly, and it is expected that this number will increase to nearly 2.5 billion by 2020 (Diran et al. (2006)), which indicates that myopia is becoming a significant global health problem (6).

Myopia is usually present as low, in this sample of children with height up to -3.0D (70.27%) according to the results of other authors (13). It tends to increase with aging of children, which is also in accordance with the results of other authors who found a positive correlation between the prevalence of myopia and age (15,19). A higher percentage prevalence of myopia in the youngest children in relation to the age group of 4-6 years is interpreted by the height of myopia and poorer eyesight previously observed, and the increase in the level of myopia with age explains the influence of these non-genetic factors, particularly the activity of the growing closeness and anthropometric measures. It would be desirable for a future announcement regarding the analysis of refractive errors to include the right interpretation of anthropometric measures with biometric and keratometric parameters of eyes in respondents with further interpretation of the emergence and change of the refractive status of the eye during life. Timely and proper monitoring and correction of refractive errors contributes to reducing visual impairment and the chance to form the youngest patient population, our children, the hope and future of the country.

Conclusion

From the observed refractive anomalies in children, hyperopia and hyperopic astigmatism in relation to myopia, myopic astigmatism and mixed astigmatism are usually represented.

In relation to the amount of refractive anomalies, the most common refractive anomalies are up to +/−3D. The most common are hyperopic and myopic astigmatism cases, with the difference of refraction power between the two principal meridians <3.0D, while in mixed astigmatism it is myopia in one meridian up to -1.5D and hyperopia <+3.0D in the second meridian. Direct astigmatism is more common, while the inverse and oblique are present in almost equal proportion.

Although in our sample low refractive anomalies and fewer high values of refractive anomalies dominate, timely detection, adequate correction and monitoring of refractive anomalies is necessary in order to prevent poor eyesight and strabismus.

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ANALIZA REFRAKCIONIH ANOMALIJA KOD DECE UZRASTA DO 15 GODINA

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Analizirane su refrakcione anomalije dece uzrasta do 15 godina, pregledane u Kabinetu za ortooptiku i pleoptiku Klinike za očne bolesti KC Niš u petogodišnjem periodu (2006-2010), u odnosu na pol, uzrast ispitanika, vrstu i visinu refrakcione anomalije.

Od 620 dece kod koje nije postojalo organsko oštećenje oka, bilo je 292 muškog i 328 ženskog pola. Najbrojnija kategorija dece uzrasta je 7-9 godina (31.77%). Ispitivanja su obuhvatala određivanje oštrine vida, refrakcije oka, proveru motiliteta, konvergencije, cover test, orjentacionu proveru vrednosti intraokularnog pritiska, biomikroskopiju i direktnu oftalmoskopiju.

Od ukupno 1240 očiju, hipermetropija je nađena kod 671 oka (54.11%), miopija kod 37 (2.98%), astigmatizam kod 532 (42.91%) i to: hipermetropni astigmatizam kod 353 (28,47%), miopni astigmatizam kod 88 (7,10%) i mešoviti astigmatizam kod 91 oka (7,34%). U odnosu na visinu refrakcione anomalije dominiraju niska hipermetropija (do +3.0D u 73,18%) i niska miopija (do –3.0D u 70,27%). Kod astigmatizma, u najvećem procentu je razlika prelomne moći oba glavna meridijana <3D (hipermetropni 87.5%, miopni 75%); kod mešovitog astigmatizma najzastupljenija je miopija u jednom meridijanu do –1,5D i hipermetropija u drugom meridijanu <+3D. Direktni astigmatizam nađen je u 81.39%, inverzni u 9,21% i kosi astigmatizam u 9,40% ispitivane dece.

Hipermetropija i hipermetropni astigmatizam su najčešće refrakcione anomalije u ispitivanom uzorku dece (82,58%). Sa uzrastom dece zapaža se postepeni pad hipermetropije, porast miopije, miopnog i mešovitog astigmatizma. Ističe se značaj pravovremene i adekvatne korekcije refrakcionih anomalija dece. *Acta Medica Medianae 2013;52(2):33-40.*

Ključne reči: *refrakcione anomalije, miopija, hipermetropija, astigmatizam*

