PREVALENCE OF REFRACTIVE ERRORS IN THE SLOVAK POPULATION CALCULATED USING THE GULLSTRAND SCHEMATIC EYE MODEL

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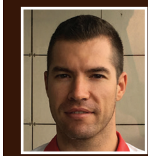

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SUMMARY

Purpose: Large part of the population suffers of some kind of refractive errors. It is supposed that their prevalence could change with the development of the society. The aim of this study is to determine the prevalence of refractive errors using calculations based on the Gullstrand schematic eye.

Methods: We used Gullstrand schematic eye to calculate refraction retrospectively. Refraction was presented as needed glasses correction in vertex distance 12 mm. Necessary data was obtained with the optical biometer Lenstar LS900. Data which could not be obtained due to the device limitation were substituted by theoretical data from the Gullstrand schematic eye. Only analyses from the right eyes were presented. Data were interpreted using descriptive statistics, Pearson correlation and t-test. Statistical tests were conducted at significance level of 5 %.

Results: In our sample were 1663 patients (665 males, 998 females) in age from 19 to 96 years. Average age was 70,8 ± 9,53 years. Average refraction of the eye was 2,73 ± 2,13D (males 2,49 ± 2,34, females 2,90 ± 2,76). Mean absolute error from emmetropia was 3,01 ± 1,58 (males 2,83 ± 2,95, female 3,25 ± 3,35). 89,06 % of the sample was hyperopic, 6,61 % was myopic and 4,33 % emmetropic. We did not find correlation between refraction and the age.

Conclusion: Females were more hyperopic than males. We did not find any statistically significant hypermetopic shift of the refraction with the age. According to our estimation the calculations of refractive errors showed hypermetropic shift of more than +2D from reality. Our results could be used in future for comparing prevalence of refractive errors using same methods as we used.

Key words: refractive errors, refraction, Gullstrand schematic eye, population, emmetropia

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INTRODUCTION

Basic refractive errors (myopia, hypermetropia and astigmatism) occur in a large proportion of the population worldwide (11). If left uncorrected or incorrectly corrected, they may cause a deterioration of visual acuity. According to the WHO, visual impairment is characterised as visual acuity worse than 6/18. Visual impairment is divided into five categories, in which 1-3 represent none to severe visual impairment. Visual acuity worse than 3/60 is considered blindness of various severity (categories 3-5) (1).

Uncorrected refractive errors constitute 43% of short-sightedness and 3% of cases of blindness, whilst this condition can be rectified relatively simply and effectively (11). These errors causing short-sightedness can be very easily diagnosed, measured and corrected with the aid of glasses or other corrective aids.

Damage to sight caused by uncorrected refractive error may have immediate or long-term consequences in children and adults, such as a loss of working or educational opportunities, loss of economic income for individuals and their families, as well as a deterioration in quality of life (12).

Of all the basic refractive errors, in recent times the epidemiology of myopia has come to the forefront, since this is beginning to represent a substantial problem in Asian countries, as well as in countries of the Western world. In recent decades an increase in myopia has been observed (6, 9, 16). Several studies are of the opinion that this may be linked to a change of lifestyle. Frequently mentioned risk factors are close-up work, education and less time spent in an outside environment (15, 17, 18). It ensues from the above observations that the prevalence of refractive errors in the population is not a static phenomenon, but has a tendency to change with the development of society and lifestyle. For this reason we decided to determine the current state of refractive errors in our population on the basis of a calculation using the Gulltrand schematic eye model. This overview of refractive errors of the population, in addition to its descriptive character, may in future serve as a point of contact upon a comparison of the development of refractive errors.

METHOD

Before commencing the analysis, we requested the approval of the data processing from the ethical commission at the University Hospital in Ružinov, Bratislava. The study was implemented upon adherence to the principles of the Helsinki declaration. It concerns retrospective data, which includes biometric information about the eyes of patients before cataract surgery. The biometric data on the eyes at the time of measurement was gathered with the aim of determining a precise calculation of the dioptric strength of the artificial intraocular lens which is to be implanted in patients during cataract surgery. The data was gathered from patients at the Department of Ophthalmology, Faculty of Medicine, Comenius University and Ružinov University Hospital in Bratislava. The biometric parameters of the eyes were measured with the aid of the optical biometer Lenstar LS900, using the principle of OLCR (Optical Low Coherence Reflectometry). A minimum of 5 measurements were conducted on each eye with the aid of the optical biometer Lenstar LS900.

In the analysis we started out from the hypothesis that eyes with an extremely short or long axial length most probably represent a certain form of anomalous development of the eye or another pathological condition (postoperative atrophy, trauma and other), and therefore do not constitute a representative sample belonging to the norm. We selected 21 and 27 mm as the limits of the norm. As a result, we excluded from the analysis eyes which were shorter than 21 mm and longer than 27 mm. Patients who had only one eye measured were excluded from the analysis, since we also wished to compare the differences between eyes in individual patients. We also excluded patients in whom the data required for calculation of refraction of the eye was missing in one or both eyes. Only eyes with the patient's own lens (“phakic eyes”) were included in the cohort.

With regard to the fact that this concerns a retrospective study on a large number of patients, in which the finding of their objective refraction with the aid of an automatic keratorefractometer was logistically very difficult to implement, we decided to calculate refraction (the value of glasses correction required to attain emmetropia of 0D) by means of the establishment of precise biometric values of the eye into the Gullstrand schematic eye model.

From the biometric measurements, the following parameters were used: axial length of eye, central corneal thickness, depth of anterior chamber, average radius of curvature of anterior surface of cornea and thickness of lens. Since depth of the anterior chamber is measured by the instrument from the surface of the cornea to the anterior surface of the lens, central corneal thickness was subtracted from this dimension for the utilisation of this model. In cases where which the Lenstar LS900 instrument was unable to measure certain necessary data (for example curvature of the posterior surface of the cornea or surfaces of the lens), the values from the given model of the eye were used. Indexes of the refraction of the optic media were selected from the model. The selected index of corneal refraction was 1.376. The selected refraction index of the chamber fluid and vitreous body was 1.336. The refraction index of the cortex and core of the lens was 1.386 and 1.406 respectively. The radius of the posterior surface of the cornea was selected at 6.8 mm. The radii of the anterior surface of the lens / anterior surface of the core of the lens / posterior surface of the core of the lens were +0.01/+0.007911/-0.00576/-0.006m (including sign conversion, i.e. measured from the peak of the refraction surface, in which the direction of through flow of beams is considered positive). After the given data was incorporated into the Gullstrand schematic eye model, we calculated the necessary inserted glasses correction in dioptres at a vertex distance of 12 mm in order to attain emmetropia.

The data was analysed and interpreted with the aid of descriptive statistics. In the case of continuous or spaced variables, first of all their normal distribution was evaluated with the aid of a visual evaluation and a Shapiro-Wilk test. Certain of the characteristics manifested slight deviations from the normal distribution (in our large number of patients these deviations do not have a pronounced impact on the analysis upon the expected normal distribution of data), and for this reason we stated the median and the range between the first and third quartile (Q1-Q3). For an evaluation of the relationship between the individual variables we used a Pearson correlation coefficient. A t-test was used for a comparison of the averages. The level of significance of 5% was selected for all the statistical analyses. The data was statistically processed with the aid of the software IBM® SPSS® Statistics.

RESULTS

Out of the total cohort of 1963 patients, following the application of the above-mentioned inclusion criteria, we included 1663 patients in the analysed cohort (of whom 665 were men and 998 women). Within the cohort the age representation of the individuals was from 19 to 96 years. Average age was 70.8 ± 9.53 years (men 69.95 ± 10.18 and women 71.57.± 8.99 years). The data gathering took place from September 2014 to August 2016.

The descriptive statistics of refraction in the right and left eye, together with absolute refraction and absolute difference in refraction between the right and left eye are presented in table 1.

The average difference in refraction between the right and left eye was not clinically or statistically significant ($p>0.05$), and as a result we decided to conduct further analyses on the right eye only. The average values for men and women are presented in table 2. It ensues from the table that women are more hypermetropic than men by as much as +0.41D. This difference is statistically significant ($p<0.001$).

We divided refractive errors according to seriousness into the following: severe myopia (less than -6D), medium severe myopia (≥ -6D to -3D), light myopia (≥ -3D to -0.5D), emmetropia (≥-0.5D to ≤+0.5D), light hypermetropia (>+0.5 to +2D), medium severe hypermetropia (≥+2D to +5D) and severe hypermetropia (more than +5D). The results of the distribution of refractive errors are presented in table 3.

With regard to the expected trend of myopisation of the

Table 1: Mean refractive errors of whole sample

		PR	LR	Abs. PR	Abs. LR	Abs. difference of R
Average		2.73	2.75	3.09	3.09	0.55
Median		2.92	2.89	3.01	2.95	0.36
St. deviation		2.13	2.13	1.58	1.59	0.74
95% CI of mean	**Lower limit**	2.63	2.65	3.01	3.02	0.52
	Upper limit	2.84	2.86	3.16	3.17	0.59
Minimum		-8.42	-8.56	0.00	0.01	0.00
Maximum		8.90	14.05	8.90	14.05	14.07
Q1-Q3 range		1.8-3.98	1.99-4.05	1.81-3.98	2.02-4.03	0.18-0.68

Table 2 Refractive errors for males and females separately

		PR	LR	Abs. PR	Abs. LR	Abs. difference of R
Males						
Average		2.49	2.51	2.83	2.85	0.54
Median		2.34	2.36	2.72	2.74	0.49
St. deviation		2.64	2.66	2.95	2.96	0.59
95% CI of mean	**Lower limit**	2.68	2.62	2.75	2.73	0.35
	Upper limit	2.02	1.98	1.50	1.45	0.64
Minimum		-7.20	-5.59	0.00	0.04	0.00
Maximum		8.90	8.86	8.90	8.86	6.73
Q1-Q3 range		1.55-3.67	1.63-3.68	1.77-3.71	1.82-3.73	0.18-0.66
Females						
Average		2.90	2.92	3.25	3.26	0.56
Median		2.76	2.78	3.15	3.15	0.51
St. deviation		3.03	3.05	3.35	3.36	0.61
95% CI of mean	**Lower limit**	3.09	3.02	3.17	3.09	0.37
	Upper limit	2.19	2.20	1.61	1.65	0.80
Minimum		-8.42	-8.56	0.00	0.01	0.00
Maximum		8.75	14.05	8.75	14.05	14.07
Q1-Q3 range		1.96-4.20	1.96-4.14	2.15-4.25	2.09-4.22	0.17-0.69

younger population, we divided our cohort into different age categories. In the younger groups and the oldest age groups, where the number of patients was small, we created groups covering ten years, in the other groups we set five year intervals. The results of refraction in individual age groups, together with the trend curve for the individual ten year categories, are presented in table 4 and graph 1.

With the aid of a bivariate analysis we determined that the correlation of refraction with age is negligible (Pearson's correlation coefficient = 0.035) and statistically insignificant ($p>0.05$). The correlation of refraction with age is illustrated in graph 2.

DISCUSSION

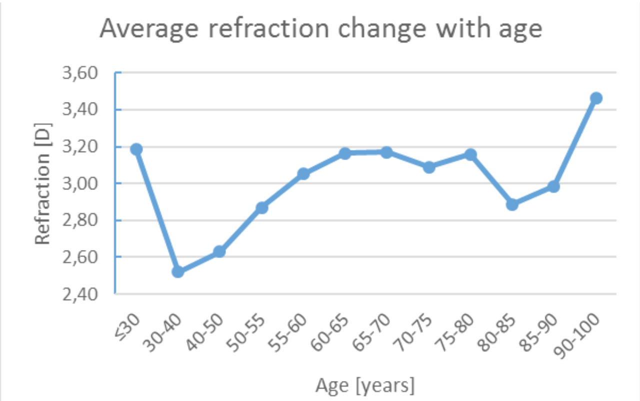
It is very difficult to conduct a perfect comparison of our results with other studies, since several studies use other criteria for the degree of ametropia. The Blue Mountains Eye Study (BMES) and the EPIC-Norfolk Eye Study used a similar definition of emmetropia as our study (3, 4). The average refraction in our group was +2.73 ± 2.13D, which is a pronounced shift toward hypermetropia in comparison with BMES, in which the average measured value of refraction was +0.67. Results similar to those of BMES were produced also by other studies (2, 4, 7). We did not expect the

Table 3 Refractive errors in stratified subgroups

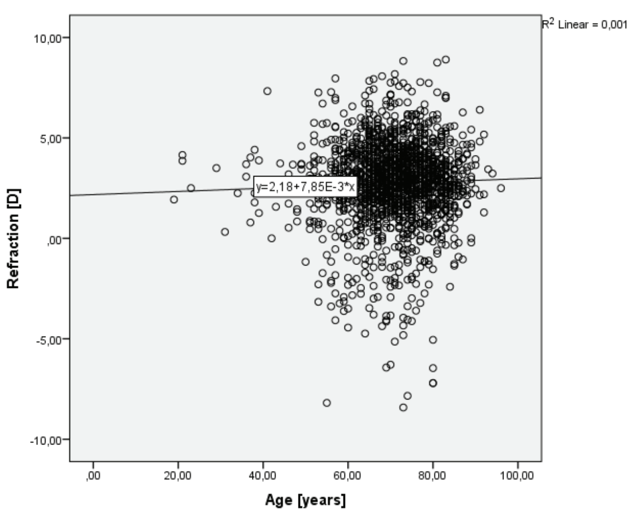
Refractive error of the eye [D]	N	% of sample
>+6	171	10.28%
(+2;+6]	1009	60.67%
(+0.5;+2]	301	18.10%
[-0.5;+0.5]	72	4.33%
[-3;-0.5)	75	4.51%
[-6;-3)	27	1.62%
<-6	8	0.48%

Table 4 Mean refractive errors in groups stratified by age

Age interval [years]	Average refractive error in SE [D]	SD	N
≤30	3,19	0,84	5
30–40	2,52	1,33	11
40–50	2,63	1,90	18
50–55	2,87	2,47	56
55–60	3,05	2,51	123
60–65	3,16	2,05	221
65–70	3,17	2,19	328
70–75	3,09	2,22	376
75–80	3,16	2,11	285
80–85	2,89	1,76	176
85–90	2,99	1,49	55
90–100	3,46	1,58	9



Graph 1 Average refraction change with age



Graph 2 Correlation of refraction with the age

Slovak population to have such a pronounced shift toward hypermetropia, and we therefore assumed imprecision on the part of the Gullstrand schematic eye model, since it produced a calculation of +2.22 in comparison with the average from BMES.

From our observation it also ensued that women were more hypermetropic than men by +0.41D (p<0.001). BMES also indicated more hypermetropic average refraction in women by +0.16D (3).

The results of the analysed cohort demonstrated that 89.06% suffer from a certain form of hypermetropia, 6.61% myopia and both 4.33% emmetropia. In comparison with other studies, the prevalence of hypermetropia is markedly higher (3, 4, 10). For this reason we chose BMES as the population average and created a distribution of refraction in our cohort, in which we shifted the limits for individual refractive errors by +2.22D (for example emmetropia was considered refraction from +1.72D to +2.72D etc.). Following this correction the representation of all hyperopes was 57%, emmetropes 20% and myopes 23%. These results are comparable with other studies (3, 4, 10).

From graph 1 it is visible that refraction had a tendency to increase with age, but the correlation of refraction with age did not confirm this rising trend (Graph 2). Increasing refraction with age was observed also in BMES (3). This may connect to the phenomenon, observed by some authors, of the shortening of the axial length of the eye with age (5, 13), which is closely linked with refractive errors of the eye. We may also find a connection with the increasing incidence of myopia in recent decades as a consequence of adaptation to working activities at a short distance (15, 17). From graph 1 we can observe a sharp drop between subjects aged under 30 years and the 3rd decade, followed by a gradual increase in refraction . This may however be a chance phenomenon, since there is a very small number of patients in the youngest age group (N=5), which may distort the results.

In certain studies a myopic shift is described in people aged over 75 years (8, 14). This was explained by possible changes of the ageing turbid lens, which causes this shift in patients above the age of 85 years (14). In our cohort we did not record such a shift, which is in accordance with the findings in BMES (3).

It ensues from our observations that the Gullstrand schematic eye model provides a hypermetropic shift of calculated refraction upon establishment of realistically measured biometric parameters. It is not possible to measure the precise value of the shift, but according to our observations this concerned more than +2D.

However, the given calculation may indicate with a fair amount of precision the trend in change of refraction with age, in which we observed a slight hypermetropic shift of refraction, which was nevertheless not statistically significant. It is very difficult to evaluate whether this shift is indeed caused by anatomical and physical changes in the optical system of the eye caused by ageing in individuals, or if it is caused by a gradual myopisation of the younger population. In order to resolve this issue, observations of individual subjects would be required over a very long observation period, which would be highly technically demanding.

Our results may serve as orientation for correction of precision of refractions measured with the aid of models of the eye based on the Gullstrand schematic eye model.

Similarly, our results may serve as a guide to the distribution of refraction in the Slovak population at the given time, in which, upon a repetition of our procedure after an interval of time, we shall be able to compare the change in the refractive situation of our population.

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