

Associations Between Contrast Sensitivity and Aging

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Summary. *Objective.* The aim of this study was to assess age-related visual functions (visual acuity and contrast sensitivity) and compare the results by different age groups.

Material and Methods. A total of 231 patients were examined. The patients were divided into 5 age groups: 10 patients in group 1, 30–39 years; 40 patients in the group 2, 40–49 years; 77 patients in the group 3, 50–59 years; 71 patients in the group 4, 60–70 years; and 33 patients in the group 5, 71–85 years. A typical Snellen's chart (the direction of the gap in Landolt C) was used for noncorrected and best-corrected visual acuity testing. Contrast sensitivity was evaluated by employing a Ginsburg Box, VSCR-CST-6500.

Results. Noncorrected visual acuity was significantly better in the group 2 than the group 3 (0.86 [0.28] vs. 0.69 [0.33], $P=0.018$). Moreover, noncorrected and best-corrected visual acuity was significantly better in the group 4 than the group 5 (0.52 [0.35] vs. 0.35 [0.28], $P<0.001$; and 0.9 [0.21] vs. 0.69 [0.27], $P<0.005$, respectively). Contrast sensitivity at the nighttime without glare was significantly worse in the group 2 than the group 1 at the spatial frequencies of 3, 12, and 18 cycles per degree ($P=0.001$, $P=0.05$, and $P=0.01$, respectively). The patients in the group 2 had significantly worse contrast sensitivity at the nighttime and daytime with glare at the spatial frequencies of 1.5, 12, and 18 cycles per degree ($P=0.054$, $P=0.04$, and $P=0.01$ and $P=0.011$, $P=0.031$, and $P=0.011$, respectively). The greatest differences in contrast sensitivity were observed between the groups 4 and 5, and it was 2 to 4 times better in the group 4. Comparing these groups, all the differences at the nighttime and daytime with and without glare were significant.

Conclusions. Contrast sensitivity was worst among the oldest persons (71–85 years), and it began to worsen already in the persons aged 40–49 years. Contrast sensitivity was very similar in the age groups of 40–49 and 50–59 years.

Introduction

Optical and neuron degenerative changes of the visual system that influence a steady decrease in visual acuity are observed from the age of approximately 40 years (1). With aging, people's vision becomes less clear; big objects can be seen clearly, but problems occur when people try to discern minor things and minor details. Additionally, senile miosis develops, the eye lenses become less clear and stiffer, and the accommodation and convergence reserves start to decrease (1). These changes reduce the access of light to the retina. Some authors suggest that contrast sensitivity starts decreasing from the age of 20 years (2). These processes are believed to progress due to the atrophy of the retinal ganglion cell layer (1). Ganglion cells help determine contrast and quickly evaluate the differences in light intensity (3).

The visual acuity test is the simplest method, which is most commonly used by ophthalmologists,

to examine the function of vision. An optotype chart, which contains 12 rows of signs (letters, numbers, rings with a gap, and drawings of various objects), is used for the examination of visual acuity. According to Snellen, visual acuity can be expressed in spatial frequencies; however, the highest spatial frequencies are evaluated by the standard visual acuity test only under conditions of maximum contrast ($V=1.0$ match 30 cycles per degree when contrast is 100%); hence, contrast sensitivity is partially evaluated. Therefore, optotypes can be seen even with decreased contrast sensitivity. The Snellen's chart provides limited information about functional vision (4).

Functional or "practical" vision is described as our day-to-day vision, i.e., what people see and how they process this information (5). A regular Snellen's chart allows evaluating the patients' ability to determine black letters on a white background from the distance, but it does not show visual quality (5), whereas the functional acuity contrast test (FACT) is considered to be more informative and accurate in examining and evaluating visual functions.

For a detailed visual examination, various func-

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tions, such as cognitive perception, health of the visual system, and the central processing function, are tested. Studies have shown that the assessment of visual acuity with the typical Snellen's chart using Landolt's rings (C optotypes) alone is insufficient for the visual function testing because it provides limited information about the central vision; thus, it is necessary to determine not only visual acuity, but also contrast sensitivity (6).

The aim of this study was to assess age-related visual functions (visual acuity and contrast sensitivity) and compare the results by different age groups.

Material and Methods

The study was conducted in the Department of Ophthalmology, Hospital of Lithuanian University of Health Sciences, after the permission (No. BE-2-14) from Kaunas Regional Ethics Committee for Biomedical Research was obtained.

In total, 231 patients were examined. The patients were divided into the following 5 age groups: group 1, 10 patients (19 eyes) aged 30–39 years; group 2, 40 patients (80 eyes) aged 40–49 years; group 3, 77 patients (153 eyes) aged 50–59 years; group 4, 71 patients (142 eyes) aged 60–70 years; and group 5, 33 patients (66 eyes) aged 71–85 years. In this study, visual acuity, transparency of the cornea and the lens, and the fundus were investigated in the patients. Biomicroscopy was performed in order to assess corneal and lenticular transparency. Noncorrected and best-corrected visual acuity (measured in decimals from 0.1 to 1.0) was evaluated using Landolt's rings (C optotypes) by the Snellen's test at a 5-m distance from the chart.

The lenses were evaluated by biomicroscopy. The lenses were examined using a slit lamp, positioning the illumination source at a 45° angle and the light beam being split to a 2-mm width.

During each examination, refraction was performed, intraocular pressure was measured, and the iris color was noted using the slit lamp. The pupils of the subjects were dilated with 1% tropicamide or 1% cycloglyli. After the dilation of the pupils, funduscopy was performed with an ophthalmoscope of the direct monocular type and the slit lamp, using a double aspheric lens of +78 diopters. Peripheral retinal examination was performed using an indirect ophthalmoscope. The results of the ophthalmic examina-

tion were recorded on standardized forms that were developed for this study. Stereoscopic color fundus photographs of the macula were obtained at 45° and 30° to the fovea for a detailed fundus analysis.

The inclusion criteria were as follows: 1) age of 30 to 85 years; 2) no other eye disorders found during a detailed ophthalmological examination; and 3) consent to participate.

The exclusion criteria were as follows: 1) related eye disorders (high refractive error, cloudy cornea, opacity of the lens [nuclear, cortical, and posterior or subcapsular cataract], keratitis, acute or chronic uveitis, glaucoma, neovascular age-related macular degeneration or geographic atrophy, diseases of the optic nerve, etc.); 2) systemic illnesses (diabetes mellitus, oncological diseases, systemic tissue disorders, chronic infectious diseases, conditions after organ or tissue transplantation, etc.); 3) nongraded color images of the fundus because of obscuration in the eye optic system or because of the quality of fundus photography; and 4) functional acuity contrast test (FACT) value of 0.

Contrast sensitivity was measured by employing a Ginsburg Box, VSCR-CST-6500 with a FACT chart at photopic (in the daytime, 85 cd/m²) and mesopic (in the nighttime, 3 cd/m²) luminance with and without glare at 5 standard spatial frequencies: 1.5, 3, 6, 12, and 18 cycles per degree (6). Contrast sensitivity testing was performed in the presence of best-corrected visual acuity.

Statistical analysis was performed using the SPSS/W 13.0 program (Statistical Package for the Social Sciences for Windows, Inc., Chicago, Illinois, USA). The χ^2 test was used for comparison of the frequencies of qualitative variables. A statistically significant difference was considered if $P < 0.05$.

Results

Table 1 shows noncorrected and best-corrected visual acuity by age groups. Noncorrected visual acuity was significantly better in the group 2 than in the group 3 ($P = 0.018$). Moreover, noncorrected and best-corrected visual acuity was better in the group 4 compared with the group 5 ($P < 0.001$ and $P < 0.005$, respectively) (Table 1).

The comparison of contrast sensitivity at the nighttime without glare between the groups 1 and 2 showed that contrast sensitivity was significantly

Table 1. Patients Groups and Results of Visual Acuity

Parameter	Age Groups, Years				
	30–39	40–49	50–59	60–70	71–85
Noncorrected visual acuity	0.89 (0.28)	0.86 (0.28)	0.69 (0.33)	0.52 (0.35)	0.35 (0.28)
Best-corrected visual acuity	0.98 (0.14)	0.98 (0.13)	0.97 (0.11)	0.9 (0.21)	0.69 (0.27)

Values are mean (standard deviation).

Table 2. Contrast Sensitivity at the Nighttime and Daytime Without Glare According to the Functional Acuity Contrast Test by Age Groups

Contrast Sensitivity	Age Groups, Years				
	30–39	40–49	50–59	60–70	71–85
At nighttime at different spatial frequencies, cycles per degree					
1.5	81.8 (20.6)	73.4 (26.9)	69.4 (23.2)	68.2 (36.4)	26.7 (25.2)†
3	100.8 (45.6)	88.4 (50.3)*	85.3 (41.1)	80.4 (53.9)	25.3 (23.4)†
6	75.8 (42.1)	74.9 (48.6)	72.8 (46.5)	57.7 (51.3)	8.2 (6.8)†
12	28.8 (14.2)	23.9 (20.3)*	22.5 (14.0)	15.2 (13.7)	2.3 (2.3)†
18	16.1 (15.1)	10.4 (7.1)*	9.02 (6.2)	6.3 (6.2)	1.6 (1.2)†
At daytime at different spatial frequencies, cycles per degree					
1.5	71.9 (22.8)	66.0 (26.0)	64.0 (22.9)	61.2 (30.6)	31.5 (28.8)†
3	106.5 (39.2)	104.7 (44.6)	97.4 (40.8)	90.4 (50.8)	38.4 (38.6)†
6	111.0 (42.7)	106.5 (56.7)	96.9 (53.7)‡	82.6 (55.8)	22.4 (20.4)†
12	45.5 (23.5)	45.3 (30.9)	37.8 (34.9)‡	30.2 (29.3)	6.3 (6.1)†
18	24.0 (16.2)	20.0 (17.3)	16.7 (9.2)	12.2 (5.3)	1.2 (1.1)†

Values are mean (standard deviation).

* $P < 0.05$ as compared with the 30–39-year age group. ‡ $P < 0.05$ as compared with the 40–49-year age group.

† $P < 0.05$ as compared with the 60–70-year age group.

Table 3. Contrast Sensitivity at the Nighttime and Daytime With Glare According to the Functional Acuity Contrast Test by Age Groups

Contrast Sensitivity	Age Groups, Years				
	30–39	40–49	50–59	60–70	71–85
At nighttime at different spatial frequencies, cycles per degree					
1.5	77.7 (23.8)	68.8 (27.6)*	66.9 (30.1)	61.3 (33.2)	26.6 (24.2)†
3	95.3 (43.8)	91.8 (48.5)	79.9 (49.0)‡	74.5 (53.3)	24.5 (24.7)†
6	69.0 (32.5)	64.0 (52.8)	62.6 (49.3)	45.7 (37.5)	7.2 (4.3)†
12	25.2 (16.8)	22.2 (17.5)*	18.8 (6.0)	10.3 (7.1)	2.2 (1.6)†
18	10.8 (9.6)	6.7 (3.7)*	5.9 (4.9)	2.2 (2.1)	0.4 (0.3)†
At daytime at different spatial frequencies, cycles per degree					
1.5	84.3 (19.8)	74.6 (29.2)*	72.5 (23.2)	64.4 (30.7)	31.2 (26.4)†
3	111.8 (39.9)	105.2 (47.1)	102.9 (35.4)	89.6 (51.2)	35.7 (32.3)†
6	117.6 (45.4)	111.3 (55.8)	108.7 (26.9)	83.3 (59.2)	25.4 (23.2)†
12	53.6 (26.9)	42.5 (36.4)*	41.8 (35.9)	31.2 (23.4)	4.1 (4.2)†
18	25.3 (19.3)	18.4 (18.4)*	16.3 (13.1)	14.5 (8.1)	2.2 (2.1)†

Values are mean (standard deviation).

* $P < 0.05$ as compared with the 30–39-year age group. ‡ $P < 0.05$ as compared with the 40–49-year age group.

† $P < 0.05$ as compared with the 60–70-year age group.

worse in the group 2 at the spatial frequencies of 3, 12, and 18 cycles per degree ($P=0.001$, $P=0.05$, and $P=0.01$, respectively) (Table 2). At the daytime without glare, no significant differences in contrast sensitivity between the groups 1 and 2 were documented at all spatial frequencies. Similar comparisons of contrast sensitivity at the nighttime and daytime with glare revealed that the patients in the group 2 had significantly worse contrast sensitivity at the spatial frequencies of 1.5, 12, and 18 cycles per degree ($P=0.054$, $P=0.04$, and $P=0.01$ and $P=0.011$, $P=0.031$, and $P=0.011$, respectively) (Table 3).

The comparison of contrast sensitivity between the groups 2 and 3 showed significant differences at the nighttime with glare at a spatial frequency of 3 cycles per degree ($P=0.001$) and at the daytime without glare at the spatial frequencies of 6 and 12 cycles per degree (both $P=0.05$) (Tables 2 and 3).

The greatest differences in contrast sensitivity were observed comparing the groups 4 and 5 (Ta-

bles 2 and 3). Contrast sensitivity was 2 to 4 times better in the group 4, i.e., younger group, than the group 5. All the differences in contrast sensitivity at the nighttime and daytime with and without glare were significant.

Discussion

It has been reported that a decrease in contrast sensitivity is directly associated with patients' age and visual acuity. The FACT is a very sensitive method used for the evaluation of the visual system and may help detect the onset of the disease even when visual acuity is still intact. This examination method also allows observing changes in the disease, such as progression or recovery. In some countries, the FACT is used to diagnose visual disability.

There are many studies (2, 7–13) analyzing age-related changes in contrast sensitivity, but to our knowledge, age-related changes in contrast sensitivity with and without glare in the Lithuanian popula-

tion by the different age groups have been evaluated for the first time. Our study showed that contrast sensitivity in the 40–49-year age group decreased at high spatial frequencies as well; it remained very similar in the age groups of 40–49 and 50–59 years and was much worse in the oldest group, i.e., patients aged 71–85 years. Our results are in agreement with those of the study performed by Owsley et al. (2). This study revealed that contrast sensitivity began decreasing at the age of 40 to 50 at higher spatial frequencies (2). Shahina et al. carried out a study of younger and older patients' groups and reported that contrast sensitivity decreased with older age, too (7). Nio et al. examined 100 healthy persons aged 20 to 69 years and confirmed that contrast sensitivity showed age-related changes at a spatial frequency of 8 cycles per degree (9). A Japanese study evaluated contrast sensitivity in a group of patients aged 40 to 79 years, whose visual acuity was 1.0 or better, and reported that 9.4% of the patients with intact visual acuity had lower contrast sensitivity (9). Hohberger et al. confirmed a significant relationship between age and a decrease in contrast sensitivity (10). Crassini et al. examined groups of younger persons (mean age, 20.4 years) and older persons (mean age, 64.4 years) when visual acuity and the visual system function were intact (11). The study results suggested that the contrast sensitivity of younger persons was better compared with older persons, but only at high spatial frequencies (11). Our results are also in agreement with those of the study by Robert et al., who investigated FACT changes in 2 groups of healthy persons: a younger group with a mean age of 18.5 years and an older group with a mean age of 73 years (12). The authors demonstrated that contrast sensitivity at low and medium spatial frequencies was 3 times better in the group of younger patients than in the group of older patients (12). Greene et al. investigated the relationship between aging and visual acuity as well as between aging and contrast sensitivity (13). The authors examined a group of young persons (mean age, 19.5 years) and a group of older persons (mean age, 68.4 years) and showed that contrast sensitivity significantly decreased in the group of older patients (13). Such results imply that the FACT is useful when evaluating age-related changes in the visual system (13). Ross et al. evaluated 2 age groups: one with participants aged 20 to

30 years and the other with participants aged 50 to 87 years (8). Older observers had reduced contrast sensitivity at all spatial frequencies when compared with their younger counterparts. This was particularly obvious at medium and high spatial frequencies. In the age range 50 to 87 years, there was a linear decline in contrast sensitivity with age at medium and high spatial frequencies. Within this age range, the responses to low spatial frequencies appeared to be independent of age (8). Our results are in disagreement with those of the study by Ross et al., because our results revealed that the FACT results were worse at low spatial frequencies (1.5 cycles per degree) in the younger age groups and in the oldest age group, especially, when we evaluated contrast sensitivity in the nighttime and daytime with glare, but when contrast sensitivity without glare was evaluated, only one statistically significant result at a medium spatial frequency was found, i.e., in the nighttime without glare, the results were worse in 40–49-year age group at a spatial frequency of 3 cycles per degree. Deterioration of contrast sensitivity at medium spatial frequencies may be due to an impact of glare at younger age and due to lens opacities at older age (14). Rouhiainen et al. have reported a significant association between contrast sensitivity and lens opacification at low and medium frequencies in posterior subcapsular opacities (14). Therefore, it seems likely that cataract (cortical or posterior subcapsular) should be primarily responsible for the trend of decreasing contrast sensitivity with age in subjects with good visual acuity (14). It has also been determined that glare reduces contrast sensitivity in older persons, especially the ones who are diagnosed with cataract (15). The study by Hohberger et al. also proved a close relationship between decreasing contrast sensitivity and age and contributed to the existing knowledge by determining and describing the influence of cataract on decreasing contrast sensitivity (10).

Conclusions

Contrast sensitivity decreased with age, and it is attributed to age-related changes in the optical system.

Statement of Conflict of Interest

The authors state no conflict of interest.

References

1. Sekuler R, Sekuler AB. Age-related changes, optical factors, and neural processes. In: Kazdin AE, editor. *Encyclopedia of Psychology* American Psychological Association. Oxford: Oxford University Press; 2000. Vol. 8. p. 180–3.
2. Owsley C, Sekuler R, Siemsen D. Contrast sensitivity throughout adulthood. *Vision Res* 1983;23:689–99.
3. Abratis R, Cibas P, Gronow G, Gutmanas A, Illert M, Hultborn H, et al. *Žmogaus fiziologija*. (Human physiology.) Kaunas: KMU; 1999. p. 87–8.
4. Ginsburg AP. Contrast sensitivity and functional vision. *Int Ophthalmol Clin* 2003;43:5–16.
5. Žaliūnienė D, Glebauskienė B, Liutkevičienė R, Špečkauskas M. The comparison of visual acuity and contrast sensitivity in patients with cataract and age-related macular degeneration implanted with foldable or rigid intraocular lenses.

- Medicina (Kaunas) 2006;42:975-82.
6. Ginsburg AP. Contrast sensitivity: determining the visual quality and function of cataract, intraocular lenses and refractive surgery. *Curr Opin Ophthalmol* 2006;17:19-26.
 7. Shahina P. Contrast sensitivity loss with aging: sampling efficiency and equivalent noise at different spatial frequencies. *J Opt Soc Am A Opt Image Sci Vis* 2004;21:169-75.
 8. Ross JE, Clarke DD, Bron AJ. Effect of age on contrast sensitivity function: uniocular and binocular findings. *Br J Ophthalmol* 1985;69:51-6.
 9. Nio YK, Jansonius NM, Fidler V, Geraghty Enorby S, Kooijman AC. Age-related changes of defocus-specific contrast sensitivity in healthy subjects. *Ophthalmic Physiol Optics* 2000;20:323-34.
 10. Hohberger B, Laemmer R, Adler W, Juenemann AG, Folkert K, Horn FK. Measuring contrast sensitivity in normal subjects with OPTEC 6500: influence of age and glare. *Graefes Arch Clin Exp Ophthalmol* 2007;245:1805-14.
 11. Crassini B, Brown B, Bowman K. Age-related changes in contrast sensitivity in central and peripheral retina. *Perception* 1988;17:315-32.
 12. Robert S, Picciano LH. Spatial vision and aging. I: Contrast sensitivity. *J Gerontol* 1980;35(5):692-9.
 13. Greene HA, Madden DJ. Adult age differences in visual acuity, stereopsis, and contrast sensitivity. *Am J Optom Physiol Opt* 1987;64:749-53.
 14. Rouhiainen P, Rouhiainen H, Salonen JT. Contrast sensitivity in different types of early lens opacities. *Acta Ophthalmol Scand* 1996;74:379-83.
 15. Aslam TM, Haider D, Murray IJ. Principles of disability glare measurement: an ophthalmological perspective. *Acta Ophthalmol Scand* 2007;85:354-60.

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