Age-related Change in Contrast Sensitivity Among Japanese Adults

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Purpose: To evaluate the age-related change in contrast sensitivity seen in a middle-aged to elderly Japanese population.

Methods: Contrast sensitivity and visual acuity were measured in subjects aged 40 to 79 years randomly recruited from a community in Aichi prefecture near Nagoya, Japan. Contrast sensitivity tests were performed using the Vistech contrast sensitivity test chart (VCTS 6500). The results were statistically analyzed relative to age.

Results: A statistically significant decrease in contrast sensitivity was seen with advancing age at each spatial frequency (Cochran-Mantel-Haenszel: $P < .001$). This trend was detected even when the subjects were limited to only those having a corrected visual acuity of 1.0 or better (Cochran-Mantel-Haenszel: $P < .001$). Overall, 9.4% of the eyes with good visual acuity had poor contrast sensitivity at a high spatial frequency, while in the 70–79-year-old group, the percentage with poor contrast sensitivity reached 21.1%.

Conclusions: The age-related decrease in contrast sensitivity was confirmed at all frequencies in our population, even when adjusted for visual acuity. Our results suggest that contrast sensitivity tests, especially at high frequencies, assess aspects of visual function that cannot be determined in the elderly population from visual acuity tests alone. **Jpn J Ophthalmol 2003;47:299–303** © 2003 Japanese Ophthalmological Society

Key Words: Adult, aging, contrast sensitivity, population-based study.

Introduction

Traditionally, visual acuity is a measure of the eye's ability to resolve small, high-contrast targets. However, by measuring only visual acuity, we can miss many visual problems because the objects in our daily life have various levels of contrast and a diverse range of sizes. It has been suggested that assessing contrast sensitivity would provide additional information about vision quality,[1] and that contrast sensitivity screening for ophthalmic disease in the elderly is more efficient than testing for visual acuity alone.[2]

Despite these advantages, the use of contrast sensitivity testing has not become prevalent. One reason may be that visual acuity testing is a basic and simple method for assessing visual function. In fact, it is well known that the results of visual acuity tests are strongly associated with contrast sensitivity and other visual function tests. Therefore, many clinical and epidemiological studies have tested only for visual acuity to assess visual function.

Although it is widely accepted that contrast sensitivity decreases with age, the accurate distribution of contrast sensitivity values according to age has not been established. This study investigated the effect of aging on visual contrast sensitivity in a large, middle-aged to elderly population, when adjustment was made for visual acuity, and demonstrates an age-related distribution pattern seen with contrast sensitivity values.

Materials and Methods

The National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA), started in 1997, is a

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population-based prospective cohort study of aging.[3] Using the NILS-LSA data, we studied the association between age and the contrast sensitivity of vision in community-dwelling participants aged 40 to 79 years randomly recruited from regions close to NILS in Aichi prefecture, near Nagoya, Japan. The study protocol was approved by the Committee on the Ethics of Human Research of National Chubu Hospital and NILS, with written informed consent obtained from each subject.

In the present study, we analyzed the baseline data of NILS-LSA obtained from March 1997 to April 2000. During this period, 2267 people (1136 men and 1131 women) participated in the NILS-LSA. Eyes with a previous history of cataract surgery and those without contrast sensitivity data were excluded. Therefore, data from 4344 eyes were included in the present study.

Distant visual acuity was measured for each eye initially by presenting correction at 5 meters. If the participant was unable to read the target at the 1.0 equivalent line, best-corrected visual acuity testing was performed following optimal refraction. Contrast sensitivity was measured for each eye using the Vistech contrast sensitivity test chart (VCTS 6500; Vistech Consultants, Dayton, OH, USA) at 3 meters, making any necessary correction for distance vision. The Vistech chart consists of 45 circular targets arranged in five rows and nine columns. Each target contains a sine-wave contrast grating, and each row has a different spatial frequency (1.5 cycles per degree [cpd], 3 cpd, 6 cpd, 12 cpd, and 18 cpd) with the contrast decreasing across the columns. The gratings are either vertical or tilted $\pm 15°$ from vertical. At each spatial frequency the final reliable contrast value was adopted as the contrast sensitivity for each participant. Over the VCTS 6500 chart, the illumination was standardized with the illumination meter supplied with the Vistech test (390 lux at center). In the present study, the contrast sensitivity was counted as zero when it was impossible to identify the highest contrast target for each frequency.

For analysis, the participants were divided into four age groups: 40–49, 50–59, 60–69, and 70–79 years. We used theCochran-Mantel-Haenszel chi-square tests to assess the relationship between contrast sensitivity and age at each frequency. Data were analyzed using the Statistical Analysis System release 6.12. A probability value of $<.05$ was considered statistically significant.

Results

A statistically significant decrease in contrast sensitivity was detected with advancing age at each spatial frequency (Cochran-Mantel-Haenszel: $P < .001$) (Table 1). A portion of all the eyes (21.0%) had zero contrast sensitivity at the highest frequency (18 cpd), and 42.8% of the eyes from the oldest age group (70–79 years) were unable to identify the highest contrast target at 18 cpd.

Table 2 shows the distribution of contrast sensitivity for eyes that had a corrected visual acuity of 1.0 or better. It was also shown that the oldest age group had lower contrast sensitivities at each frequency (Cochran-Mantel-Haenszel: $P < .001$). Despite having good visual acuity, 9.4% of all eyes had zero contrast sensitivity at the highest frequency (18 cpd). In the 70–79 year age group, 21.1% of the eyes had a zero value at 18 cpd.

Discussion

Our report on the distribution of visual contrast sensitivity within a large Japanese population confirmed the generally accepted trend for contrast sensitivity to decrease with advancing age. Interestingly, this trend was detected even when data were limited to subjects having a corrected visual acuity of 1.0 or better. In the 70–79 year age group, particularly, 21.1% of the subjects with good visual acuity had zero contrast sensitivity at 18 cpd.

It is known that certain visual problems, such as cataracts and glaucoma, may affect the eye's contrast sensitivity, with cataracts being the most common cause of decreased contrast sensitivity in middle-aged and elderly populations. Rouhiainen et al.[4] have reported that a significant association between contrast sensitivity and lens opacification was seen at high spatial frequencies in cortical opacities and at low and medium frequencies in posterior subcapsular opacities; when adjusted for age and visual acuity, however, nuclear opacification did not impair contrast sensitivity. Therefore, it seems likely that cataracts (cortical or posterior subcapsular) should be primarily responsible for the trend of decreased contrast sensitivity with age in our subjects with good visual acuity.

There are some limitations in the present study. The reliability of Vistech VCTS 6500 has been reported to be uncertain,[5] and we have not had the opportunity to examine this question within the population of the present study. However, there are some advantages in using the Vistech chart for testing large populations, in that testing requires only a few minutes and, therefore, is not taxing for cognitively impaired or elderly participants. In addition, the large number of subjects in the NILS-LSA contributes to the general applicability of our results.

It has been widely accepted that a corrected visual acuity of 1.0 or better is considered normal. In the present study, therefore, good visual acuity was defined as a corrected visual acuity of 1.0 or better regardless of

Table 1. Distribution (Percentile) of Contrast Sensitivity in all Eyes

Frequency*	Contrast Sensitivity									Value of Chi-square(df = 1)†
1.5 (cpd)	0	3	7	12	20	35	70	120	170	
40–49 (y) (n = 1128)	0 (0.0)	12 (0.2)	0 (0.0)	3 (0.3)	204 (18.1)	664 (58.9)	228 (20.2)	21 (1.9)	6 (0.5)	
50–59 (y) (n = 1123)	2 (0.2)	1 (0.1)	0 (0.0)	6 (0.5)	276 (24.6)	643 (57.3)	184 (16.4)	9 (0.8)	2 (0.2)	266.4
60–69 (y) (n = 1102)	3 (0.3)	3 (0.3)	2 (0.2)	13 (1.2)	397 (36.0)	557 (50.5)	114 (10.3)	13 (1.2)	0 (0.0)	$p < .001$
70–79 (y) (n = 991)	7 (0.7)	12 (1.2)	6 (0.6)	45 (4.5)	474 (47.8)	377 (38.0)	67 (6.8)	3 (0.3)	0 (0.0)	
Total (n = 4344)	12 (0.3)	18 (0.4)	8 (0.2)	67 (1.5)	1351 (31.1)	2241 (51.6)	593 (13.7)	46 (1.1)	8 (0.2)	
3 (cpd)	0	4	9	15	24	44	85	170	220	
40–49 (y) (n = 1128)	1 (0.1)	0 (0.0)	1 (0.1)	2 (0.2)	20 (1.8)	323 (28.6)	649 (57.5)	126 (11.2)	6 (0.5)	
50–59 (y) (n = 1123)	2 (0.2)	1 (0.1)	1 (0.1)	5 (0.5)	40 (3.6)	393 (35.0)	592 (52.7)	88 (7.8)	1 (0.1)	299.7
60–69 (y) (n = 1102)	3 (0.3)	1 (0.1)	2 (0.2)	6 (0.5)	64 (5.8)	500 (45.4)	445 (40.4)	77 (7.0)	4 (0.4)	$p < .001$
70–79 (y) (n = 991)	9 (0.9)	9 (0.9)	9 (0.9)	23 (2.3)	123 (12.4)	521 (52.6)	268 (27.0)	25 (2.5)	4 (0.4)	
Total (n = 4344)	15 (0.4)	11 (0.3)	13 (0.3)	36 (0.8)	247 (5.7)	1737 (40.0)	1954 (45.0)	316 (7.3)	15 (0.4)	
6 (cpd)	0	5	11	21	45	70	125	185	260	
40–49 (y) (n = 1128)	1 (0.1)	4 (0.4)	7 (0.6)	58 (5.1)	305 (27.0)	265 (23.5)	403 (35.7)	77 (6.8)	8 (0.7)	
50–59 (y) (n = 1123)	2 (0.2)	1 (0.1)	18 (1.6)	78 (7.0)	341 (30.4)	264 (23.5)	335 (29.8)	78 (7.0)	6 (0.5)	526.4
60–69 (y) (n = 1102)	3 (0.3)	5 (0.5)	59 (5.4)	134 (12.2)	432 (39.2)	199 (18.1)	219 (19.9)	47 (4.3)	4 (0.4)	$p < .001$
70–79 (y) (n = 991)	24 (2.4)	30 (3.0)	96 (9.7)	216 (21.8)	425 (42.9)	119 (12.0)	71 (7.2)	9 (0.9)	1 (0.1)	
Total (n = 4344)	30 (0.7)	40 (0.9)	180 (4.1)	486 (11.2)	1503 (34.6)	847 (19.5)	1028 (23.7)	211 (4.9)	19 (0.4)	
12 (cpd)	0	5	8	15	32	55	88	125	170	
40–49 (y) (n = 1128)	8 (0.7)	15 (1.3)	100 (8.9)	182 (16.1)	243 (21.5)	232 (20.6)	278 (24.7)	64 (5.7)	6 (0.5)	
50–59 (y) (n = 1123)	13 (1.2)	28 (2.5)	110 (9.8)	199 (17.7)	223 (19.9)	203 (18.1)	298 (26.5)	44 (3.9)	5 (0.5)	593.3
60–69 (y) (n = 1102)	36 (3.3)	45 (4.1)	192 (17.4)	267 (24.2)	242 (22.0)	158 (14.3)	135 (12.3)	27 (2.5)	0 (0.0)	$p < .001$
70–79 (y) (n = 991)	129 (13.0)	101 (10.2)	274 (27.7)	227 (22.9)	159 (16.0)	66 (6.7)	29 (2.9)	5 (0.5)	1 (0.1)	
Total (n = 4344)	186 (4.3)	189 (4.4)	676 (15.6)	875 (20.1)	867 (20.0)	659 (15.2)	740 (17.0)	140 (3.2)	12 (0.3)	
18(cpd)	0	4	7	10	15	26	40	65	90	
40–49 (y) (n = 1128)	112 (9.9)	75 (6.7)	76 (6.7)	249 (22.1)	269 (23.9)	213 (18.9)	117 (10.4)	17 (1.5)	0 (0.0)	
50–59 (y) (n = 1123)	129 (11.5)	81 (7.2)	90 (8.0)	237 (21.1)	248 (22.1)	206 (18.3)	124 (11.0)	8 (0.7)	0 (0.0)	526.6
60–69 (y) (n = 1102)	245 (22.2)	139 (12.6)	102 (9.3)	263 (23.9)	188 (17.1)	110 (10.0)	48 (4.4)	7 (0.6)	0 (0.0)	$p < .001$
70–79 (y) (n = 991)	424 (42.8)	183 (18.5)	96 (9.7)	169 (17.1)	77 (7.8)	31 (3.1)	9 (0.9)	2 (0.2)	0 (0.0)	
Total (n = 4344)	910 (21.0)	478 (11.0)	364 (8.4)	918 (21.1)	782 (18.0)	560 (12.9)	298 (6.9)	34 (0.8)	0 (0.0)	

*cpd: cycles per degree.
†Relationship between contrast sensitivity and age was assessed using Cochran-Mantel-Haenszel Statistics for 4 by 9 table at each frequency.

Table 2. Distribution (Percentile) of Contrast Sensitivity in the Eyes with Good Visual Acuity (≥1.0)

Frequency*	Contrast Sensitivity									Value of Chi-square(df = 1)*†
1.5 (cpd)	0	3	7	12	20	35	70	120	170	
40–49 (y) (n = 1011)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	172 (17.0)	604 (59.7)	210 (20.8)	19 (1.9)	6 (0.6)	
50–59 (y) (n = 904)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	195 (21.6)	534 (59.1)	165 (18.3)	8 (0.9)	2 (0.2)	67.1
60–69 (y) (n = 668)	0 (0.0)	1 (0.2)	1 (0.2)	1 (0.2)	195 (29.2)	377 (56.4)	81 (12.1)	12 (1.8)	0 (0.0)	$p < .001$
70–79 (y) (n = 370)	0 (0.0)	0 (0.0)	0 (0.0)	3 (0.8)	134 (36.2)	192 (51.9)	40 (10.8)	1 (0.3)	0 (0.0)	
Total (n = 2953)	0 (0.0)	1 (0.0)	1 (0.0)	4 (0.1)	696 (23.6)	1707 (57.8)	496 (16.8)	40 (1.4)	8 (0.3)	
3 (cpd)	0	4	9	15	24	44	85	170	220	
40–49 (y) (n = 1011)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.1)	12 (1.2)	273 (27.0)	599 (59.3)	120 (11.9)	6 (0.6)	
50–59 (y) (n = 904)	0 (0.0)	0 (0.0)	1 (0.1)	2 (0.2)	19 (2.1)	288 (31.9)	512 (56.6)	81 (9.0)	1 (0.1)	65.0
60–69 (y) (n = 668)	0 (0.0)	0 (0.0)	1 (0.2)	2 (0.3)	13 (2.0)	269 (40.3)	315 (47.2)	64 (9.6)	4 (0.6)	$p < .001$
70–79 (y) (n = 370)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	12 (3.2)	189 (51.1)	154 (41.6)	14 (3.8)	1 (0.3)	
Total (n = 2953)	0 (0.0)	0 (0.0)	2 (0.1)	5 (0.2)	56 (1.9)	1019 (34.5)	1580 (53.5)	279 (9.5)	12 (0.4)	
6 (cpd)	0	5	11	21	45	70	125	185	260	
40–49 (y) (n = 1011)	0 (0.0)	2 (0.2)	3 (0.3)	33 (3.3)	256 (25.3)	247 (24.4)	388 (38.4)	74 (7.3)	8 (0.8)	
50–59 (y) (n = 904)	0 (0.0)	0 (0.0)	6 (0.7)	34 (3.8)	248 (27.4)	230 (25.4)	308 (34.1)	72 (8.0)	6 (0.7)	122.7
60–69 (y) (n = 668)	0 (0.0)	1 (0.2)	10 (1.5)	46 (6.9)	234 (35.0)	146 (21.9)	182 (27.3)	45 (6.7)	4 (0.6)	$p < .001$
70–79 (y) (n = 370)	0 (0.0)	0 (0.0)	6 (1.6)	39 (10.5)	197 (53.2)	70 (18.9)	51 (13.8)	6 (1.6)	1 (0.3)	
Total (n = 2953)	0 (0.0)	3 (0.1)	25 (0.9)	152 (5.2)	935 (31.7)	693 (23.5)	929 (31.5)	197 (6.7)	19 (0.6)	
12 (cpd)	0	5	8	15	32	55	88	125	170	
40–49 (y) (n = 1011)	1 (0.1)	7 (0.7)	67 (6.6)	152 (15.0)	221 (21.9)	222 (22.0)	271 (26.8)	64 (6.3)	6 (0.6)	
50–59 (y) (n = 904)	3 (0.3)	9 (1.0)	64 (7.1)	130 (14.4)	186 (20.6)	182 (20.1)	283 (31.3)	42 (4.7)	5 (0.6)	159.5
60–69 (y) (n = 668)	6 (0.9)	9 (1.4)	67 (10.0)	143 (21.4)	174 (26.1)	127 (19.0)	117 (17.5)	25 (3.7)	0 (0.0)	$p < .001$
70–79 (y) (n = 370)	2 (0.5)	15 (4.1)	89 (24.1)	88 (23.8)	98 (26.5)	46 (12.4)	26 (7.0)	5 (1.4)	1 (0.3)	
Total (n = 2953)	12 (0.4)	40 (1.4)	287 (9.7)	513 (17.4)	679 (23.0)	577 (19.5)	697 (23.6)	136 (4.6)	12 (0.4)	
18 (cpd)	0	4	7	10	15	26	40	65	90	
40–49 (y) (n = 1011)	69 (6.8)	58 (5.7)	63 (6.2)	228 (22.6)	254 (25.1)	206 (20.4)	116 (11.5)	17 (1.7)	0 (0.0)	
50–59 (y) (n = 904)	58 (6.4)	53 (5.9)	61 (6.8)	191 (21.1)	218 (24.1)	197 (21.8)	118 (13.1)	8 (0.9)	0 (0.0)	132.9
60–69 (y) (n = 668)	73 (10.9)	70 (10.5)	64 (9.6)	163 (24.4)	151 (22.6)	97 (14.5)	43 (6.4)	7 (1.1)	0 (0.0)	$p < .001$
70–79 (y) (n = 370)	78 (21.1)	59 (16.0)	49 (13.2)	95 (25.7)	52 (14.1)	27 (7.3)	8 (2.2)	2 (0.5)	0 (0.0)	
Total (n = 2953)	278 (9.4)	240 (8.1)	237 (8.0)	677 (22.9)	675 (22.9)	527 (17.9)	285 (9.7)	34 (1.2)	0 (0.0)	

*cpd: cycles per degree.
†Relationship between contrast sensitivity and age was assessed using Cochran-Mantel-Haenszel Statistics for 4 by 9 table at each frequency.

age group. However, it seems likely that there was some difference in distribution of visual acuity among age groups even in the subjects with good visual acuity, because some subjects with visual acuity of 1.0 or better should have various degrees of cataract. In the NILS-LSA, the distribution of visual acuity of 1.0 or better and the estimation of cataract were not well investigated. It is possible that this also affected our results.

The traditional test for visual acuity examines only high contrast, high frequency sensitivity, using high contrast black on white letters. Testing only for visual acuity when assessing visual function may be inadequate because objects in daily life vary in levels of contrast and range of size under various lighting conditions. In particular, within the middle-aged to elderly population, pathological problems, such as presbyopia and decreasing transparency of media, will degrade their visual condition. Contrast sensitivity measures two variables, size and contrast, while visual acuity measures only size; therefore, contrast sensitivity tests provide additional information about vision.

Our report on the distribution of contrast sensitivity in a middle-aged to elderly population demonstrates that there is an age-related decrease in contrast sensitivity at all frequencies. It was also shown that 9.4% of the eyes having good visual acuity (1.0 or better) had poor contrast sensitivity at a high frequency, especially in the 70–79 year group where 21.1% of eyes had poor contrast sensitivity. In addition, our results showed that the distribution of contrast sensitivity at the higher frequencies was wider than that at the lower frequencies. Therefore, our results suggest that contrast sensitivity tests can assess different aspects of visual function that visual acuity tests alone do not address, especially at high frequencies. We believe that contrast sensitivity should also be measured when assessing the visual function of middle-aged or elderly populations for a complete assessment of visual quality.

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