J. Korean Oph. Opt. Soc.
Vol. 16, No. 3, pp. 307-312, September 2011

Distribution of Color Vision Deficiencies by Age in Some Area of Kyeonggi-Do

Eun-Hee lee, Sung-il Cho* and Domyung Paek*

Department of Visual Optics, Far East University
*Graduate School of Public Health, Seoul National University
(Received July 22, 2011: Revised August 22, 2011: Accepted September 17, 2011)

Purpose: To investigate the prevalence of congenital and age-related color vision deficiencies over a wide range of ages among residents in two urban communities of Kyeonggi-Do. **Methods:** A total of 935 subjects, consisting of 452 males and 483 females, participated in this study. Lanthony D-15 desaturated panels test were used to assess color vision. **Results:** Prevalence of color vision deficiency was 4.81% for total, 6.64% for males and 3.11% for females. Congenital color vision deficiency was 3.54% for males and 0.41% for females. Tritan deficiency, which was the post-natal age-related, was 2.99% (3.32% for males, and 2.69% for females). **Conclusions:** The result imply that color vision deficiencies is influenced by age. As an age-related color vision deficiencies, Tritan is most frequently found in the age group over 50.

Key words: Age, Color vision deficiency, Prevalence, Tritan

Introduction

The eye is one of the most important organs in humans. Some people see colors differently or mistakenly identify colors, and color vision deficiencies are classified as either congenital or acquired. Color vision in humans relies on three different cone types, trichromacy, in the retina: long- (L), middle- (M), and short- (S) wavelength-sensitive cones. The L and M cones are especially important in congenital color vision deficiencies, which are classified as either protan, deutan, or tritan. Approximately 25% of congenital color vision deficiency cases result from the absences of either L cones or M cones, which are referred to as protoanopia and deuteranopia, respectively. In about 75% of congenital color vision deficiency cases, either the L cones or M cones have decreased spectral sensitivity. These conditions are called protanomaly and deuteranomaly, respectively. A Tritan deficiency is caused by the absence or altered spectral sensitivity of S cones but is extremely rare, representing approximately 0.005% of congenital color deficiency cases[1,2].

In contrast to congenital deficiencies, tritan deficiencies represent the majority of acquired color deficiencies, although in some congenital cases, red-green or blue-yellow and red-green impairments do occur[3]. Acquired color vision deficiencies have been associated with brain trauma, disease, exposure to toxic materials such as solvents, and aging. The significant, positive correlation between acquired deficiencies and aging results directly from age-related changes in lens opacity and secondarily from macular degeneration[1,4,5], and changes in the ocular media caused by prolonged exposure to light[6].

The genes for the red and green cone receptors are X-linked. As a result, color vision impairments do not manifest in heterozygous females and are more prevalent in males. In European studies, about 8% of males and 0.4% of females in the general population have a red-green deficiency[7,8]. In Koreans, congenital color vision deficiency reportedly occurs in about 5.9% of males and 0.44% of females[9].

The macular pigmentation of Asians and Caucasians are different from each other and can lead to different color discrimination[10]. Knowing the prevalence of color vision

Corresponding Author Address: Eun-Hee Lee, 369-700, Department of Visual optics, Far East University, Wanggang-ri, Gamgok-myeon, Eumseong-gun, Chungbuk, Korea
TEL: 043-879-3701, **FAX:** 043-879-3730, **E-mail:** ehlee@kdu.ac.kr

deficiencies in a population is important, but this requires accurate, specific color vision standards[11]. The main purpose of the present study was to examine the prevalence rates of congenital and age-related color vision deficiencies across a wide range of ages among general population in an urban communities of Kyeonggi-Do.

Materilas and Methods

1. Subjects

A community health survey was conducted during a 3-week period in Siwha & Banwoul area, KyeongGi-Do.

The purpose of the survey was explained in town-hall meetings with local government officers, and convenience sampling was conducted to recruit the first 1,000 participants. Consents were obtained from either participants themselves or their guardians.

Initially, 991 subjects enrolled in the study. 56 of those were excluded from study with hypertension or diabetes mellitus or encephalopathy and eye disease associated lenticular opacity, cataract, and optic nerve pathology due to associated glaucoma through questionnaire. A total of 935 subjects, consisting of 452 males and 483 females ranging in age from 7 to 78 years, were finally included in the study.

2. Color vision testing

Color vision was assessed by the Lanthony D-15 desaturated panel by monocular. The test panel consisted of 15 movable color caps with one fixed reference cap. The subjects were instructed to put the movable caps of the most similar colors next to each other starting from the fixed cap. The color vision test was performed under 1150 lux of illumination (Osram 200W/11-860, color temperature 6000K) over 30 cm on the desk in indoor, similar to daylight. Quantitative evaluation for color vision loss was estimated with the color confusion index (CCI) developed by Bowman[4,12]. The CCI was calculated by dividing the total color vision score (TCVS) of each individual, which was the sum of the color differences using the total color distance score, by a perfect score. A CCI of 1.0 indicated normal color vision, and an increased CCI indicated color vision impairment. In the qualitative analysis, color vision impairments were divided into four types: Protan, Duetan, Tritan, and Unclassified (Complex) color vision loss.

3. Statistical analysis

The data were analyzed using SAS version 9.01. The χ^2 were used to compare the distribution of variables in relation to color vision loss. Especially, Mantel-Haenszel χ^2-test were used to compare the distribution of variables for trend like age. For continuous variables, our results were expressed as the mean (±SD) of the data. The CCI was evaluated with a nonparametric Mann-Whitney U-test and Kruskal-Wallis test due to a skewed distribution.

Results

The study population had an overall average age of 31.5 ± 17.7 years. Their age range was 7 to 78 years. The 10-19, 30-39, and 40-49-year-old age groups contained the highest numbers of subjects (Table 1).

The average CCI was 1.08±0.21. The CCI showed slightly U-shape by age. Table 2 show a dramatic trend for females < 10, 10-29, and then again different for over 50 years old. For males this difference is not as apparent until over 60 years old.

Color vision deficiencies were seen in 45 (4.81%) total subjects, 30 (6.64%) males and 15 (3.11%) females in both eyes. Congenital color deficiencies, including protan, deutan and unclassified or complex, were significantly more prevalent in males (16, 3.54%) than in females (2, 0.41%) on examination (Table 3). The self-reported prevalence rates of congenital color deficiency were 14 (3.10%) for males and 1 (0.21%) for females. Only red-green deficiency was

Table 1. Number and percentage of male and female subjects by age

Age*	Male N(%)	Female N(%)	Total N(%)
<10	59(13.05)	30(6.21)	89(9.52)
10-19	145(32.08)	114(23.60)	259(27.70)
20-29	14(3.10)	33(6.83)	47(5.03)
30-39	65(14.38)	129(26.71)	194(20.75)
40-49	118(26.11)	111(22.98)	229(24.49)
50-59	17(3.76)	27(5.59)	44(4.71)
60-69	25(5.53)	27(5.59)	52(5.56)
≥70	9(1.99)	12(2.48)	21(2.25)
Total	452(100)	483(100)	935(100)
Mean±SD	29.7±18.4	33.2±16.9	31.5±17.7

*p<0.005 by Mantel-Haenszel test for trend

Table 2. Color confusion index values according to age

	Age (years)							
	<10	10-19	20-29	30-39	40-49	50-59	60-69	≥70
Male*	1.06 (.07)	1.08 (.27)	1.05 (.04)	1.07 (.29)	1.11 (.33)	1.13 (.20)	1.20 (.31)	1.40 (.53)
Female*	1.09 (.16)	1.04 (.07)	1.03 (.05)	1.05 (.17)	1.04 (.05)	1.11 (.11)	1.14 (.23)	1.09 (.07)
Total*	1.07 (.11)	1.06 (.21)	1.04 (.04)	1.06 (.21)	1.08 (.24)	1.12 (.15)	1.17 (.27)	1.22 (.37)

*$p < 0.0001$ by the Kruskal-Wallis test. Unit: Mean(SD).

Table 3. Qualitative results in males and females

Type	Male	Female	Total
	N (%)	N (%)	N (%)
Total abnormal*	30 (6.64)	15 (3.11)	45 (4.81)
Protan	5 (1.11)	1 (0.21)	6 (0.64)
Deutan*	8 (1.77)	1 (0.21)	9 (0.96)
Tritan	15 (3.32)	13 (2.69)	28 (2.99)
Unclassified	4 (0.88)	1 (0.21)	6 (0.53)

*$p < 0.05$ relative to sex.

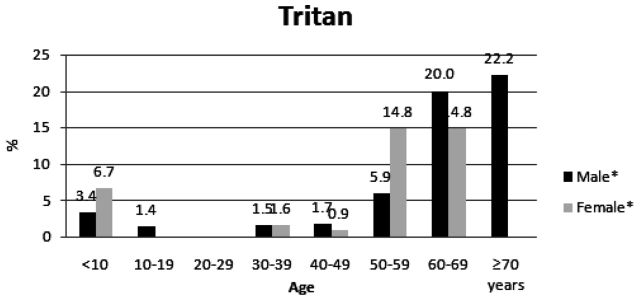

Fig. 2. Distribution of tritan deficiencies according to age and gender (unit: %). *$p < 0.001$ by Mantel-Haenzel test for trend.

present in 12 (2.65%) males and 1 (0.21%) female. One male with congenital color deficiency showed duetan in the right eye and an unclassified type in the left eye. Tritan deficiency was seen in 28 (2.99%) total subjects, including 15 (3.32%) males and 13 (2.69%) females (Table 3). The prevalence of tritan deficiencies tended to increase in the subjects of over 50 years. In actuality, tritan deficiencies were seen in 16 (13.68%) including 8 (15.69%) for male and 8 (12.12%) for female of the subjects who were 50 years or older, comparative to 12 (1.47%) of the subjects who were under 50 years.

As the distribution of congenital color vision deficiencies by age except seventies, the deficiency was mainly found in male subjects and the difference of prevalence by age was not found (Fig. 1). Fig. 2 represent prevalence of tritan deficiencies by each age group. The prevalence of age related tritan deficiencies steeply increased from subjects of in their fifties (Fig. 2).

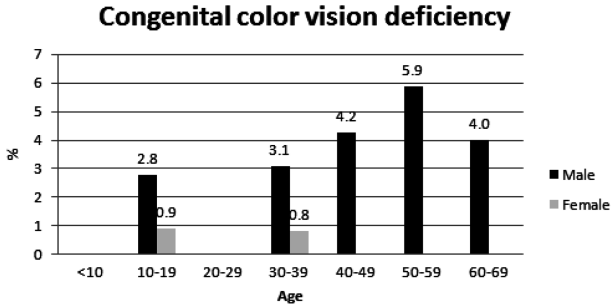

Fig. 1. Distribution of congenital color vision deficiencies (protan+duetan+unclassified) according to age (unit: %).

Discussion

The objective of this study was to investigate the prevalence of congenital and age-related color vision deficiencies among residents in Siwha & Banwoul area, KyeongGi-Do. Prevalence of color vision deficiency was 4.81% (45 out of 935 subjects), with 6.64% for males and 3.11% for females. The number of males with a congenital color deficiency was significantly larger than females (16 versus 2, 3.54% versus 0.41%) on examination. Out of them, 12 (2.65%) males and 1 (0.21%) female had only red-green deficiency.

Color vision in our study was assessed quantitatively and qualitatively with the Lanthony D-15 desaturated panel. Although the Ishihara test is widely used to screen for congenital color vision deficiency, it was not designed to detect tritan deficiencies[13]. Researchers can not identify slight color vision problems by the Fansworth-Munsell 100-hue test, but due to the large number of panel presented, this test provides detailed information about more progressed deficiencies. It is known that Fansworth D15

test is not useful for the detection of acquired color vision loss[14]. The Lanthony D-15 desaturated panel test was designed to have a high sensitivity and specificity[15] and allowed rapid and easy evaluation of mild to moderate loss in chromatic discrimination for congenital and acquired color vision deficiencies[16]. Therefore we selected Lanthony D-15 test from many color vision test methods[14].

The prevalence of color vision impairment may differ among different ethnic groups and is related to geographic latitude and cultural development[8]. Al-Aqtum et al.[17] suggested that color blindness is associated with the primitive way of life, such as rural versus urban areas. Davies et al.[18] showed that the incidence of color vision defects was higher in rural area than in urban area.

In a former study in Korea, the prevalence of congenital color deficiency was 3.15% (297 out of 9438 total study subjects), 5.9% for males and 0.44% for females[9], which was slightly higher than the one in our study. In the former Korean study, however, they used Ishihara test and the study population was middle school students in many parts of the country. So it is hard to comparison as our study. Even if studies are conducted in the same country, the results can differ because of difference in study sites, methods of color vision testing, or age range and the number of the study population. In another study ethnically similar, Singapore-based study, the reported prevalence of red-green color blindness was 5.2% for male and 0.2% for female[19].

In a study of 2058 secondary-school students of Tehran, Iran, Modarres *et al.*[20] reported that the prevalence of congenital color vision deficiencies was 8.18% for males and 0.43% for females. In a study of the Turkish army close to Iran, Citirik *et al.*[21] reported that the prevalence of red-green color blindness was 7.33±0.98% (5.10% protan and 2.23% deutan) among 941 healthy young men. The rate is lower for Turkish males than for Tehran. In a Caucasian study of 540 Inuit from East Greenland and 545 controls from East Greenland and Denmark, the prevalence of color blindness was only 1.0% (3/290) for Inuit males, which was significantly lower than the 8.7% (15/173) among Danish males of Denmark[22]. Regarding to age, young children and old aged subjects had higher error scores and more color vision defects than subjects in their twenties. The best correction score was observed among subjects in their twenties. Increases in CCI and color vision deficiency and decreases in color discrimination along with age were indicated among subjects over 50 years old. The CCI was positively and significantly correlated with age. The type of color vision deficiency that had increased with age was mostly tritan deficiency. Tritan deficiencies were observed among 13.68% of those over 50 years old, including 8 (15.69%) males and 8 (12.12%) females, compared to 1.47% of those less than 50 years old. The age-related losses of color vision may also have resulted from yellowing of the lens or degeneration[1,5] of macula with degeneration tryptophan. It is possible that they might difficult to discriminate for blue-yellow axis with troubles of short wavelength sensitive cones[23]. Moreover, it is possible that the acquired color vision defects in older subjects might have originated from hidden or early stage eye diseases including lenticular opacity, cataract, optic nerve pathology due to glaucoma and age-related macular degeneration. However, as we had screened out subjects with any histories of ocular diseases related with color vision, the color vision defects observed among older subjects most likely reflect the acquired defects without definite ophthalmic pathologies.

Other studies have shown similar results of decline in color discrimination alongwith age. Davies *et al.*[18] showed that the incidence of color vision loss increased significantly with age ($p<0.0002$). In their results, tritan errors with protan and deutan were the most frequent among African, old British, Greek, and tritan errors also increased with age. The authors suggested that the reduction in the effective intensity of blue light would result in an increased likelihood of making tritan errors, and that tritan errors among old age groups could be due to "accelerated aging".

In other study of general population, Kinnear *et al.*[24] showed that the performance on the F-M 100-hue test varied as a U-shape function of age after excluding red-green color abnormalities or defects. Younger children make significantly more misplacement errors than those in their twenties. The best performance is achieved by those in their late teens and early twenties. The test result of older adults deteriorates with age. The blue-yellow sensitivity deteriorated more steeply than the red-green sensitivity for those over 50 years old. These results support our finding that color vision deficiencies is influenced by age. Tritan is most frequently found in the age group over 50.

Acknowledgements

The study was carried out with financial support of the NIER (National Institute of Environmental Research in Korea).

References

[1] Pokorney J., Smith V. C., Verriest G., and Pinkers A. J., "Congenital and acquired color vision defects", Grune and Stratton, New York, pp. 183-242(1979).

[2] Swanson W. H. and Cohen J. M., "Color vision", Ophthalmol. Clin. North Am., 16(2):179-203(2003).

[3] Geller A. M. and Hudnell H. K., "Critical issuesin the use and analysis of the Lanthony Desaturate Color Vision test", Neurotoxicol. Teratol., 19(6):455-465(1997).

[4] Bowman K. J., "A method for quantitative scoring of the Farnsworth Panel D-15", Acta Ophthalmol.(Copenh), 60(6):907-916(1982).

[5] Campagna D., Mergler D., Huel G., Belanger S., Truchon G., Ostiguy C., and Drolet D., "Visual dysfunction among styrene-exposed worker", Scand J. Work Environ. Health, 21(5):382-90(1995).

[6] Werner J. S., "The damaging effects of light on the eye and implications for understanding changes in vision across the life span", In: P. Bagnoli and W. Hodos, Eds. The Changing Visual System. New York: Plenum Press., pp. 295-309(1991).

[7] Lomax R. B., Ridgway P., and Meldrum M., "Dose occupational exposure to organic solvents affect colour discrimination?", Toxicol. Rev., 23(2):91-121(2004).

[8] Birch J., "Diagnosis of defective of colour vision", 2nd Ed., Butter worth-Heinemann, Oxford, UK, pp. 21-112(2001).

[9] Kim H. B., Lee S. Y., Choe J. K., Lee J. H., and Ahn B. H., "The incidence of congenital color deficiency among Koreans", J. Korean Med. Sci., 4(3):117-120(1989).

[10] Woo G. C. and Lee M. H., "Are ethnic differences in the FM-100 scores related to macular pigmentation?", Clin. Exp. Optom., 85(6):372-377(2002).

[11] Atchison D. A., Bowman K. J., and Vingry A. J., "Quantitative scoring methods for D15 Panel tests in the diagnosis of congenital color vision deficiencies", Optom. Vis. Sci., 68(1):41-48(1991).

[12] Geller A. M., "A table of color distance scores for quantitative scoring of Lanthony Desaturate Color Vision Test", Neurotoxicol. Teratol., 23(3):265-267(2001).

[13] Iregren A., Andersson M., and Nylen P., "Color vision and occupational chemical exposures. II. Visual function in non-exposed subjects", Neurotoxicology, 23(6):735-745(2002).

[14] Iregren A., Andersson M., and Nylen P., "Color vision and occupational chemical exposure: I. An overview of tests and effects", 23(6):719-733(2002).

[15] Lanthony P., "Evaluation du Panel D-15 desature. I. Methode de quantification et scores normaux", J. Fr. Ophthalmol., 843-847(1986).

[16] Lanthony P., "The desaturated panel D-15", Doc. Ophthalomol., 46(1):185-189(1978).

[17] Al-Aqtum M. T. and Al-Qawasmeh M. H., "Prevalence of Colour blindness in Young Jordanians", Ophthalmologica, 215(1):39-42(2001).

[18] Davies I. R. L., Glynis L., Corbett G. G., and Jerrett D. J., "Cross-cultural difference in colour vision: Acquired "colour-blindness" in Africa", Pers. Individ. Dif., 25:1153-1162 (1998).

[19] Chia A., Gazzard G., Tong L., Zhang X., Sim E. L., Fong A., et al., "Red-green colour blindness in Singaporean children", Clin. Experiment. Ophthalmol., 36(5):464-467(2008).

[20] Modarres M., Mirsamadi M., and Peyman G. A., "Prevalence of congenital color deficiencies in secondary-school students in Tehran", Int. Ophthalmol., 20(4):221-222(1997).

[21] Citirik M., Acaroglu G., Batman C., and Zilelioglu O., "Congenital Color Blindness in Young Turkish Men", Ophthalmic Epidemiol., 12(2):133-137(2005).

[22] Norn M., "Prevalence of congenital colour blindness among Inuit in East Greenland", Acta Ophthalmol. Scand., 75(2): 206-209(1997).

[23] Jackson G. R. and Owsley C., "Visual dysfunction, neurodegenerative disease, and aging", Neurol. Clin., 21(3):709-728(2003).

[24] Kinnear P. R. and Sahraie A., "New Farnsworth-Munsell 100 hue test norms of normal observers for each year of age 5-22 and for age decades 30-70", Br. J. Ophthalmol., 86(12):1408-1411(2002).

경기도 일부 지역의 연령에 따른 색각장애의 분포

이은희 · 조성일* · 백도명*

극동대학교 안경광학과

*서울대학교 보건대학원

투고일(2011년 7월 22일), 수정일(2011년 8월 22일), 게재확정일(2011년 9월 17일)

목적: 경기도 두 도시지역 거주자들중 넓은 범위의 연령대에서 선천적색각이상과 연령관련 색각이상의 유병률을 조사하였다. **방법:** 남자 452명, 여자 483명으로 구성된 총 935명의 연구대상자가 본 연구에 참여하였다. 색각검사는 Lanthony 15 panel test를 사용하였다. **결과:** 연구대상자 중 색각이상을 나타낸 유병률은 전체 4.81%, 남자 6.64%, 여자 3.11%였다. 선천적 색각이상은 남자 3.54%, 여자 0.41%였다. 연령에 따른 후천적 청황색색각이상은 2.99%(남자 3.32%, 여자 2.69%)였다. **결론:** 연구결과는 색각이상이 연령에 영향을 받는다는 것을 나타내며, 나이에 의한 색각장애로서 청황색색각이상은 50세 이후 연령그룹에서 가장 높은 비율로 발생한다.

주제어: 연령, 색각이상, 유병률, 청황색색각이상