Normal Range of Cambridge Low Contrast Test; a Population Based Study

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Purpose: To determine the range of contrast sensitivity (CS) and its determinants in a normal population, Mashhad, Iran.

Methods: In this cross-sectional population based study, 4,453 individuals were invited of whom 3,132 persons agreed to participate (response rate, 70.4%). CS data from 2,449 eligible individuals were analyzed. CS was determined using the Cambridge low contrast square-wave grating test, and its associations with age, gender, best-corrected visual acuity (BCVA) and manifest refractive spherical equivalent (MRSE) refractive error, were analyzed.

Results: Mean age of the participants was 29.1±17.3 (range, 4–89) years and 66.4% were female. Mean CS was 239.6±233.3 and 234.6±228.6 cps in right and left eyes, respectively.

Mean binocular CS was 310.9±249.0 cps. Multiple linear regression showed that CS was inversely correlated with older age (β=-1.1, P<0.001), female gender (β=-40.1, P<0.001), poorer BCVA (β=-165.4, P<0.001), and severity of myopia (β=-10.2, P<0.001).

Conclusion: The normal range of Cambridge low-contrast grating test reported herein may serve as a reference for the general population in Iran. Our findings can be used for both research and clinical applications, particularly for evaluations of the outcomes of refractive surgery. In the current study, CS was lower in older subjects, myopic individuals and patients with lower BCVA.

Keywords: Normal Value; Contrast Sensitivity; Cambridge Test; Population Based Study

INTRODUCTION

Contrast sensitivity (CS) provides valuable information on visual function, independent of visual acuity (VA).1 CS is the ability of the eye to detect a slight difference in luminance of two regions without distinct contours, whereas VA is the ability to distinguish one object from another and to detect fine details of a visible object.2 In a healthy eye, CS and VA are strongly correlated, however CS may be decreased despite normal vision.3 Studies have shown that CS is of importance in detecting low-contrast moving objects,4 driving,4 working with computers, studying,5 and performing daily activities.6
Measurement of CS can be useful for detection, screening and evaluation of a variety of ocular diseases such as cataracts, glaucoma, age-related macular degeneration (AMD), and diabetic retinopathy. CS can also be used for assessment of intraocular lenses, prescription of contact lenses, and post-refractive surgery.

Evaluation of low-contrast CS is particularly important in patients with visual complaints but only a slight decrease in VA who report visual disturbances even after optical correction. For early detection of prognostic factors or indicators of disease progression, normal values should first be determined based on population based studies.

Two types of tests (letter and grating tests) are used to measure CS. Grating tests include the Cambridge low-contrast grating test and the CSV-1000; letter tests include Pelli-Robson and Mars letters. Some researchers believe that grating tests are superior to letter tests. However, values based on these two sets of tests are different and not interchangeable.

The Cambridge low-contrast test is readily available, inexpensive, and easy to use with acceptable repeatability. This psychophysical test evaluates CS at a spatial frequency of 4 cycles per degree (cpd), and the results are based on Michelson’s formula. In CS testing, minimum contrast is determined across a range of spatial frequencies. In CS testing, contrast sensitivity function is determined across a range of spatial frequencies, but Cambridge test evaluates CS at only one spatial frequency. This test has been used in the diagnosis and treatment of ocular and neurologic diseases in pre-schoolers, school-age children and adults.

Given the application of CS and the importance of its normal range in different populations, the goal of this study was to determine the normal range of CS and its determinants in a representative sample of the general population in Mashhad, Iran using the Cambridge low-contrast test.

METHODS
This cross-sectional study was performed on the urban population of Mashhad, the second most populated city in Iran located in the Northeast of the country. The sampling methodology has been described elsewhere. In summary, 4,453 individuals were invited, of whom 3,132 agreed to participate (response rate, 70.4%). Individuals with any type of ocular disease, ocular surgery or trauma were excluded from the study.

Random cluster sampling was used in 120 clusters. The cluster sample size was based on the cluster’s population relative to the total population. The target population of this study was the over 4-year-old urban population. All examinations were performed at an optometry clinic in the city. The Institutional Review Board approved this project. After explaining the objective of the study, written informed consent was obtained from each individual.

Examinations included determination of uncorrected visual acuity (UCVA), visual acuity with current glasses, dry and cycloplegic refraction, best corrected visual acuity (BCVA), slit lamp biomicroscopy, direct and indirect ophthalmoscopy, and contrast sensitivity.

Manifest refraction was performed in all persons prior to measuring corrected visual acuity. Visual acuity was assessed using a Snellen E-chart and a mirror system. Manifest, subjective and cycloplegic refraction were evaluated using Topcon 8000 autorefractometer (Topcon Corporation, Tokyo, Japan) and retinoscope (Beta 200, Heine Corporation, Herrsching, Germany). Cycloplegic refraction was performed following CS measurement in all individuals aged ≤15 years, 30 minutes following instilling of 3 drops of cyclopentolate 1% at 5-minute intervals. Myopia and hyperopia were defined as manifest refraction spherical equivalent (MRSE) refractive error less than −0.5 D or more than +0.5 D, respectively.

CS was first measured without optical correction and then with best spectacle correction when UCVA was less than 20/20. CS assessment was measured using the Cambridge low-contrast grating test (Clement Clarke, London, UK) at spatial frequency of 4 cpd, equal to acuity of 20/150. Each eye was first tested separately followed by binocular assessment. The test included 12 pairs of plates with luminance of 150 cd/m². The series of plate pairs were presented in descending contrast, and a forced
choice procedure was used four times for each eye. The observer was told to choose whether the top or bottom plate contained the grating. The test score was determined by adding the number of pages for which an error occurred. CS was determined using a conversion table.

Statistical analysis was performed using SPSS version 16 (IBM, USA). Descriptive data was reported for the right, left, and both eyes. Only data from the right eye was considered for analysis. Pearson’s correlation coefficient was used to evaluate the correlation between quantitative variables. An independent samples t-test was used to compare mean values. One-way ANOVA was used to evaluate differences in CS among age groups. Multiple linear regression was used to determine the adjusted effect of multiple variables on CS. The design effect of the cluster sampling protocol was considered when calculating 95% confidence intervals (CI) and the results were adjusted appropriately.

RESULTS

Of 3,132 individuals who agreed to participate, 2,449 persons met the inclusion criteria and their data was analyzed. Mean age of the participants was 29.1±17.3 (range, 4–89) years including 66.4% female subjects.

Mean CS score for right and left eyes and under binocular conditions was 239.6±233.3, 234.6±228.6, and 310.9±249.0, respectively. Table 1 summarizes CS values for right, left, and both eyes based on age and gender. Table 2 shows descriptive data associated with CS in the study population. Mean values of data for right and left eyes were as follows: BCVA, 0.03±0.12 and 0.03±0.17 logMAR; astigmatism, -0.42±0.67 and -0.42±0.71 D; MRSE, 0.26±1.39 and 0.28±1.45 D, respectively.

Independent sample t-test showed that CS was higher in men than women (P<0.001). Pearson’s correlation coefficient showed that CS score significantly decreased with increasing age, lower BCVA, higher astigmatism, and severity of myopia (P<0.001).

CS scores for the right, left, and both eyes were significantly different between individuals with normal (UCVA of 20/20) and decreased (UCVA <20/20) binocular vision (P<0.001, Figure 1). One-way ANOVA and post-hoc analyses revealed that difference in

### Table 1. Mean and standard deviation of contrast sensitivity stratified by age and gender in the study population (n=2,449)

| Age (years) | OD      | OS      | OU      |
|------------|---------|---------|---------|
| Male       |         |         |         |
| <20        | 287.2 ± 158.4 | 276.7 ± 159.5 | 352.2 ± 168.6 |
| 20-40      | 295.4 ± 139.8 | 284.3 ± 145.3 | 372.4 ± 134.3 |
| 41-60      | 238.3 ± 132.2 | 221.8 ± 131.3 | 304.5 ± 143.9 |
| >60        | 154.7 ± 114.8 | 139.3 ± 94.7  | 199.9 ± 129.6 |
| total      | 269.9 ± 140.0 | 258.1 ± 138.3 | 337.2 ± 144.4 |
| Female     |         |         |         |
| <20        | 241.4 ± 155.2 | 234.7 ± 144.1 | 318.3 ± 157.5 |
| 20-40      | 227.8 ± 159.0 | 226.7 ± 153.2 | 301.2 ± 167.3 |
| 41-60      | 205.7 ± 152.4 | 209.3 ± 177.1 | 276.7 ± 189.1 |
| >60        | 170.9 ± 104.6 | 170.1 ± 109.4 | 223.6 ± 121.9 |
| total      | 224.9 ± 134.1 | 223.3 ± 132.9 | 298.3 ± 149.3 |
| Total      | 239.6 ± 233.3 | 234.6 ± 228.6 | 310.9 ± 249.0 |

OD, right eye; OS, left eye; OU, both eyes

### Table 2. Distribution of contrast sensitivity in the study population (n=2,449)

|     | Mode | Median | Percentile 5 | Percentile 95 | Minimum | Maximum | Kurtosis | Skewness | P-value † |
|-----|------|--------|--------------|---------------|---------|---------|----------|----------|-----------|
| OD  | 290.0 | 210.0 | 49.0 | 520.0 | 10.0 | 560.0 | -0.4 | 0.6 | <0.001 |
| OS  | 290.0 | 210.0 | 49.0 | 520.0 | 8.0 | 560.0 | -0.3 | 0.7 | <0.001 |
| OU  | 560.0 | 290.0 | 78.0 | 560.0 | 20.0 | 560.0 | -1.0 | 0.1 | <0.001 |

† Kolmogorov-Smirnov test
OD, right eye; OS, left eye; OU, both eyes
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CS scores between emmetropic and hyperopic individuals was not significant, but CS score was significantly lower in myopic subjects as compared to emmetropic and hyperopic individuals (P<0.001, Table 3).

Multiple linear regression analysis revealed that CS was significantly and inversely correlated with older age (β=-1.1, P<0.001), female gender (β=-40.1, P<0.001), poorer BCVA (β=-165.4, P<0.001), and severity of myopia (B=-10.2, P<0.001). Specifically, CS showed a decrease of 1.1 units with each year of older age, a reduction of 165.4 units for each 1 logMAR unit of poorer BCVA, and an increase of 10.2 units for each 1 D increase in MRSE, and was 40.1 units higher in men.

DISCUSSION

There have been few population based studies on CS. To the best of our knowledge, this is the first population based report on CS assessed by the Cambridge test to determine the normal range of this index and therefore comparison with other reports is not possible. Studies have shown that binocular CS is always higher than monocular CS.26,27 Hirvea et al28 reported binocular CS logarithm of 2.2 in individuals aged ≥70 years using the low contrast Cambridge test. Binocular CS logarithm of individuals aged ≥60 years in our study was 2.1 which is lower than that in the above-mentioned study. One reason for this might be demographic differences in the populations.

In a study by Abrishami et al9 using the Cambridge test, CS was reported to be 309.3±113.4 and 217.6±152.4 in healthy subjects and patients with diabetic retinopathy, respectively. Their reported CS values were similar to those in our study.

Consistent with the literature, our study showed a decrease in CS with age.26,29,30 Different techniques have been used to evaluate optical and neural contributions to this decrease in CS with age, but no consensus has been reached. One possible explanation is that there are individual differences in the extent of the decrease in CS with age, which would make each study dependent upon the composition of its population.31 The contrast of the retinal image decreases with age as a result of increased light scatter due to increased media opacity. Increased high order aberrations,32 a decrease in the number of retinal cones,33 and a decrease in neuroadaptative mechanisms34 with age are other reasons for lower CS among the elderly. Also, conditions such as cataracts, glaucoma, and retinal disorders associated with aging are other causes of decreased CS. Considering the effect of age on CS, it is prudent to employ an age-specific normal range for CS in each age group to ensure accurate comparisons.

The relationship between gender and CS is controversial and results have been contradictory. Solberg et al35 found no gender difference whereas Korth et al36 reported that CS was higher in women. However, in another population-based study conducted in Iran, CSV-

Table 3. Mean and standard deviation of contrast sensitivity with different refractive errors (n=2,449)

|                  | Myopia      | Emmetropia  | Hyperopia   |
|------------------|-------------|-------------|-------------|
|                  | >3.0 D      | -3.0 to -0.5 D | +0.5 to +2.0 D | +2.0 to +4.0 D |
| Number of subjects | 367 | 1,249 | 833 |
| CS OD            | 185.4 ± 145.3 | 216.3 ± 146.2 | 240.3 ± 129.5 | 257.3 ± 145.8 | 230.4 ± 163.4 |
| CS OS            | 182.4 ± 142.7 | 203.1 ± 135.9 | 256.5 ± 129.9 | 251.4 ± 141.0 | 240.4 ± 175.3 |
| CS OU            | 245.2 ± 156.4 | 265.3 ± 146.0 | 317.3 ± 145.1 | 330.7 ± 150.3 | 270.0 ± 140.7 |

D, diopter; CS, contrast sensitivity; OD, right eye; OS, left eye; OU, both eyes
1000 CS was reported to be higher in men.\(^3\) A possible reason for these discrepancies may be hormonal changes in women, which may result in changes in the structure of the lens and the composition of the aqueous humor.\(^3\)

CS has always shown a significant inverse correlation with VA (in logMAR notations) in both diseased eyes and healthy individuals; in other words, CS decreases with worsening vision.\(^3,22,28\) Moreover, even in individuals with normal vision, CS is very variable. Similar to Shahroud eye cohort study using CSV-1000,\(^3\) our study showed that CS was lower in myopic individuals as compared to hyperopic and emmetropic participants, possibly due to global retinal expansion and loss of some ganglion cells. In cases with less severe myopia, neural processes may be responsible for decreased visual function.\(^39\)

A significant inverse correlation between CS and astigmatism was also noted; CS decreases as astigmatism increases. This correlation was also reported in another study\(^40\) and is believed to result from distorted and defocused retinal images in astigmatic eyes.

In summary our study revealed that CS is lower in the elderly, women, myopic individuals, and those with decreased VA. CS scores obtained herein can be regarded as the normal range for the Cambridge low-contrast grating test, and may be used for the evaluation of disease course and treatment outcomes associated with procedures such as refractive surgery. However, the wide variation in CS among individuals with normal vision should also be noted.

Conflicts of Interest
None.

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