Original Article

Comparison of CSV-1000 and Metrovision contrast sensitivity tests in normal eyes

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ABSTRACT

Background: Measuring contrast sensitivity (CS) allows a better understanding of the visual performance of the human eye. This study aimed to examine the correlation and agreement between the results of two sine-wave grating-based CS measurement methods, Metrovision and CSV-1000, in normal eyes.

Methods: This cross-sectional, comparative study was performed between December 2018 and April 2019, at an optometry clinic. Subjects underwent comprehensive ocular examinations, which included pupil reflexes, subjective refraction, external eye examinations, smooth pursuit eye movement assessment, the cover–uncover test, and detailed slit-lamp examination of the anterior and posterior segments. Metrovision and CSV-1000 were employed to assess CS under photopic conditions. The correlation and agreement of the results of the two tests were evaluated.

Results: CS was measured for 104 normal eyes for 3, 6, 12, and 18 cycles per degree (cpd) spatial frequencies (participants' mean age ± standard deviation: 37.3 ± 26.4 years). The CSV-1000 measurements were significantly higher for the 3 and 6 cpd spatial frequencies (both $P = 0.01$); however, at higher spatial frequencies, CS scores were similar. The highest and lowest differences between the two tests were recorded for the 3 cpd spatial frequency and 18 cpd spatial frequency, respectively. Except for the 3 cpd spatial frequency, in both eyes, the findings correlated significantly between the CSV-1000 and Metrovision ($P < 0.05$). The narrowest and widest limits of agreement between the two tests were found for the 12 and 3 cpd spatial frequencies, respectively.

Conclusions: The CSV-1000 method estimated CS higher than the Metrovision method, mostly at lower spatial frequencies. Furthermore, the agreement between the two methods was greater at higher spatial frequencies than at lower frequencies. This should be kept in mind when using the two methods interchangeably in visual screening.

KEY WORDS

contrast sensitivity, spatial frequencies, correlation, agreement, limit of agreement, Metrovision, CSV-1000, Bland–Altman analysis, Spearman rank correlation

INTRODUCTION

The visual system provides most environmental information to humans. The functional integrity of this system may be affected by various diseases. In everyday life, humans perform activities such as reading, moving, and face recognition, which require recognizing objects with different contrasts. To perform these activities, a healthy visual system is needed [1-6].

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How to cite this article: Tahkor A, Heravian Shandiz J, Azimi Khorasani A, Ansari Moghadam AR. Comparison of CSV-1000 and Metrovision contrast sensitivity tests in normal eyes. Med Hypothesis Discov Innov Optom. 2021 Summer; 2(2): 63-70. https://doi.org/10.51329/mehdioptometry127

Received: 26 June 2021; Accepted: 18 October 2021

Contrast sensitivity (CS) refers to the ability of the visual system to distinguish an object from its background [3]. Measuring CS promotes understanding of the visual performance of the human eye, and helps in the identification of any defects in the integrity of visual system constituents. It also facilitates the diagnosis and monitoring of eye diseases, including cataracts, glaucoma, and optic nerve diseases. Because of the clinical importance of CS results in ocular disease diagnosis and treatment evaluation [1, 5, 7-9], studies have attempted to provide simple, fast, and reliable methods for measuring CS.

CS-measuring methods fall into two main categories: some methods are designed in periodic patterns, using sine-wave pattern, and others use a non-periodic pattern, typically employing letters. Thus, different charts have been compared [1-4, 7, 10, 11].

Thayaparan et al. [10] compared the repeatability of the Mars CS chart and Test Chart 2000 with the Pelli–Robson chart. They found that CS measurement with the Mars CS chart demonstrated better repeatability than Pelli–Robson chart, while for the Test Chart 2000, the repeatability was worse than that of the Pelli–Robson chart. Khambhiphant et al. [1] examined the agreement between three newly developed numbers CS charts and the Mars CS chart and found reasonable agreement with the Mars CS chart. They concluded that the newly developed numbers CS charts were inexpensive and could replace the Mars CS chart [1]. Zeri et al. [11] checked the accuracy and repeatability of the computerized Pelli–Robson chart displayed on LCD systems against its standard printed version and found that the computer test is not interchangeable with the standard chart. Mohammadi et al. [2] examined the degree of agreement between the CS results of the Freiburg visual acuity and contrast test (FrACT) and the Monpack3 device (Metrovision, Perenchies, France) in both amblyopic and normal eyes. CS was measured for 1, 3, and 5 cycles per degree (cpd) spatial frequencies, and the results were analyzed using the Bland–Altman analysis. The FrACT CS test showed higher scores at all spatial frequencies, except for the 1 cpd frequency, in amblyopic anisometropic eyes [2].

In the present study, we examined the correlation and agreement between the results of two sine-wave grating-based CS measurement methods (Metrovision and CSV-1000) in normal eyes, as no previous studies have compared these two methods.

METHODS

This cross-sectional, comparative study was performed between December 2018 and April 2019 at the optometry clinic of the School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, Iran. The Medical Ethics Committee of Mashhad University of Medical Sciences approved the study protocol (Code: IR.MUMS.REC.312.1397). The study was conducted according to the principles of the Helsinki Declaration. Before the study, all steps were described to the participants simply and completely, and it was explained that the procedures would not be invasive. All participants provided written informed consent. Participants were asked about their general health and the use of any medication or history of any systemic or ocular diseases that could affect contrast perception, and those with a positive history were excluded. We included apparently healthy subjects aged 19–35 years, with a minimum and maximum best-corrected visual acuity of 20/20 to 20/40, respectively.

A comprehensive ocular examination was conducted to confirm the ocular health of all participants. Pupil reflexes, including the swinging flashlight test, direct, and consensual responses, were normal. Objective refraction was performed using a retinoscope (streak retinoscope, Beta 200, Heine, Germany). The results were refined by subjective refraction and were balanced using the Duochrome test. Finally, the best corrected visual acuity of each individual was recorded in logarithm of the minimum angle of resolution (LogMAR) notation. In addition, external eye examinations, smooth pursuit eye movement assessment, the cover–uncover test, and detailed anterior and posterior segment examination, using a slit-lamp (Haag-Streit, Bern, Switzerland) was performed.

We employed two sine-wave grating-based CS measurement tests, including Metrovision (MonCv3; Metrovision, Perenchies, France) and CSV-1000 (VectorVision, Inc., Greenville, OH, USA) to assess contrast sensitivities. The effects of ambient illumination on CS have previously been studied [12, 13]. To ensure consistent results, all measurements were scheduled between 9:00 AM and 12:00 PM, and were performed under photopic conditions by the same optometrist. Because any experience of psychophysical testing could affect test results, participants were asked if they had taken the test before. To prevent the effects of learning or of fatigue, all measurements were made in a random order between the two tests, which were performed 5 min apart.

Metrovision is an electrophysiology testing device that uses vertical sine-wave gratings to measure the CS at different spatial frequencies. Each grating is initially presented at very low contrast, and the contrast then

increases progressively. The patient was instructed to press a button when vertical black and white lines were detected on a plain screen. The CS function (CSF) curve was plotted for the right and left eyes of all participants using the Metrovision CS test. Because CS was assessed on a CSV-1000 chart for the 3, 6, 12, and 18 cpd spatial frequencies, the CS scores of these spatial frequencies were extracted from the CSF diagram provided by the Metrovision device [2, 14].

The CSV-1000 CS test device is equipped with a fluorescent light source that retro-illuminates the transparent chart and uses sine-wave gratings. The test distance was 2.5 m. Four spatial frequencies, 3, 6, 12, and 18 cpd, arranged in four double rows were tested. Each double row consisted of 17 circular achromatic patches with a diameter of 3.81 cm. The first patch from the left had very high contrast, and represented the sample. The patient was asked to look at this patch first. The contrast decreased from left to right in the remaining 16 patches, which were lined up in eight columns across a row. The chart brightness was automatically adjusted to 85 candelas/meter squared (cd/m^2). CS measurements were performed with the best refractive correction in place while the patient was positioned level with the chart at a distance of 2.5 m [15].

CS is the inverse of the contrast threshold. As a standard in visual sciences, the results of CS measurements were reported on a logarithmic (log) scale, because sensory systems respond to stimuli logarithmically [15]. Furthermore, this scale is more suitable for statistical analyses [15, 16]. Therefore, the results of both tests were converted into log units. Statistical analysis was performed using IBM SPSS Statistics for Windows (version 19.0; IBM Corp., Armonk, NY, USA). Because the data obtained from the two methods at the tested frequencies showed a non-normal distribution by the Kolmogorov–Smirnov test ($P < 0.05$), the correlation between these quantitative data was checked using Spearman's rank correlation. Statistical significance was set at $P < 0.05$. The Bland–Altman method was used to analyze the agreement between the two CS tests and the 95% limit of agreement (LoA) between the two methods was computed as the mean of the differences ± 1.96 standard deviation (SD) of the differences.

RESULTS

Overall, 52 participants (104 eyes) with a mean ± SD age of 37.3 ± 26.4 years were included. The mean ± SD of the best-corrected visual acuity was 0.00 ± 0.00 logMAR. The mean ± SD of spherical equivalent in the right and left eye was 0.1 ± 0.3 Diopter (D), and 0.2 ± 0.3 D, respectively. The mean ± SD of CS at the tested spatial frequencies using the CSV-1000 and Metrovision tests are shown in Table 1. The CSV-1000 measurements were significantly higher at 3 and 6 cpd in both eyes ($P < 0.05$ for all). At higher spatial frequencies, including 12 and 18 cpd, the results were similar (Table 1). Figure 1 shows the CSFs of the two CS tests at the various spatial frequencies in the right and left eye. For the 3 and 6 cpd spatial frequencies, the difference between the mean scores of the two tests was statistically significant ($P < 0.05$ for all).

The highest and lowest difference between the two tests was observed for the 3 cpd spatial frequency in the right eye (0.39 log units) and for the 18 cpd spatial frequency in the left eye (0.00 log units).

As shown in Table 2, except for the 3 cpd spatial frequency, in both eyes, the correlation between the CSV-1000 and Metrovision methods was significant at other tested spatial frequencies ($P < 0.05$ for all), ranging from a weak positive correlation for the 6 cpd spatial frequency in the left eye, to a very strong positive correlation for the 12 cpd spatial frequency in the left eye, and 18 cpd spatial frequency in both eyes.

We assessed the degree of disagreement and tendency of the difference between the two CS tests using the Bland–Altman method. Figure 2 shows the Bland–Altman plot presenting the mean difference between two CS scores (CSV-1000 - Metrovision) versus the mean scores ([CSV-1000 + Metrovision] / 2) for each tested spatial

Table 1. Comparison of contrast sensitivity scores (in log units) of the right and left eyes at various spatial frequencies checked by two CS tests

	Right Eye				Left Eye			
Special Frequency	**3 cpd Mean ± SD**	**6 cpd Mean ± SD**	**12 cpd Mean ± SD**	**18 cpd Mean ± SD**	**3 cpd Mean ± SD**	**6 cpd Mean ± SD**	**12 cpd Mean ± SD**	**18 cpd Mean ± SD**
Metrovision	1.35 ± 0.03	1.84 ± 0.10	1.67± 0.12	1.24 ± 0.11	1.38 ± 0.07	1.76 ± 0.11	1.63 ± 0.13	1.21 ± 0.12
CSV-1000	1.74 ± 0.09	1.95 ± 0.09	1.67 ± 0.13	1.25 ± 0.12	1.69 ± 0.09	1.94 ± 0.09	1.64 ± 0.13	1.21± 0.14
***P*-value**	**0.001**	**0.001**	0.435	0.304	**0.001**	**0.001**	**0.001**	0.690

Abbreviations: CS, contrast sensitivity; cpd, cycles per degree; SD, standard deviation; Metrovision, Metrovision contrast sensitivity test; CSV-1000, CSV-1000 contrast sensitivity test chart. *P*-value < 0.05 is shown in bold.

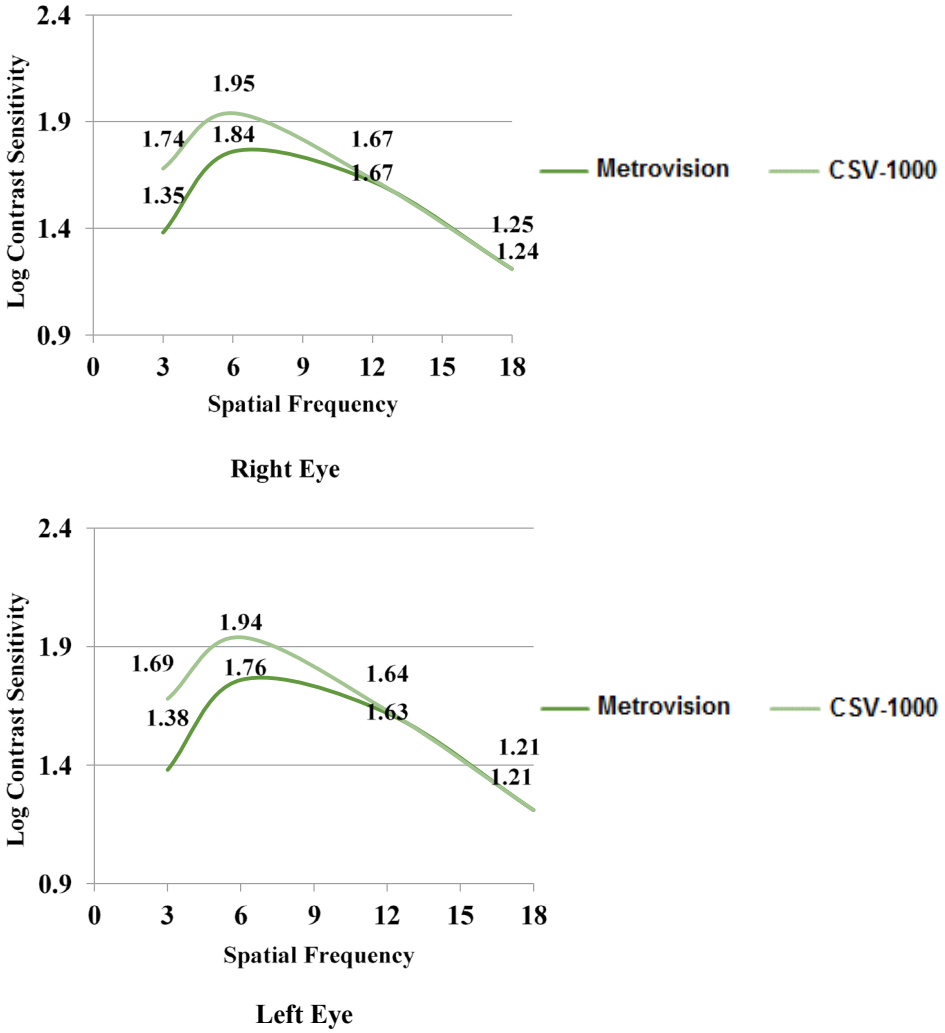

Figure 1. Contrast sensitivity function (CSF) of two tests (Metrovision and CSV-1000) at the tested spatial frequencies (3, 6, 12, and 18 cycles per degree [cpd]), in the left and right eyes.

Table 2. Correlation between CSV-1000 and Metrovision contrast sensitivity tests at the tested spatial frequencies

	Right Eye				Left Eye			
Special Frequency	**3 cpd**	**6 cpd**	**12 cpd**	**18 cpd**	**3 cpd**	**6 cpd**	**12 cpd**	**18 cpd**
Correlation Coefficient*	+ 0.024	+ 0.670	+ 0.823	+ 0.901	+ 0.210	+ 0.418	+ 0.949	+ 0.917
***P*-value**	0.864	**0.001**	**0.001**	**0.001**	0.135	**0.002**	**0.001**	**0.001**

Abbreviations: cpd, cycles per degree.*Spearman's rank correlation; *P-value* < 0.05 is shown in bold.

frequency [15] in both eyes, along with the LoA. The lowest and highest differences between the CS scores of the two tests were detected at a spatial frequency of 18 cpd in the left eye (0.00 log units) and 3 cpd in the right eye (0.39 log units), respectively. The narrowest and widest LoA between the two tests was found at a spatial frequency of 12 cpd in the left eye and 3 cpd in the left eye.

The best agreement between the two tests was for the 18 cpd spatial frequency in the right eye. Thus, the difference between the scores of the two tests varied least at this spatial frequency ($r^2 = 0.00$). Except for the 3 cpd spatial frequency of Metrovision, at all tested spatial frequencies, the right eye had higher CS scores than the left eye ($P < 0.001$ for all).

DISCUSSION

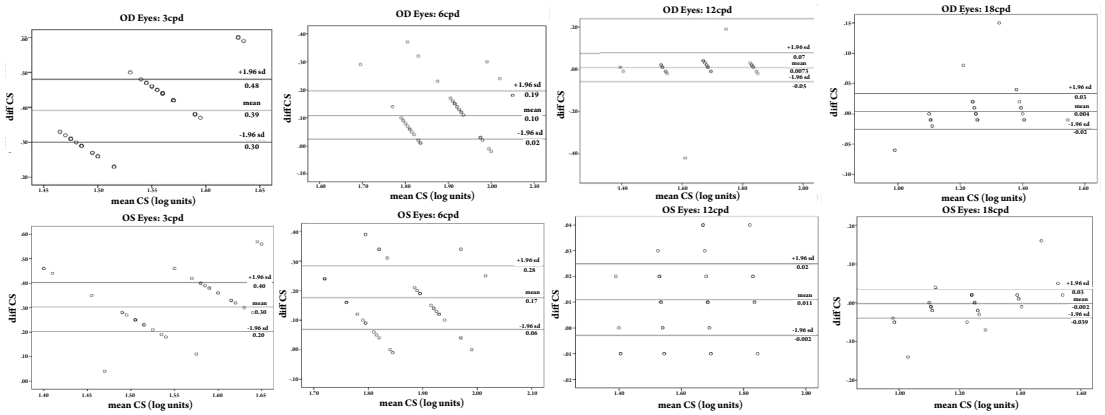

Figure 2. Bland–Altman plots showing the mean difference (diff CS) between two contrast sensitivity (CS) tests (solid middle line) versus the mean CS scores ([CSV-1000 + Metrovision] / 2) for each tested spatial frequency in the right and left eye, with the limits of agreement (LoA) (solid upper and lower lines).

In this study, CS scores were obtained for 104 normal eyes using the CSV-1000 and Metrovision CS methods at the 3, 6, 12, and 18 cpd spatial frequencies. The CSV-1000 measurements were significantly higher than the Metrovision measurements for the 3 and 6 cpd spatial frequencies in both eyes, whereas CS scores were similar at higher spatial frequencies. The highest and lowest differences between the two tests were recorded at the 3 cpd spatial frequency in the right eye and 18 cpd spatial frequency in the left eye, respectively. Except at the 3 cpd spatial frequency in both eyes, the correlation between the CSV-1000 and Metrovision measurements was significant. The lowest and highest differences between the CS scores of the two tests were detected at the 18 cpd spatial frequency in the left eye and at the 3 cpd spatial frequency in the right eye. The narrowest and widest LoA between the two tests was found at the 12 and 3 cpd spatial frequencies, respectively, both in the left eye. Except at the 3 cpd spatial frequency in the Metrovision CS test, for all tested spatial frequencies, the right eye had significantly higher CS scores than the left eye. Overall, the maximum CS scores were recorded at the middle spatial frequencies with both the CSV-1000 and Metrovision. These results are not unexpected, as previous studies had also shown that the maximum CS of a normal visual system occurred at middle spatial frequencies [17-22]. Among the majority of tested spatial frequencies, the mean difference between the two methods (CSV-1000 - Metrovision) had positive numerical values, which indicates that the CSV-1000 estimated compared to Metrovision estimate CS as higher. This difference was higher for the low and middle spatial frequencies (3 and 6 cpd) and lower for high spatial frequencies (12 and 18 cpd).

Despite the low correlation or lack of correlation between the two methods at low to middle spatial frequencies, we found a high correlation for the high spatial frequencies. Although the participants in this study were normal-sighted individuals, the difference between the two methods increased as CS decreased. This indicates that the CSV-1000 method estimated a higher CS score than did the Metrovision method at lower spatial frequencies. Therefore, in cases of abnormal and pathological vision, the CSV-1000 method may result in more false-negatives as it estimates the CS score as being higher, although a specific design, with subjects with different visual impairment levels, is necessary to investigate this further [23].

Another explanation for the observed differences between the CS scores of the two tests could be attributed to the magnocellular or parvocellular-based systems. A magnocellular-based system is activated at a low spatial frequency and contrast, while in a parvocellular-based system, the opposite is true [24]. In Metrovision, the contrast and spatial frequency initially involves low-contrast gratings, which progressively increases to a higher level until the patient can detect the shape of gratings [2, 14, 25]. It can be postulated that the magnocellular-based system initially functions until it gradually reaches saturation, and then, with increasing contrast and spatial frequency, the parvocellular-based system takes over [24]. In contrast, in the CSV-1000 method, sine-wave gratings with high contrast are first shown to the patient, and when the patient is able to detect this correctly, the contrast is gradually reduced [15]; therefore, at the beginning of the test, the parvocellular-based system is activated, and as the test proceeds, its activity gradually reduces and is replaced by that of the magnocellular-based system. Therefore, in these two methods, magnocellular- and parvocellular-based systems could operate in different orders, and the conditions of performing the two methods differ from each other. This may result in the difference between the methods, which is likely to increase when assessing CS at low spatial frequencies.

CS scores recorded with the CSV-1000 were significantly higher at the 3 and 6 cpd spatial frequencies than the Metrovision scores, and were almost similar for the 12 and 18 cpd spatial frequencies. The higher background brightness in the CSV-1000 chart, which results in higher CS scores, could be an alternative explanation for this observed difference. The CSV-1000 stimulus is displayed using an internal retro-illumination system on a translucent chart [15], and the luminance level is calibrated automatically, which initiates at a light level of 85 cd/m^2 [26]. This interaction between screen brightness and contrast stimuli may result in higher CS scores in CSV-1000. In contrast, Metrovision uses a stimulus with an incremental contrast, and sine-wave gratings are displayed at each contrast level for a short period [2, 14, 25], while luminance can be set from 0.08 to 80 cd/m^2 [27]. Although a short time (5 s) was used in the CSV-1000 in the current study, to compensate for this discrepancy between the two methods, this display period was higher than the duration of the Metrovision stimuli. Increasing the duration of stimuli could improve the CS scores, which may contribute to the higher scores obtained with the CSV-1000.

Stimulus detection can be affected by adaptation and perceptual fading [28, 29], which can reduce CS scores. Metrovision shows sine-wave gratings vertically, with a progressive increase in contrast from low to high, until the shape of the grating can be detected by the observer [2, 14, 25]. In contrast, the CSV-1000 uses stepped contrast, such that the contrast for a given frequency decreases in steps [15, 30]. Each patch of CSV-1000 has a given contrast [30], which increases the patient's experience in stimulus evaluation, thus increasing the visibility of the stimulus as compared with Metrovision. This difference may also lead to the higher CS scores recorded by the CSV-1000, and may provide another explanation for the observed differences in the CS scores measured by the two methods in our study. Although Metrovision automatically demonstrates gratings three times, it restarts from the contrast threshold recorded in the previous step, rather than from the beginning [2]. This, in turn, could result in lower CS scores in Metrovision.

Statistically, the 95% LoA indicates the range of values that are expected to cover agreement for the majority of subjects surveyed. Therefore, it guides clinicians to decide whether the two methods agree sufficiently to be used in clinical evaluations [31]. In the current study, the 95% LoA between the two methods (Metrovision and CSV-1000) was lower at high spatial frequencies, and the use of these spatial frequencies in visual screening may be more appropriate than low spatial frequencies when planning to use the Metrovision and CSV-1000 methods interchangeably.

To the best of our knowledge, the correlation and agreement between the Metrovision and CSV-1000 CS tests in normal eyes has not been reported previously. However, this study was limited by its cross-sectional design and lack of a control group, at least a group with ocular disease that would result in deteriorated CS scores. Including such controls could further reveal differences between Metrovision and CSV-1000 methods in pathological conditions, which may not necessarily show the same results as we have recorded for normal eyes. In addition, further investigation is needed to compare these two methods as well as other CS tests to establish a standard set and find the best method for measuring CS in routine clinical practice. The visual acuity of our participants was fully corrected and all were normal-sighted individuals, which affects the generalizability of our results. It should be noted that in both mild and deep amblyopic eyes, CS scores could be different from those obtained in our study subjects. Future studies with a larger sample size [31], assessing CS scores according to eye dominance [17], or including cases with visual impairment such as amblyopic eyes, could reveal subtle differences between the results of these two CS tests, which ultimately may help in better interpreting CS scores obtained with these two methods. Finally, as CSF changes from birth to adulthood [32], future studies comparing CS test methods should include subgroups with a broad age range.

CONCLUSIONS

Our results revealed that the CSV-1000 method estimates CS as being higher than that estimated by the Metrovision method, particularly at lower spatial frequencies. However, the agreement between the two methods was higher at higher spatial frequencies than other frequencies. Therefore, it is necessary to consider this fact when using the two methods interchangeably in visual screening.

ETHICAL DECLERATIONS

Ethical approval: The Medical Ethics Committee of Mashhad University of Medical Sciences approved the study protocol (Code: IR.MUMS.REC.312.1397), and the study was conducted according to the principles of the Helsinki Declaration. Before the study, all steps were fully described to the participants and they were reassured that the procedures would not be invasive. All participants provided written informed consent.
Conflict of interests: None

FUNDING

None.

ACKNOWLEGMENTS

This study is the outcome of a Master's dissertation in Optometry with the ethical code IR.MUMS.REC.312.1397. We express our gratitude and appreciation to the Vice-Chancellor for Research at the Mashhad University of Medical Sciences. Moreover, we thank the Optometry Department of Mashhad University of Medical Sciences for good cooperation and our colleagues who helped us complete our study on time.

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