Original Article

Normative database for Spaeth Richman contrast sensitivity test for Indian eyes

Sonia Bariya, Parul Ichhpujani, Obaidur Rehman, Suresh Kumar

Purpose: To ascertain normative database of contrast sensitivity (CS) using Spaeth/Richman CS test (SPARCS) in the Indian population. **Methods**: This cross-sectional study enrolled 200 healthy individuals, and CS was tested in both eyes of each participant using SPARCS. A detailed ocular examination was done before enrollment to rule out pathologies that may affect CS. A practice test was performed in the right eye (OD), followed by uniocular testing in each eye and a final binocular test. **Results:** Data of 400 eyes of 200 subjects who fulfilled the inclusion criteria was evaluated. The average age of subjects was 46.57 ± 16.77 years (range 21–79 years), with a slight female preponderance (53%, n = 106). A statistically significant decline in average SPARCS scores was noted with increasing age ($P < 0.05$), ranging from 86.68 (20–29 years age group) to 67.44 (70–79 years age group). Higher scores were noted in binocular testing than uniocular testing (Interclass correlation coefficient [ICC] = 0.83; $P < 0.001$). Females achieved statistically significant higher total scores in uniocular SPARCS testing (both OD and OS), but there was no significant difference noted between the two genders in binocular testing. Correlation between practice and main tests was statistically Significant with an interclass correlation coefficient of 0.54 ($P < 0.001$). **Conclusion:** Normative database for SPARCS was established for Indian eyes, with a decreasing trend noted in peripheral as well as central CS scores with increasing age.

Access this article online

Website: www.ijo.in

DOI: 10.4103/ijo.IJO_491_22

Quick Response Code:

Key words: Contrast Sensitivity, CS, normative database, peripheral contrast sensitivity, SPARCS

Humans have a richly patterned visual environment, and the extent of interpreting its spatial information depends on one's visual function, which encompasses visual acuity (VA) and contrast sensitivity (CS). VA measures the minimum resolvable angle, while CS measures the minimum contrast required to note the relative difference in luminance between an object and its background.

VA charts measure the minimum angle of visual resolution using high-contrast targets only (18–24 cycles per degree [cpd]). However, in real-life scenarios, high contrast is not always needed and several tasks may require peripheral visual function, dependent on low spatial contrast (3–6 cpd). CS has an important role in VA, visual field, dark adaptation, motion recognition, and pattern recognition. CS is hampered in pathologies like glaucoma, diabetic retinopathy, age-related macular degeneration (ARMD), cataract, and may even be affected by refractive surgeries.[1] Loss of CS in the presence of intact Snellen VA has already been noted in pathologies affecting afferent sensory visual function, like multiple sclerosis, cerebral lesions, and glaucoma.[2]

Central CS can be evaluated from the central area of retina corresponding to macula and peripheral CS by evaluating extramacular areas.[1] Many CS tests have been designed for and administered to the normal population, and each test has its own normative database. Most of these tests measure only central CS. In the present study, we used Spaeth/Richman CS test (SPARCS), which is a new internet-based computer program that features multiple answer choices and a bracketing technique that measures an individual's CS both centrally and peripherally. Since it uses contrast gratings, it does not require literacy or pattern recognition. Also, gratings appear randomly in five areas, thus presenting multiple choices to the individual and reducing chances of guessing the correct answer. Only one study exists in literature that reports normative data of CS (both central and peripheral) using SPARCS in Caucasian eyes.[3] There is no study reporting normative data of central and peripheral CS in Indian eyes, and we aim to address this issue with the current study.

Methods

Study design

This prospective, cross-sectional study was conducted at a multispecialty tertiary care institute. We enrolled 200 consecutive healthy individuals from the outpatient services of ophthalmology department, who were free of ocular disease and presented for refractive errors.

The study was registered with the Clinical Trials Registry of India (CTRI), available online at https://www.ctri.nic.in, before enrollment of the first participant (CTRI/2020/06/025632). The

Department of Ophthalmology, Government Medical College and Hospital, Chandigarh, India

Correspondence to: Dr. Parul Ichhpujani, Department of Ophthalmology, Government Medical College and Hospital, Sector 32, Chandigarh - 160 030, India. E-mail: parul77@rediffmail.com

Received: 22-Feb-2022 Revision: 10-May-2022
Accepted: 01-Jul-2022 Published: 30-Sep-2022

Cite this article as: Bariya S, Ichhpujani P, Rehman O, Kumar S. Normative database for Spaeth Richman contrast sensitivity test for Indian eyes. Indian J Ophthalmol 2022;70:3476-82.

study was approved by the institutional ethics committee and was in accordance with the tenets of Declaration of Helsinki.

Healthy individuals aged more than 18 and less than 70 years of either gender with best corrected VA (BCVA) better than 20/50 were enrolled.

Patients with history of incisional or laser eye surgery in the past 3 months, pathological visual impairment (e.g., glaucoma, cataract more than grade 2 using Lens Opacity Classification System III (LOCS III) grading,[4] diabetic retinopathy, ARMD), or any medical condition which, in the investigator's opinion, precluded the patient from providing reliable and valid data (such as cognitive impairment, Parkinson's disease, Alzheimer's disease, or any other neurological or musculoskeletal disease) were excluded. Patients with refractive error greater than +6 D or −6 D, astigmatism more than +2 D, and a history of using retinotoxic medications (such as linezolid, hydroxychloroquine, etc.) were also excluded.

Participants and data collection methodology

A careful detailed history was taken in all cases. All patients underwent a detailed clinical examination that included uncorrected VA (UCVA) and BCVA assessment, slit-lamp examination, +90 D fundus examination, intraocular pressure (IOP) measurement using a calibrated Goldmann applanation tonometer, visual field examination, and SPARCS.

VA values were converted to Log of Minimum Angle of Resolution (logMAR) scale for statistical analysis. Humphrey perimeter HVF 750 II (Zeiss Meditec, Dublin, CA, USA) using SITA-Fast 24-2 protocol was used to test visual fields to rule out glaucoma. Subjects' current symptoms, health problems, medications, and ocular comorbidities were also documented to have a pristine sample of normal individuals.

CS assessment

SPARCS was accessed via https://www.sparcscontrastcenter.com, where each patient was assigned a unique identification number.

In SPARCS, contrast threshold is determined using a staircase strategy with reversals. Initial correct responses advance four levels until an incorrect response is made. After the incorrect response, the contrast level presented is two levels easier. Thereafter, the algorithm advances or regresses one level at a time until two incorrect responses are made at a specific level, which establishes the threshold. The range of contrast tested is from 100% to 0.45% (logCS 0.00–2.35) and decreases by approximately 0.15 log units between levels. The contrast value is calculated by Weber contrast. The central area and four peripheral areas each receive separate scores. The log-based score of each of the five testing areas is scaled out of 20, making a maximum SPARCS score of 100. SPARCS scores in individual areas can be converted to logCS using the equation: log CS score = (SPARCS score × 2.346353)/20.

Total SPARCS scores can be converted to logCS using the equation: log CS score = (SPARCS score × 2.346353)/100.

SPARCS was performed by the same examiner using the same computer with internet access. The monitor screen had a 1024 × 768 resolution, 256 gray levels, and dimensions of at least 22 cm width and 26.5 cm height, as is required for this test. The individual sat 50 cm away from the monitor screen, as at this distance, the screen employed 30° of horizontal vision and 23.5° of vertical vision and the central test area occupied 5° horizontally and 3.5° vertically.

To avoid learning effects, one demonstration and one practice trial were conducted before documenting the final SPARCS values. Vertical square wave gratings appeared randomly in one of the five areas for a duration of 0.3 s and a spatial frequency of 0.4 cpd, and the patient had to select the area with gratings. After this, the candidate fixated again on the central area and clicked on it to prompt the test to show the next image.

All the tests were attempted under supervision. A practice test was conducted for the right eye (OD) to acquaint the participants with the test. The participants were given a break of 5–15 min after the practice test. SPARCS was done both as both uniocular and binocular testing. The non-tested eye was covered with an occlude, and appropriate habitual correction was used. Scores were noted, and time duration of the practice trial and final SPARCS testing was recorded using a stopwatch. Testing was conducted in a room with fluorescent lighting and no windows to minimize glare and reflections. Room lighting was kept in the range 750–780 lux, measured using a luxmeter application on smartphone (Lux Light Meter Pro Version 2.1, developed by Marina Polyanskaya).

Statistical analysis

Optimum sample size for the proposed study was calculated on the basis of anticipated 84.4% sensitivity of SPARCS. In order to establish normative database in the general population, the sample size was calculated on the basis of 95% confidence interval and 5% of absolute precision. On the basis of this assumption, the sample size was found to be 196, and we enrolled 200 patients.

The formula used was $n = 4pq/L2$, where P = true positivity rate, q = 1 − true positivity rate (false negativity rate), and L = absolute precision. Probable range based on 95% confidence interval provided by $P \pm 1.96 \sqrt{pq}/\sqrt{n}$ was established for prospective use.

Data was coded in MS Excel spreadsheet program, and Statistical Package for the Social Sciences (SPSS) version 23 (IBM Corp.) and R version 4.0.0 were used for data analysis. Descriptive statistics were elaborated in the form of means/standard deviations and medians/interquartile ranges (IQRs) for continuous variables and frequencies and percentages for categorical variables. Group comparisons for continuously distributed data were made using independent sample t test when comparing two groups. If data were found to be non-normally distributed, appropriate nonparametric tests in the form of Wilcoxon test were used. Chi-squared test was used for group comparisons for categorical data. In case the expected frequency in the contingency tables was found to be <5 for >25% of the cells, Fisher's exact test was used instead. Linear mixed effects regression modeling was conducted to find out the significant associations for SPARCS score. Patient ID was kept as the random effect, and age, gender, BCVA, spherical equivalent (SE), astigmatism, quadrant, laterality, and attempt type were kept as the fixed effects. P values < 0.05 were statistically significant.

Results

This cross-sectional study evaluated data of 400 eyes of 200 patients who fulfilled the inclusion criteria set for the study. The average age was 46.57 ± 16.77 years (range 21–79 years), and there was a slight female preponderance (53%, *n* = 106). Seven eyes of four patients (one unilateral and three bilateral) had history of cataract surgery (phacoemulsification) with monofocal intraocular lens (IOL) implantation (non-tinted). The basic demographics of the study population are summarized in Table 1.

Ocular examination

The average BCVA (logMAR) in OD of the study population was 0.13 ± 0.15, with an average spherical refractive error of 0.96 ± 0.68 D and an average cylindrical refractive error of 0.12 ± 0.33 D. The average BCVA (logMAR) in the left eye (OS) of the study population was 0.12 ± 0.11, with an average spherical error of 0.64 ± 0.60 D and a cylindrical error of 0.05 ± 0.21 D. All participants had clear corneas, and slit-lamp examination (anterior as well as posterior segment examination) was unremarkable. Ocular examination findings and average SPARCS scores (total and quadrant-wise) of the entire study population are presented in Table 2.

CS scores and testing time

SPARCS scores of each age group were separately analyzed for uniocular as well as binocular testing. In all three test settings (OD, OS, and binocular), the differences in scores with increasing age across the six age groups were statistically significant. For every 1 unit increase in age (years), the total SPARCS score decreased by 0.33 units for uniocular testing and 0.18 units for binocular testing. Time taken was also recorded for all age groups, and a statistically significant difference was noted in time taken to complete the test with increasing age ($P < 0.05$). For every 1 unit increase in age (years), the test duration increased by 0.03 min for uniocular and binocular tests. The average SPARCS scores and time taken for each test across the six age groups are presented in Table 3.

Gender

Females achieved statistically significant higher total scores in uniocular SPARCS testing (both OD and OS) than males ($P < 0.05$) and also finished the test faster ($P < 0.05$). But there was no significant difference noted between the two genders on binocular testing.

Discussion

Sensitivity to contrast is an important independent aspect of visual function that can vary more than fourfold across normal individuals.[5] Factors causing interindividual variation have not been clearly understood, but have been attributed to genetic and environmental factors. Genetic influence on CS was studied by Haak[6] in monozygotic and dizygotic twin pairs, who concluded that central CS (using Mars CS test) was moderately heritable with a strong influence of nongenetic factors like variation in cognitive ability, task engagement, and individual specific environmental experiences.

Data from diverse ethnicities cannot be lumped together. Apart from individual differences, a study by Oen *et al*.[7] showed that variation in CS also exists with race/ethnicity. They observed that Chinese individuals had lower CS (Vistech charts; Michelson contrast) than other races, including Malays, Indians, and Eurasians. The association of CS with race highlights the importance of using nomograms based on local populations.[7] Lacunae exist in literature regarding CS values for black ethic groups (Caribbean, African, and others).

Gupta *et al*.[3] had not performed a gamma correction to adjust for the low contrast levels or to measure the screen

Table 1: Summary of basic demographics and clinical parameters

Basic details	Mean±SD	Median (IQR)	Min.-max.	Frequency (%)
Age overall (years)	46.57±16.77	44.50 (33.75-62.00)	21.00-79.00	
Male	52.17 (15.83)	53.5 (40.25-65.75)	21-79	-
Female	41.60 (16.07)	38 (26-52.25)	22-78	
Age group				
20-29 years	24.78 (2.13)	25 (23-26)	-	-
30-39 years	35.68 (3.00)	36 (34-37)		
40-49 years	46.10 (5.62)	45 (43-48)		
50-59 years	50.81 (6.07)	54 (46.5-55)		
60-69 years	63.72 (4.18)	64 (62-66.25)		
70-79 years	73.52 (4.22)	74 (72-76)		
Systemic diseases				
None	_	_	_	178 (89.0%)
HTN				18 (9.0%)
COPD				2 (1.0%)
Thyroid disorder				2 (1.0%)
Surgical intervention				
None	_	_	_	193 (96.5%)
Cataract surgery				7 (3.5%)
Time since surgery (years)	3.00±1.73	2.00 (2.00-4.00)	1.00-6.00	_
Medication history				
None	_	_	_	184 (92.0%)
Antihypertensives				15 (7.5%)
Thyroxine				1 (0.5%)

COPD=chronic obstructive pulmonary disease, HTN=hypertension, IQR=interquartile range, SD=standard deviation

Table 2: Summary of ophthalmic examination and average SPARCS scores

Ophthalmic examination	Mean±SD	Median (IQR)	Min.-max.
BCVA (logMAR)			
OD	0.13±0.15	0.00 (0.00-0.2)	0.00-0.6
OS	0.12±0.11	0.00 (0.00-0.2)	0.00-0.50
Spherical error (diopters)			
OD	0.96±0.68	0.75 (0.50-1.25)	0.00-3.25
OS	0.64±0.60	0.50 (0.19-0.75)	0.00-2.75
Cylindrical error (diopters)			
OD	0.12±0.33	(0.00-0.00)	0.00-1.50
OS	0.05±0.21	0.00 (0.00-0.00)	0.00-1.00
IOP			
OD	13.44±2.13		
OS	13.49±2.06		
Lens			
Clear	372		
Cataract (<NS2/NO2)	21		
Monofocal IOL	7		
SPARCS score (total)			
Practice test	77.08±7.86	78.00 (72.75-83.00)	42.0-93.0
Main test (OD)	79.38±9.05	81.00 (76.00-85.00)	43.0-98.0
Main test (OS)	79.40±8.39	81.50 (74.00-85.00)	52.0-98.0
Binocular	83.89±6.46	85.00 (81.00-88.00)	63.0-96.0
SPARCS score (ST)			
Practice test	14.70±2.14	14.43 (13.32-16.67)	9.3-17.7
Main test (OD)	15.29±2.05	15.59 (14.04-17.43)	10.0-20.0
Main test (OS)	15.34±2.04	15.93 (14.04-17.43)	10.0-20.0
Binocular	15.57±2.20	15.93 (14.04-17.43)	11.9-20.0
SPARCS score (SN)			
Practice test	14.24±2.41	14.04 (12.30-15.93)	5.3-20.0
Main test (OD)	15.17±2.15	15.93 (14.04-17.43)	10.0-17.4
Main test (OS)	14.90±2.20	14.87 (13.37-16.64)	5.9-20.0
Binocular	14.90±2.20	15.93 (14.04-17.43)	10.0-20.0
SPARCS score (CC)			
Practice test	16.92±3.43	20.00 (14.04-20.00)	9.8-20.0
Main test (OD)	17.74±3.22	20.00 (15.93-20.00)	10.0-20.0
Main test (OS)	17.41±3.25	20.00 (14.04-20.00)	4.6-20.0
Binocular	17.92±2.99	20.00 (15.93-20.00)	2.3-20.0
SPARCS score (IT)		14.04 (12.30-15.93)	4.4-20.0
Practice test	14.35±2.34	14.87 (13.37-17.43)	8.0-17.4
Main test (OD)	14.80±2.37	14.04 (13.37-15.93)	10.0-20.0
Main test (OS)	14.65±1.90	15.20 (13.37-17.43)	10.0-20.0
Binocular	15.06±2.16		
SPARCS score (IN)			
Practice test	14.07±1.99	14.04 (12.30-15.63)	9.8-20.0
Main test (OD)	14.83±2.03	14.87 (13.60-16.64)	9.8-17.4
Main test (OS)	14.25±2.06	14.04 (13.20-15.93)	7.6-20.0
Binocular	14.91±2.03	14.31 (13.99-16.62)	10.0-20.0
Time duration			
Practice test	6.33±1.23	6.34 (5.33-7.25)	4.0-10.4
Main test (OD)	5.41±1.05	5.24 (4.62-5.97)	2.9-9.1
Main test (OS)	5.99±1.17	5.88 (5.03-6.60)	4.0-13.4
Binocular	5.41±0.91	5.29 (4.63-6.06)	3.3-7.8

BCVA=best corrected visual acuity, IOL=intraocular lens, IQR=interquartile range, SD=standard deviation, SPARCS=Spaeth/Richman contrast sensitivity test

luminance. We maintained standard lighting conditions to negate the difference in CS under photopic and mesopic conditions, which has been observed in few previous studies.[8] Our testing setup was similar to the one used by Gupta *et al*.;[3] however, in our study, all the tests were performed under specific lighting conditions that were calibrated using a luxmeter application. Additionally, with the help of Color Calibration Wizard of Windows 10, we calibrated gamma and color balance from time to time.

It is well established that CS follows a developmental trajectory,[7] improving up to the age of 12 years and a decline is seen in later life around 40–50 years, which is confined to high spatial frequencies. Our study reaffirmed that older subjects have significantly reduced CS ($P < 0.05$) when compared to

Table 3: SPARCS scores and time taken for test age group wise

	Age group (years)						Kruskal-Wallis test	
	20-29	30-39	40-49	50-59	60-69	70-79 Years	χ^2	*P*
SPARCS total (uniocular- OD)								
Mean (SD)	86.68 (4.86)	81.73 (3.99)	79.70 (8.40)	79.00 (5.31)	76.41 (8.27)	67.44 (11.98)	72.024	<0.001
Median (IQR)	86 (83-90)	82 (78-85)	81 (76.5-85)	80 (75-83)	78 (74-82.25)	67 (58-76)		
Range	80-98	73-89	45-90	65-87	56-87	43-86		
SPARCS total (uniocular- OS)								
Mean (SD)	84.17 (6.39)	82.95 (5.03)	79.73 (6.62)	79.48 (7.30)	75.66 (8.96)	70.04 (8.92)	57.391	<0.001
Median (IQR)	85 (82-87)	84 (81-85)	81 (76.5-83.75)	80 (76-84)	74.5 (70.75-82)	72 (65-75)		
Range	64-98	69-93	56-90	61-94	59-94	52-82		
SPARCS (total) (binocular)								
Mean (SD)	86.51 (5.18)	85.90 (3.60)	83.23 (3.53)	87.68 (4.04)	81.59 (5.75)	75.36 (8.99)	20.776	<0.001
Median (IQR)	87 (82-89)	86 (84-88)	83.5 (81-85)	87 (84-90.5)	82 (77.5-85.25)	75 (68-80)		
Range	76-96	76-94	74-90	80-96	71-94	63-94		
	Time taken (minutes)						*P*	
Test duration (practice)	5.55±0.91	5.73±0.91	6.08±1.06	7.34±1.25	6.57±0.94	7.35±1.03	<0.001[1]	
Test duration (main test- OD)	4.91±0.63	5.23±1.12	5.16±0.95	5.22±0.77	5.93±1.04	6.39±1.11	<0.001[1]	
Test duration (main test- OS)	5.22±0.75	5.50±0.70	5.94±1.21	6.42±0.97	6.35±0.95	7.15±1.51	<0.001[1]	
Test duration (binocular)	4.66±0.38	5.05±0.63	5.15±0.82	6.06±0.94	5.69±0.70	6.40±0.69	<0.001[2]	

IQR=interquartile range, SD=standard deviation, SPARCS=Spaeth/Richman contrast sensitivity test

younger counterparts. Richman *et al*.[9] were among the first ones to conduct studies using SPARCS. While comparing SPARCS scores in glaucoma patients and normal population, they noted a total SPARCS score ranging from 87.2 to 52.9 in their group of controls, from the age group of 20–30 years to over 80 years. Gupta *et al*.[3] established a normative SPARCS database in Caucasian eyes, noting a range of total SPARCS score from 86.37 (20–29 years age group) to 74.51 (70–79 years age group). Similarly, our study evaluated SPARCS scores specifically for healthy Indian eyes and noted scores ranging from 86.68 (20–29 years age group) to 67.44 (70–79 years age group). Previous studies have also noted similar decline in CS scores with increasing age, using different tests of CS. Ross *et al*.[10] used stationary sine-wave gratings on an oscilloscope to determine CS in Caucasian eyes, noting a range of 1.648 (20–30 years age group) to 1.435 (50–87 years age group). Another study by Sia *et al*.[11] used Vectorvision CSV-1000 test chart in Australian eyes and observed similar decline in CS scores with age (from 1.7 [35–44 years age group] to 1.38 [75 + years]) for medium to high spatial frequency. Tang and Zhou[12] explained this decline in CS as an age-related anatomical and physiological change in visual sensory pathway, including the cortex (major), lateral geniculate nucleus, photoreceptors, and retinal ganglion cells (minor). Environmental differences during development might also affect the adult sensitivity due to prolonged adaptation to a restricted range of contrast.[11]

Time duration to take the test was also studied across various age groups. It was observed that older subjects took more time (6.39 min for 70–79 years age group) to complete the test than the younger ones (4.91 min for 20–29 years age group). The increasing difference in the duration to complete the test was statistically significant ($P < 0.05$). The explanation behind this was given by Porciatti,[13] who stated that the reaction time to sensory stimuli slows down with age by approximately 75 ms at low velocity (1 deg/sec) and by 44 ms at high velocity (10 deg/sec). This appreciable increase in reaction time may be due to slowing of sensory and motor responses and deterioration of vision with aging.

In our study, we observed that females performed better than males during uniocular testing across all the age groups. Our findings resonate with those noted by Brabyn and McGuinness,[14] and the possible explanation is that females are more anisotropic than males. Differential patterns of horizontal eye movements between the sexes may be involved, with females using more frequent or more rapid saccades. Literature has been mixed about gender influence on CS. A study by Solberg and Brown[15] suggested that males and females do not differ in terms of CS. Abramov *et al*.[16] put forward the "hunter–gatherer hypothesis" to support that males are more sensitive to high spatial frequencies, whereas females do better for static or slow-moving targets. This theory used historical roles of males and females as hunters and gatherers, respectively, to support the difference in CS.

We also observed statistically significant difference in total SPARCS scores between participants with cataract (70.9 ± 8.21) and pseudophakic (75.20 ± 10.55) participants ($P < 0.05$). None of the pseudophakic subjects had posterior capsular opacification.

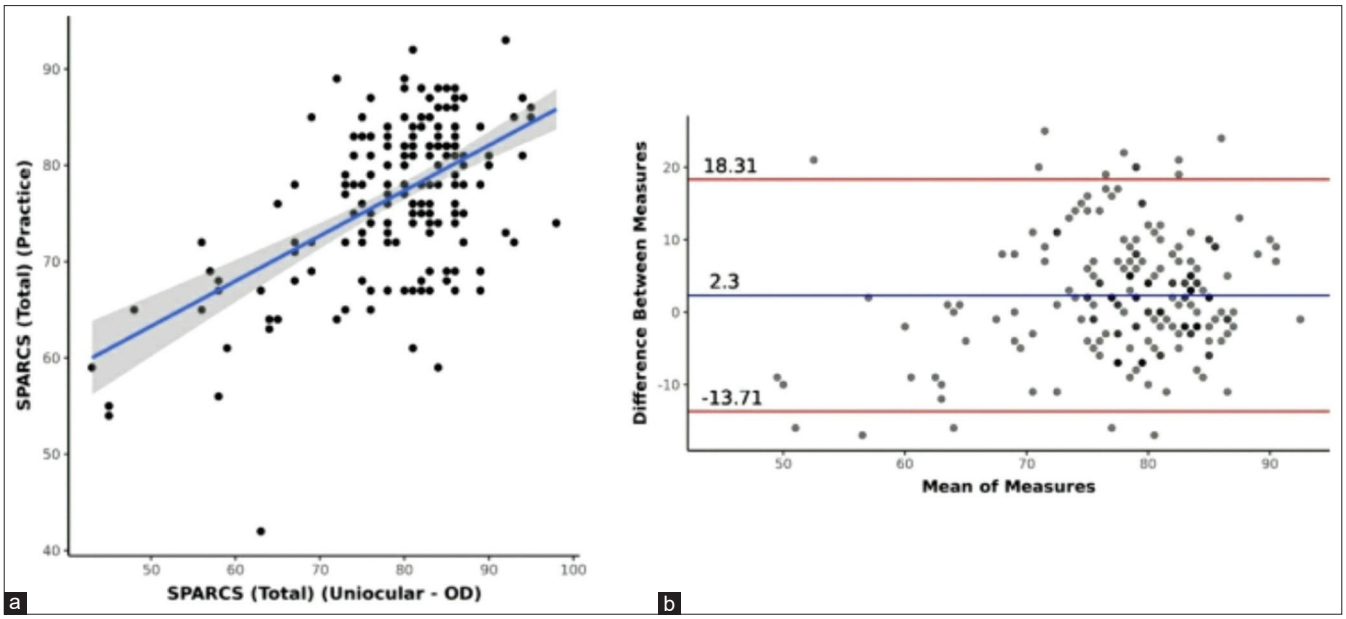

Figure 1: Agreement between SPARCS (TOTAL) (Practice) and SPARCS (TOTAL) (Uniocular OD) (*n*=200). (a) Scatterplot showing association between SPARCS (TOTAL) (Practice) and SPARCS (TOTAL) (Uniocular OD). Blue line represents general trend of correlation between two variables; shaded grey area represents the 95% confidence interval of this trendline. Stastically significant correlation (ICC=0.54, *P*<0.001) (b) Bland Altman plot comparing the mean and difference between the two measures. Blue line represents the mean of difference between two measures, red line represents limits of agreement (mean ± 2SD) (92.5% observations had a difference within the limits of agreement (±16.01))

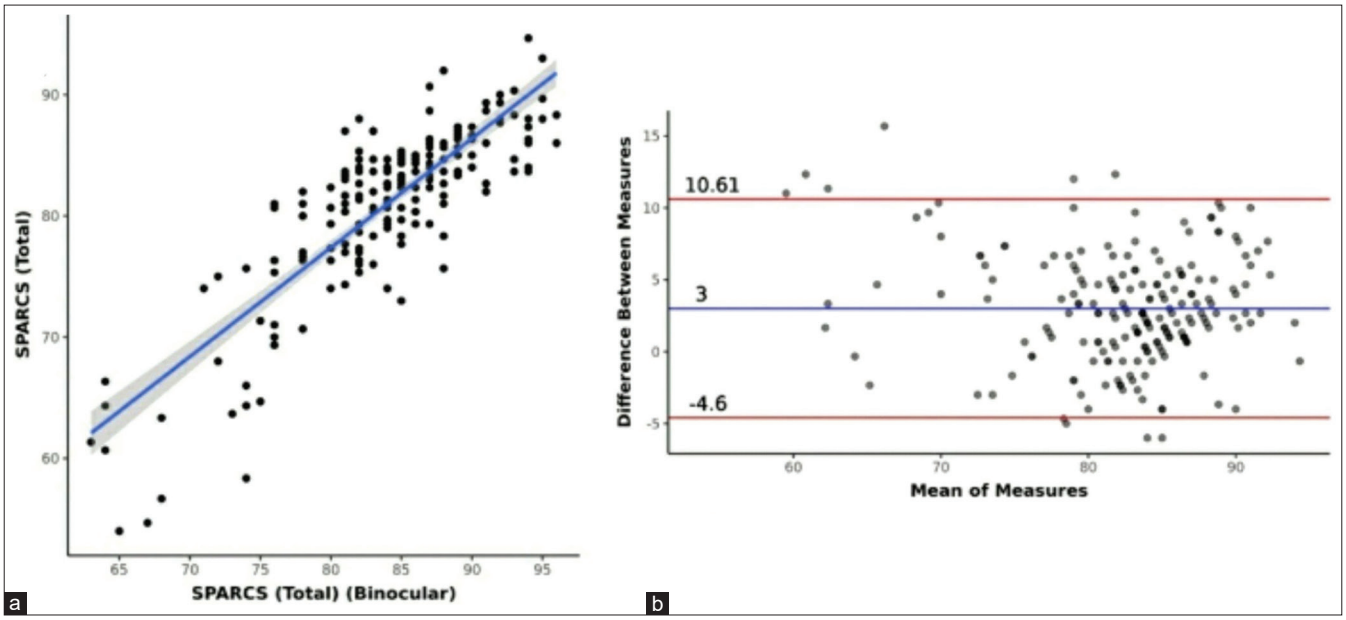

Figure 2: Agreement between SPARCS (TOTAL) and SPARCS (TOTAL) (Uniocular OD) (*n* = 200) (a) Scatterplot showing association between SPARCS (TOTAL) (Binocular) and SPARCS (TOTAL) (Average). Blue line represents general trend of correlation between two variables; shaded grey area represents the 95% confidence interval of this trendline. Stastically significant correlation (ICC=0.83, *P*<0.001) (b) Bland Altman plot comparing the mean and difference between the two measures. Blue line represents the mean of difference between two measures, red line represents limits of agreement (mean ± 2SD) (95% observations had a difference within the limits of agreement (±7.60))

Since only seven patients were pseudophakic, our findings cannot be extrapolated onto the general population and the effect of monofocal IOLs on CS cannot be ascertained from such a small sample size. This finding is different from what was observed by Gupta *et al.*,[3] who had noted lower CS in pseudophakes than cataracts.

A statistically significant difference ($P < 0.001$) was noted between average SPARCS scores of uniocular practice test OD (77.08 ± 7.86) and main test OD (79.38 ± 9.05). The association between the two measures is described in Fig. 1a and b. This difference can be explained as a learning curve for the test. Based on our findings, we suggest that

while performing SPARCS, a practice test must be performed to acquaint the patient with the test. The difference in average SPARCS scores, however, was not statistically significant between OD and OS. Quadrant-wise scores were highest in the central quadrant followed by superotemporal quadrant, superonasal quadrant, inferotemporal quadrant, and lastly, in the inferonasal quadrant.

We also performed binocular CS testing and noted better average scores than the uniocular tests with less test duration for completion of the binocular test. The association between the two measures is described in Fig. 2a and b. Previous studies have examined uniocular CS in normal and pathological conditions, whereas in the real world, patient uses binocularity to identify targets and perform tasks. A study by Alberti and Bex[17] explained binocular contrast summation in healthy eyes, where binocular CS was greater than monocular CS and a stimulus could sometimes be detected binocularly when its contrast was too low to be detected by either of the two eyes independently. The same study also highlighted that binocular vision may underestimate the vision of weaker eye, because the worse eye may be suppressed (impaired stereoacuity, difference in fixation patterns from those in monocular condition).

In the current clinical scenario, CS is an underperformed and undervalued test. Subtle changes in CS may be seen in early stages of diseases such as glaucoma and multiple sclerosis,[2,18,19] which might not be apparent on clinical examination. Thus, CS testing may hold a key in picking up early changes in disorders of afferent visual system. Chart-based or letter-based tests of CS suffer from several shortcomings such as equipment cost, inability to perform test in illiterates, uneven lighting conditions, and poor test–retest repeatability. SPARCS overcomes all these limitations.

Conclusion

We present an age-based normative database for central and peripheral CS using SPARCS in the Indian population. The strengths of our study include a robust sample size, standardized lighting conditions, uniocular as well as binocular testing, and a practice test (to negate a learning curve). Testing at a fixed, low spatial frequency is a relative drawback of SPARCS, but this low spatial frequency end of vision provides a complement to Snellen VA.[9,20]

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Thayaparan K, Crossland MD, Rubin GS. Clinical assessment of two new contrast sensitivity charts. Br J Ophthalmol 2007;91:749–52.
2. Regan D, Silver R, Murray TJ. Visual acuity and contrast sensitivity in multiple sclerosis-hidden visual loss: An auxiliary diagnostic test. Brain 1977;100:563-79.
3. Gupta L, Waisbourd M, Sanvicente CT, Hsieh M, Wizov SS, Spaeth EE, *et al*. Establishment of a normative database and evaluation of the test-retest repeatability of the Spaeth/Richman contrast sensitivity test. Jpn J Ophthalmol 2019;63:73–81.
4. Chylack LT Jr, Wolfe JK, Singer DM, Leske MC, Bullimore MA, Bailey IL, *et al*. The lens opacities classification system III. The longitudinal study of cataract study group. Arch Ophthalmol 1993;111:831-6.
5. Baker DH. What is the primary cause of individual differences in contrast sensitivity? PLoS One 2013;8:e69536.
6. Haak KV. Genetic influence on contrast sensitivity in young adults. Acta Ophthalmol 2019;97:e663-4.
7. Oen FT, Lim TH, Chung MP. Contrast sensitivity in a large adult population. Ann Acad Med Singap 1994;23:322-6.
8. Puell MC, Palomo C, Sánchez-Ramos C, Villena C. Normal values for photopic and mesopic letter contrast sensitivity. J Refract Surg 2004;20:484-8.
9. Richman J, Spaeth GL, Wirostko B. Contrast sensitivity basics and a critique of currently available tests. J Cataract Refract Surg 2013;39:1100–6.
10. Ross JE, Clarke DD, Bron AJ. Effect of age on contrast sensitivity function: Uniocular and binocular findings. Br J Ophthalmol 1985;69:51-6.
11. Sia DI, Martin S, Wittert G, Casson RJ. Age-related change in contrast sensitivity among Australian male adults: Florey Adult Male Ageing Study. Acta Ophthalmol 2013;91:312-7.
12. Tang Y, Zhou Y. Age-related decline of contrast sensitivity for second-order stimuli: Earlier onset, but slower progression, than for first-order stimuli. J Vis 2009;9:18.
13. Porciatti V, Fiorentini A, Morrone MC, Burr DC. The effects of ageing on reaction times to motion onset. Vision Res 1999;39:2157-64.
14. Brabyn LB, McGuinness D. Gender differences in response to spatial frequency and stimulus orientation. Perception & Psychophysics 1979;26:319–24.
15. Solberg JL, Brown JM. No sex differences in contrast sensitivity and reaction time to spatial frequency. Percept Mot Skills 2002;94:1053-5.
16. Abramov I, Gordon J, Feldman O, Chavarga A. Sex & vision I: Spatio-temporal resolution. Biol Sex Differ 2012;3:20.
17. Alberti CF, Bex PJ. Binocular contrast summation and inhibition depends on spatial frequency, eccentricity and binocular disparity. Ophthalmic Physiol Opt 2018;38:525-37.
18. Atkin A, Wolkstein M, Bodis-Wollner I, Anders M, Kels B, Podos SM. Interocular comparison of contrast sensitivities in glaucoma patients and suspects. Br J Ophthalmol 1980;64:858-62.
19. Bodis-Wollner I, Diamond SP. The measurement of spatial contrast sensitivity in cases of blurred vision associated with cerebral lesions. Brain 1976;99:695-710.
20. Richman J, Zangalli C, Lu L, Wizov SS, Spaeth E, Spaeth GL The Spaeth/Richman contrast sensitivity test (SPARCS): Design, reproducibility and ability to identify patients with glaucoma. Br J Ophthalmol 2014;99:16–20.