TITLE: Assessment of visual function and structural retinal changes in Zen meditators: Potential effect of mindfulness on visual ability

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All subjects provided detailed consent to participate in this study, which was conducted in accordance with the guidelines established by the Ethics Committee of the Miguel Servet Hospital and based on the principles of the Declaration of Helsinki.

ABSTRACT

The aim of the present study was to evaluate whether Zen meditation (a mindfulness-based practice) stimulates visual function and increases retinal and retinal nerve fiber layer (RNFL) thickness. This cross-sectional controlled study included 36 eyes of 18 meditators and 76 eyes of 38 age- and sex-matched healthy non-meditators. The average response of both eyes in each subject was analysed. All subjects underwent evaluation of high and low contrast visual acuity (using ETDRS charts), contrast sensitivity vision (CSV) using the Pelli Robson chart and CSV 1000E test, color vision (using the Farnsworth and L´Anthony desaturated D15 color tests), stereoscopic vision using the TNO test, and retinal and RNFL thickness using optical coherence tomography (OCT). Differences in visual function and RNFL thickness were compared between groups. Our results indicated that meditators exhibited significantly better visual acuity with the three contrast levels used, and significantly better contrast sensitivity vision (CSV 1000E) than healthy non-meditators ($p \leq 0.05$). Retinal and RNFL structural measurements did not differ significantly between groups. Ganglion cell layer thickness was moderately correlated with visual acuity, CSV, color vision, and stereoscopic vision ($p \leq 0.05$; $r > 0.6$). In conclusion, visual function was enhanced in meditators without significant alterations in the retinal morphologic structure. Further studies are needed to determine whether there is a causal association between mindfulness and visual function improvement.

KEY WORDS: Mindfulness, retinal nerve fiber layer, ganglion cell layer, optical coherence tomography, visual function.

INTRODUCTION

The scientific basis of mindfulness involves the capture of a quality of consciousness characterized by clarity and vividness of current experience and functioning, and may be important for disengaging individuals from automatic thoughts, habits, and unhealthy behavior patterns, thus having a potentially key role in fostering informed and self-endorsed behavioral regulation, which has long been associated with enhanced well-being (Ryan and Deci 2000). Theorists from many schools of personality theory and psychotherapy have discussed the importance of observant open awareness and attention in the optimization of self-regulation and well-being (Martin 1997). Mindfulness meditation has beneficial effects on a number of psychiatric (mainly anxiety and depression disorders), functional somatic, and stress-related symptoms and, therefore, has been increasingly incorporated into psychotherapeutic programs (Baer 2003). Mindfulness practice typically recruits a number of brain regions, mainly prefrontal, parietal, and subcortical brain areas. Due to its widespread activation pattern, distributed functional brain networks are suggested to be critical neural correlates of mindfulness practice (Hasenkamp and Barsalou 2012). The scientific basis of mindfulness involves attention, body awareness, regulation of emotion, changes in self perspective, and neural modulation of specific brain areas, including the anterior cingulate cortex, posterior cingulate cortex, medial prefrontal cortex, insula, temporo-parietal junction, hippocampus, and amygdala (Hölzel et al. 2011).

Four different mental states during meditation were recently identified. Each state is preferentially related to activity in different intrinsic brain networks, and these networks are believed to promote specific cognitive functions, such as attentional control or core affect (Hinterberger et al. 2014).

Several neuroimaging studies support these findings. Recent papers demonstrated differences in grey matter and/or white matter, and even longitudinal changes in the brains of meditators (Grant et al. 2010). Cross-sectional studies comparing mindfulness meditators with non-meditators revealed a higher grey matter concentration in the hippocampus in meditators (Hölzel et al. 2008).

Evidence suggests that attentional brain regions are involved in many meditative practices. Not all studies agree on which regions are active during meditation, however, and it is likely that the findings are dependent on the particular practice studied and methodology used (Brefczynski-Lewis e al. 2007). It is generally thought that repeated engagement of relevant brain networks over time induces neuroplastic changes that mediate positive cognitive, emotional, and behavioral outcomes.

Various studies report a correlation between axonal loss observed in the optic nerve and visual dysfunction in neurodegenerative diseases based on findings from digital imaging techniques, such as optical coherence tomography (OCT) (Bambo et al. 2014; Fisher et al. 2006; Sepulcre et al. 2007). More recently, segmentation analysis of the different retinal layers provided by new software programs for OCT have provided a more specific measurement of the retinal ganglion cell layer (GCL) and suggested correlations not only with axonal structures in the optic nerve, but also with central nervous system structures (Saidha et al. 2011; Syc et al 2012). Based on these findings, it is likely that mindfulness based-practices could positively influence visual function by enhancing neuroplasticity in the central nervous system. For example, the right dorsal anterior cingulate cortex, thought to have a role in vision-related cognition and emotion such as anxiety (Shimura et al. 2013), is responsive to mindfulness practice (Hölzel et al. 2011).

Neurodegenerative processes such as multiple sclerosis and Parkinson disease are widely associated with visual problems, including loss of visual acuity, defects in color vision and visual masking tests, changes in pupillary response to mydriatics, changes in contrast sensitivity function, and visual evoked potentials (Elliott et al. 2015). Other findings include disturbances of complex visual functions such as in reading ability, visuospatial function, and naming and identifying objects (Armstrong and Kergoat 2015). Zen meditation may be considered a potential brain activity enhancer and even a complementary activity to improve quality of life and visual function in patients with some evidence of neurodegeneration. Thus, the aim of the present study was to explore the potential association of regular mindfulness practice with objective visual function parameters and retinal structure measurements

METHOD

Participants

The study included 36 eyes from 18 meditators and 76 eyes from 38 age- and sex-matched healthy non-meditators.

The group of meditators was recruited from the Soto Zen Spanish Buddhist community. The subjects included in the study met the following inclusion criteria: 18 to 65 years old; able to understand Spanish; long-term Zen meditative practice (at least 8 years meditating for an average of 1 hour daily), previous to that period of 8 years the participant could have practiced any other kind of meditation; no psychiatric disorder or pharmacologic treatment for at least 1 year before the study began. Exclusion criteria were the presence of significant refractive errors (>5 diopters of spherical equivalent refraction or 3 diopters of astigmatism); intraocular pressure ≥21 mmHg; media opacifications; concomitant ocular disease, including history of glaucoma or retinal pathology; systemic conditions that could affect the visual system; evidence of ocular, psychiatric or neurologic disease of any nature; or best-corrected visual acuity (BCVA) on the Snellen scale <20/30.

Procedure

All subjects underwent a complete ophthalmologic examination, including anterior segment, pupillary reflex, and funduscopic evaluation. Visual function was assessed by measuring the BCVA using an ETDRS chart with three contrasts (100%, 2.50%, and 1.25%), contrast sensitivity vision (CSV) using CSV 1000E test and Pelli-Robson chart, color vision using the Farnsworth desaturated D15 and L´Anthony desaturated D15 tests, and stereoscopic vision using the TNO test. All vision function measurements were obtained under monocular vision and controlled lighting conditions (photopic - mean luminance of 85 cd/m^2, high mesopic -5 cd/m^2, and low mesopic -3 cd/m^2) with best correction.

All procedures adhered to the tenets of the Declaration of Helsinki, and the local ethics committee approved the experimental protocol. All participants provided informed consent to participate in the study. In this study, the average measurements of both eyes in each subject were included in the analysis.

In this study, we considered Zen meditation as being “constantly aware of what is occurring in the present moment to keep the mind in the specific state in which the experiential insight (*satori*) can arise”, which is closely related to the concept of mindfulness described above (Chiesa and Malinowski 2011).

Measures

Best-corrected visual acuity (BCVA) was evaluated using an ETDRS chart at three contrast levels: 100%, 2.50%, and 1.25% (% being the level of contrast, i.e., 100% representing black letters over white background and 1.25% light grey letters over white background).

Contrast sensitivity vision (CSV) is a better tool than visual acuity for evaluating visual function. The definition of "contrast" is technically the difference in brightness between light and dark bands, divided by the mean brightness. The "contrast threshold" is the minimum contrast required for a group of bands and letters to be perceived by the eye, and the term "contrast sensitivity" is considered to be its inverse. We used two tests to measure CSV: the CSV 1000E and the Pelli-Robson.

The CSV-1000E instrument is used worldwide for standardized CSV and glare testing. All patients were evaluated at a distance of 2.5 m from the chart under monocular vision at four spatial frequencies (3, 6, 12, and 18 cycles per degree [cpd]). The chart comprised four rows of patches. Each row presented 17 circular patches 1.5 inches in diameter. The first patch on the left in each row presented a very high contrast grating (sample patch). The remaining 16 patches appear in 8 columns across the row. In each column, one patch presents a grating and the other patch is blank. The patches that present a grating decrease in contrast moving from left to right across the row. The patient indicates whether the grating appears in the top patch or the bottom patch for each column. The CSV curve, in which the visual threshold was represented for each spatial frequency, was analyzed. Each contrast value for each spatial frequency was then transformed into a logarithmic scale according to standardized values.

The Pelli-Robson chart comprises horizontal lines of capital letters over a white background, organized in triplets, with two triplets per line, and each triplet having the same contrast: the contrast decreases from one triplet to the next, even within each line, and there is a record of the score corresponding to the last triplet seen by the patients.

Stereopsis is defined as the perception of depth produced by the detection of two visual stimuli from both eyes in combination, and is considered the maximum development of binocular vision necessary the presence of fusion. The TNO test is considered the most reliable test for measuring stereoscopic vision. It consists of a near vision duochrome chart (red-green), to be used at 40 cm, and is formed by seven sheets. The three first charts inform about the existence of stereopsis, the fourth one indicates if one eye is being neutralized, and the three last pages quantify the stereopsis from 480” to 15” of arch. The tests were performed under binocular vision.

Color vision was assessed using the Color Vision Recorder program. This software is designed for the Windows operating system and analyzes chromatic discrimination by classification of colors. It includes the classic test of Farnsworth 100-hue (FM-100), Farnsworth - Munsell D15, and L´Anthony D15. All patients in the study were evaluated using the Farnsworth - Munsell D15 and L´Anthony D15 protocols (often used to differentiate between subjects with severe loss of color vision and those with milder color defects or normal color vision), and different output parameters, such as the Confusion Index, Color Confusion Index (CCI), Confusion angle, and Scatter Index, were recorded (Bowman 1982; Vingrys & King-Smith 1988). The tests were performed under monocular vision.

Structural analysis of the retina and retinal nerve fiber layer (RNFL) was performed using the Cirrus OCT device by the same experienced operator and manual correction of the OCT output was not applied. An internal fixation target was used because it provides the highest reproducibility (Schumann et al. 1996), and poor quality scans were rejected prior to data analyses. Image quality assessment was based on the signal strength measurement that combines the signal-to-noise ratio with the uniformity of the signal within a scan (scale 1–10, where 1 is categorized as poor image quality and 10 as excellent). Images included for evaluation had a quality score of at least 7.

The Cirrus OCT optic disc protocol generates 200 x 200 cube images with 200 linear scans enabling analysis of the RNFL of a 6-mm^3 area around the optic nerve. For each scan series of RNFL analysis, the mean, superior, inferior, temporal, and nasal thickness was measured.

Cirrus segmentation analysis for retinal layers also provides measurements of GCL thickness, evaluating six areas of the macular cube (superior, superonasal, inferonasal, inferior, inferotemporal, and superotemporal sectors) and measurements of the mean and minimum GCL plus the inner plexiform layer (GCL + IPL) value of a set of 360 spokes, where each average represents the mean number of the pixels along the spoke that lies within the measurement annulus. The minimum is selected because the thinnest portion of the GCL + IPL in the perifoveal region is considered to indicate the status of the ganglion cells (the most important cells in the visual pathway).

Data Analyses

All data analyses were performed using SPSS software version 20.0 (SPSS Inc., Chicago, IL). The Kolmogorov-Smirnov test was used to assess sample distribution. Due to the parametric distribution of the data, differences between the two groups of the study were compared using Student’s t test and the Bonferroni correction for multiple comparisons among the structural parameters analyzed. A correlation study was conducted between the structural and functional parameters in the meditators group to measure the strength of the association. We examined whether reduction in RNFL thickness was associated with a vision decrease (contrast sensibility or visual acuity reduction or loss in chromatic discrimination). A correlation analysis between years of practicing mindfulness and visual function was performed. The linear correlation was determined using Pearson's correlation coefficient. Values of $p \leq 0.05$ were considered to indicate statistically significant differences and $p \leq 0.005$ in cases where the Bonferroni correction was used.

RESULTS

A total of 18 meditators and 38 non-meditator healthy controls were included in the study. The mean age of the meditators was 49 years (SD=11.98) and the mean age of the healthy controls was 49 years (SD=8.33). There were no statistically significant differences in age (p=0.952), sex (p=0.455), or intraocular pressure (p=0.771) between groups.

Functional parameter: Meditators had a better BCVA at all three contrast levels of the ETDRS chart compared to controls (-0.118±0.04 in meditators vs -0.090±0.08 in controls at 100%, p=0.027; 0.276±0.13 vs 0.398±0.10 at 2.50%, p<0.001; and 0.421±0.16 vs 0.531±0.13 at 1.25%, p<0.001) using Bonferroni analysis for multiple tests. CSV was better in meditators examined at the 18 cpd frequency of the CSV 1000E chart, when analyzed based on the number of correct localized gratings (1.25±0.28 in meditators vs 1.16±0.19 in non-meditators, p=0.049). Results for the other frequencies examined in the tests (3, 6, and 12 cpd) revealed no statistically significant differences (p=0.285, p=0.755, and p=0.621, respectively). The results of the Pelli Robson, color vision (L´Anthony and Farnsworth indexes), and stereoscopic vision (TNO) tests were not significantly different between groups. The results are shown in Table 1.

Structural parameters: Retinal and RNFL measurements obtained by OCT revealed no significant differences between groups. The results are shown in Table 2.

Correlation between functional and structural parameters: The nasal and inferonasal measurements of the GCL were significantly correlated with functional parameters. The Farnsworth AC CCI correlated with the nasal GCL ($r=-0.653$; $p<0.001$) and inferonasal GCL ($r=-0.630$; $p<0.001$). The Farnsworth C Index was moderately and inversely correlated with nasal GCL thickness ($r=-0.643$; $p<0.001$) and with the inferonasal thickness ($r=-0.629$; $p<0.001$). Nasal and inferonasal thicknesses correlated with the results of the Farnsworth CCI ($r=-0.646$ and -0.626 respectively, $p<0.05$) and with the Farnsworth S Index ($r=-0.664$ and $r= -0.636$, respectively, $p<0.05$).

The Pelli Robson CSV results were directly and strongly correlated with the nasal and inferonasal thickness measurements ($r=0.705$ for the nasal GCL and $r=0.632$ for the inferonasal GCL; $P<0.001$).

The correlation between the stereoscopic vision measured by the TNO test and RNFL thickness in the temporal quadrant was significant and moderate ($r=0.743$, $p<0.001$). The results are shown in Table 3.

The correlation analysis between years of practicing mindfulness and visual function revealed no statistically significant correlation.

DISCUSSION

The present study evaluated objective parameters of visual function and the morphologic structure of the retina in long-term Zen meditators in comparison with healthy non-meditating individuals to elucidate a possible association between brain changes in meditators and the visual pathway. Visual function was evaluated in mindfulness practitioners by quantifying visual acuity, which is often the only objective visual function parameter evaluated in routine ophthalmologic examinations, as well as at three different contrast levels, providing much more information (Lim et al. 2010). Other aspects of visual function, such as contrast sensitivity, color vision, and stereopsis, were also analyzed. We found that intensive Zen meditation practice is associated with better visual acuity (especially at low contrasts of 2.5% and 1.25%) and the differentiation of objects at different contrasts (especially at a frequency of 18 cpd). It is noteworthy that we measured the potential impact of mindfulness meditation on objective parameters of visual function, because one competing hypothesis would be that mindfulness better regulates anxiety and depression symptoms, which could modify the self-perception of visual acuity, as previously reported (Goodrich et al. 2014; Owsley and McGwin 2004).

The number of years meditating, however, was not correlated with eye function, and a possible explanation is that individuals who choose to meditate simply have better eye function to begin with. The potential causality between mindfulness and improvement in visual function requires further evaluation using experimental studies.

We also detected an association between nasal and inferonasal thickness of the GCL and color vision. Our findings revealed a low and moderate correlation between retinal structural parameters and visual functional tests, consistent with previous findings in patients with neurodegenerative disease (Garcia-Martin et al. 2013). Ganglion cells in the retina adapt to visual contrast and pool visual inputs over their receptive fields through an array of parallel bipolar cells with smaller receptive fields (Baccus and Meister 2002; Kim and Rieke 2001). Higher contrast is linked to reduced sensitivity of the retinal ganglion cells as well as altered temporal filtering characteristics, which results in faster responses, shorter integration times, and a preference for higher temporal frequencies.

Limitations of the study: Sample sizes were relatively small, which may have affected our ability to identify some potential associations. Meditators were not divided into groups depending on the frequency of their practice. This should be a topic of future studies. The study design does not allow us to rule out the possibility that individuals who choose to practice Zen meditation simply have better visual functioning to begin with, and thus further experimental studies are necessary. The intensity of the association in the correlation analysis was only moderate, with a maximum Pearson correlation factor (r) value of 0.743, although the results obtained are consistent.

This is a remarkable finding and consistent with other reported benefits of mindfulness. Pasquini et al reported electrophysiologic changes in long-term regular meditators (Pasquini et al. 2015). They used high-resolution electroencephalography applied to slow potentials, power spectra, and potencies related to the events to obtain encephalographic records in 17 Soto Zen Buddhist meditators. Induced beta band power is considered a direct electrophysiologic correlate of attention and relates to an increase in neuronal excitation and cognitive activity, reflecting externalized attention in higher vigilance and anticipation states. Induced theta power increases in a wide variety of tasks, and may be related, at least in part, to nonspecific factors related to the task, such as attentional demand. The main findings of their study were correlations between the frequency of weekly meditation practice and higher theta-induced relative power, higher induced power ratio (ratio theta/beta), and higher ratio of induced relative powers (theta/beta ratio). In our study, we did not analyze the frequency of meditation practice and only compared meditators versus non-mediators, but further analysis by subdividing the groups to correlate the frequency of practice with the magnitude of the findings is recommended, given the significant difference found in visual acuity and contrast sensitivity vision in the present study. Travis reported a beta band power increase in the frontal cortex during transcendental meditation practice, and related this finding to active attention processing (Travis 2011). Also, beta power significantly increases during the meditative state compared with the premeditative state (only sitting and relaxing) in yoga practitioners, highlighting a more vigorous brain activity during the meditative process (Travis 2011).

It is also possible that mindfulness practices are linked to an enhanced visual sensory experience by inducing dopamine release, as previously observed with Yoga Nidra, a type of mindfulness meditation (Kjaer et al. 2002).

The acute, short, and long-term modulatory effects of meditation on oxidative stress have been investigated (Mahagita 2010). Long-term transcendental and Zen meditators exhibit diminished oxidative stress based on reduced lipid peroxidation and biophoton emission. Glutathione levels and the antioxidant enzyme activity (catalase, superoxide dismutase, glutathione peroxidase, and glutathione reductase) are enhanced in Yoga and Sudarshan Kriya practitioners (Mahagita 2010). One year of Tai Chi training is reported to promote superoxide dismutase activity and lower lipid peroxidation (Mahagita 2010). Diaphragmatic breathing after exhaustive exercise more rapidly attenuates oxidative stress than normal breathing (Grant and Rainville 2009). These data suggest possible roles of meditation and meditation-based techniques for decreasing oxidative stress, which may help to prevent or alleviate deterioration of related diseases. Further research is needed, however, to elucidate the cellular and molecular mechanisms, which remains a challenge. Zen meditation is also associated with low sensitivity in both affective and sensory dimensions of pain. Grant evaluated gray matter differences in meditators as well as between patients with chronic pain and controls, and investigated whether the differences in brain morphometry are associated with the low pain sensitivity observed in Zen practitioners (Grant et al. 2010). When meditative practices are divided into the broad categories of focused attention (FA) and open monitoring (OM) techniques, OM influences both sensory and affective pain ratings. The neural pattern underlying pain modulation during OM suggests meditators actively focus on the noxious stimulation while inhibiting other mental processes, consistent with descriptions of mindfulness (Grant 2014). Together, these findings suggest that evaluation of the visual pathway and measurement of the retinal structure by OCT are clinically powerful tools for investigating cerebral damage as well as the potential benefits of techniques such as meditation. Researchers also observed that experienced meditators had increased gamma activity in the occipital and frontoparietal regions due to improved sensory awareness (Cahn et al. 2010).

Zen meditation is not an MBI, but rather it is a spiritual practice. Although MBI is not considered equivalent to a spiritual practice, some studies have focused on long-term meditators of spiritual practices such as Zen because they are considered to exemplify the benefit that can be obtained by practicing MBI for years. Examination of the integration of visual function and meditation is justified by several reports of changes in the brains of meditators (Fayed et al. 2013), and the retina is a part of the brain in which these changes can also appear. Meditation may modify the retinal structure as it does other parts of the brain. The findings are thought to be a consequence of the biologic changes that meditation produces in the brain.

The reason for the effect of Zen meditation on visual function is not clear, but we postulate that mindfulness relaxes crystalline deposits, favoring some aspects of visual function. Another possible explanation is that meditators have developed an aptitude to perceive more detail, such as changes in the color or the contrast.

The present findings demonstrated group differences in visual function in Zen meditators compared with non-meditators. Further studies with a larger sample size are needed to determine the usefulness of visual function tests and retinal measurements for evaluating the effects of Zen meditation in the brain and visual pathways.

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Table 1: Mean and standard deviation (SD) of visual functional parameters in meditators and healthy non-meditators. Results in bold letters indicate statistical significance (p≤0.05) and results with * indicate statistical significance using the Bonferroni correction (p≤0.002). Average measurements of both eyes in each subject were used in the analysis.

	MEDITATORS		**HEALTHY NON-MEDITATORS**		**SIGNIFICANCE (P)**
	Mean	SD	Mean	SD	
BCVA ETDRS 100	-0.11	0.03	-0,09	0.05	**0.025**
BCVA ETDRS 2.5	0.26	0.09	0.38	0.09	**<0.001***
BCVA ETDRS 1.25	0.43	0.13	0.51	0.11	**<0.001***
Pelli Robson	1.86	0.27	1.89	0.12	0.243
CSV 1000 3 cpd	1.68	0.15	1.74	0.16	0.334
CSV 1000 6 cpd	2.03	0.14	2.00	0.12	0.809
CSV 1000 12 cpd	1.68	0.20	1.65	0.15	0.556
CSV 1000 18 cpd	1.27	0.21	1.15	0.17	**0.041**
Farnsworth AC CCI	1.18	0.41	1.14	0.51	0.651
Farnsworth C- index	1.32	0.65	1.25	0.45	0.435
Farnsworth CCI	1.23	0.61	1.19	0.42	0.543
Farnsworth Conf Angle	55.12	18.67	55.45	28.01	0.890
Farnsworth S-index	1.99	1.21	1.68	0.40	0.091
Farnsworth time	75.65	29.09	87.90	46.78	0.303
L´Anthony AC CCI	1.12	0.45	1.11	0.48	0.954
L´ Anthony C-index	1.45	0.45	1.47	0.55	0.802
L´ Anthony CCI	1.34	0.54	1.34	0.57	0.979
L´ Anthony Conf Angle	53.24	48.90	54.00	37.09	0.809
L´ Anthony S-index	1.77	0.56	1.77	0.65	0.988
L´ Anthony time	87.45	42.88	90.87	47.99	0.657
TNO average	114.00	106.07	120.99	105.18	0.449

Abbreviations: BCVA, best corrected visual acuity; CSV, contrast sensitivity vision; ETDRS, early treatment diabetic retinopathy study; cpd, cycles per degree; AC CCI, age-corrected color confusion index; CCI, color confusion index; C-index, confusion index; Conf Angle, confusion angle; S-index, scatter index.

Table 2: Mean and standard deviation (SD) of structural parameters (retinal nerve fiber layer, ganglion cell layer and macular thicknesses) obtained with the Cirrus HD optical coherence tomography device in meditators and healthy non-meditators. Bold font indicates statistical significance (p≤0.05). No results were statistically significant using the Bonferroni correction (p≤0.003 for retinal nerve fiber layer thicknesses and p≤0.005 for ganglion cell analysis). Average measurements of both eyes in each subject were used in the analysis.

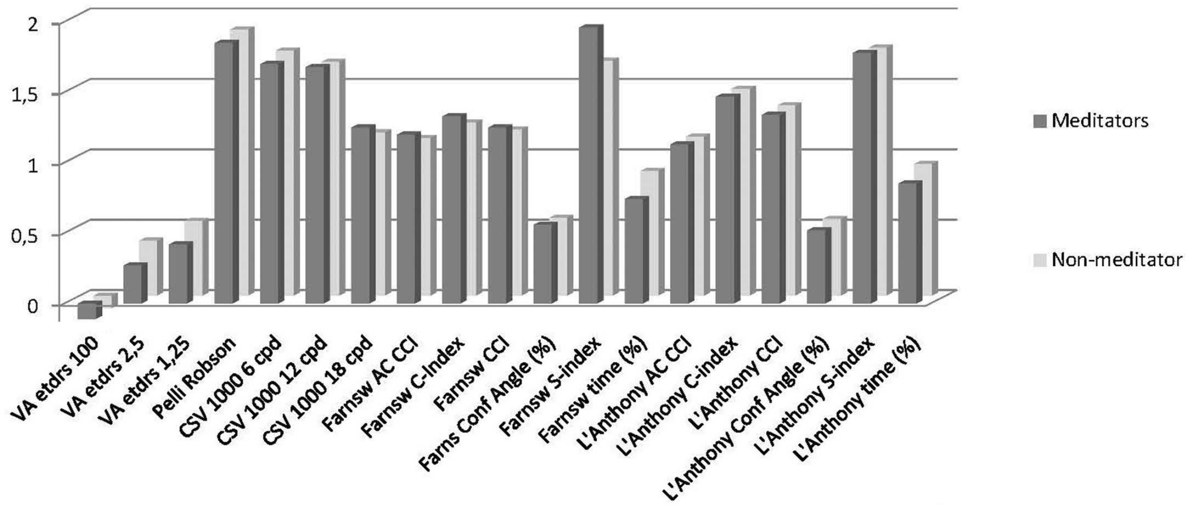
	STRUCTURAL PARAMETERS	MEDITATORS		NON MEDITATORS		**SIGNIFICANCE (P)**
		Mean	SD	Mean	SD	
Retinal nerve fiber layer thickness	Average	90.98	10.07	91.03	8.84	0.976
	Superior	114.23	14.65	113.33	11.31	0.543
	Nasal	69.69	10.25	68.39	9.67	0.375
	Inferior	119,30	24.22	121.57	14.56	0.444
	Temporal	61.07	13.695	65.89	12.87	**0.043**
	Sector 1	117.11	34.81	114.77	43.14	0.234
	Sector 2	106.32	34.12	104.00	23.59	0.314
	Sector 3	90.03	20.80	86.70	18.86	0.098
	Sector 4	54.68	15.66	56.99	16.92	0.505
	Sector 5	67.09	17.93	65.76	17.15	0.411
	Sector 6	100.11	18.61	100.98	21.50	0.769
	Sector 7	133.19	28.90	135.67	32.77	0.400
	Sector 8	121.42	13.82	126.90	18.22	0.081
	Sector 9	60.78	15.59	62.43	11.78	0.656
	Sector 10	48.32	7.84	52.07	16.68	0.200
	Sector 11	73.55	19.44	80.23	18.08	**0.016**
	Sector 12	119.0	15.55	127.34	21.09	**0.036**
Ganglion cell layer thickness	Avg. IPL+GCL	80.65	12.67	83.56	7.77	0.291
	Min. IPL+ GCL	77.19	9.60	79.32	4.09	0.520
	Fovea	255.29	7.07	256.60	6.43	0.896
	Inferior	78.34	7.12	83.59	4.04	0.123
	Inferonasal	79.43	6.79	82.76	9.11	0.404
	Nasal	82.90	6.54	85.65	4.21	0.302
	Superior	82.19	5.67	84.61	4.64	0.440
	Inferotemporal	81.71	6.22	82.23	5.50	0.821
	Temporal	80.65	7.03	81.02	4.11	0.900

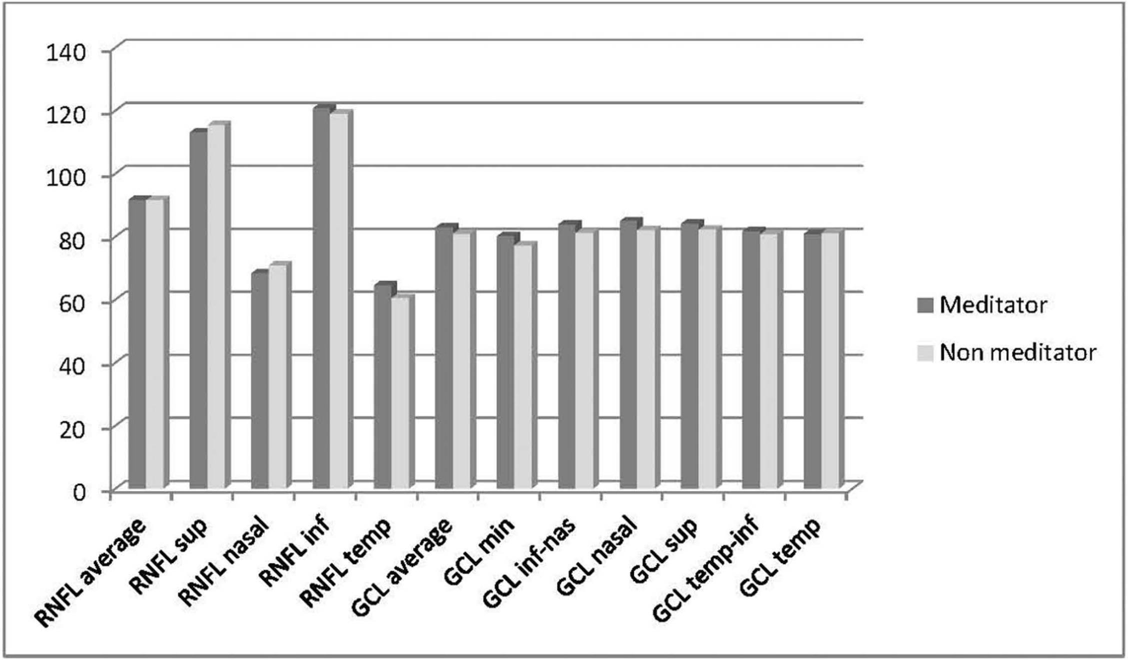
Abbreviations: GCL ganglion cell layer; IPL, inner plexiform layer; Min., minimum; Avg., average.

Table 3: Correlation between visual function parameters and structural parameters of the retina – retinal nerve fiber layer (RNFL) and ganglion cell layer thickness. Average measurements of both eyes in each subject were used in the analysis.

		Visual function parameters									
		BCVA ETDRS 100%		Pelli Robson		TNO		Farnsworth AC CCI		Farnsworth S Index	
		R	p	r	p	R	P	r	p	r	p
RNFL thickness	Average	-0.302	**0.012**	0.566	**<0.001**	0.390	0.077	-0.202	0.214	-0.121	0.207
	Superior	-0.299	**0.007**	0.446	**0.001**	0.289	0.301	-0.175	0.200	-0.144	0.321
	Nasal	-0.101	0.665	0.319	**0.005**	0.090	0.765	-0.021	0.906	0.198	0.346
	Inferior	-0.278	**0.014**	0.467	**<0.001**	0.381	0.092	-0.088	0.525	-0.079	0.598
	Temporal	-0.123	0.544	0.165	**0.002**	0.739	**<0.001**	-0.108	0.312	-0.163	0.134
Ganglion cell layer thickness	Superior	-0.210	0.201	0.632	**<0.001**	0.304	0.218	-0.576	**0.018**	-0.544	**0.021**
	Nasal	-0.209	0.306	0.700	**<0.001**	0.326	0.456	-0.599	**0.010**	-0.678	**<0.001**
	Inferonasal	-0.281	0.189	0.677	**<0.001**	0.399	0.511	-0.669	**<0.001**	-0.645	**<0.001**
	Inferior	-0.381	**0.015**	0.505	**<0.001**	0.105	0.733	-0.512	**0.027**	-0.512	**0.039**
	Inferotemporal	-0.324	**0.046**	0.465	**<0.001**	0.119	0.489	-0.322	0.091	-0.311	0.123
	Temporal	-0.290	0.098	0.512	**0.001**	0.278	0.333	-0.490	**0.026**	-0.479	**0.019**
	Average IPL+ GCL	-0.217	0.107	0.655	**<0.001**	0.178	0.675	-0.577	**0.004**	-0.567	**<0.001**
	Minimum IPL+ GCL	-0.376	**0.011**	0.530	**0.005**	0.097	0.661	-0.410	**0.047**	-0.521	**0.038**

Abbreviations: RNFL, retinal nerve fiber layer; r, Pearson correlation, BCVA, best corrected visual acuity; GCL ganglion cell layer; IPL, inner plexiform layer; CCI, color confusion index; S index, Scatter index.


2
1,5
1
0,5
0
VA etdrs 100
VA etdrs 2,5
VA etdrs 1,25
Pelli Robson
CSV 1000 6 cpd
CSV 1000 12 cpd
CSV 1000 18 cpd
Farnsw AC CCI
Farnsw C-Index
Farnsw CCI
Farns Conf Angle (%)
Farnsw S-index
Farnsw time (%)
L'Anthony AC CCI
L'Anthony C-index
L'Anthony CCI
L'Anthony Conf Angle (%)
L'Anthony S-index
L'Anthony time (%)
Meditators
Non-meditator



140
120
100
80
60
40
20
0
RNFL average
RNFL sup
RNFL nasal
RNFL inf
RNFL temp
GCL average
GCL min
GCL inf-nas
GCL nasal
GCL sup
GCL temp-inf
GCL temp
Meditator
Non meditator