Original Investigation

Relationships Between Measures of the Ability to Perform Vision-Related Activities, Vision-Related Quality of Life, and Clinical Findings in Patients With Glaucoma

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IMPORTANCE To our knowledge, few studies have combined an objective measure of vision-related performance (VRP) and subjective measures of vision-related quality of life (VRQoL) with clinically related visual parameters, particularly in a large, prospective, cohort study setting.

OBJECTIVE To examine the relationships between clinical visual assessments and both a VRP and 2 self-reported VRQoL measurements.

DESIGN, SETTING, AND PARTICIPANTS Patients (N = 161) with moderate-stage glaucoma recruited from the Glaucoma Service at Wills Eye Hospital, Philadelphia, Pennsylvania, were enrolled from May 2012 to May 2014 in an ongoing prospective, 4-year longitudinal observational study. This report includes cross-sectional results from the baseline visit. Patients received a complete ocular examination, automated visual field (VF) test and Cirrus optical coherence tomographic scan. Contrast sensitivity was measured with the Pelli-Robson and the Spaeth-Richman Contrast Sensitivity (SPARCS) tests. Vision-related performance was assessed by the Compressed Assessment of Ability Related to Vision (CAARV) test. Vision-related QoL was assessed by the National Eye Institute Visual Function Questionnaire 25 (NEI-VFQ-25) and a modified Glaucoma Symptom Scale (MGSS).

MAIN OUTCOMES AND MEASURES Correlations between clinical measures and CAARV, NEI-VFQ-25, and MGSS scores.

RESULTS A total of 161 patients were enrolled in the study. The strongest correlation was found between SPARCS score in the better eye and total CAARV score (r = 0.398; 95% CI, 0.235-0.537; P < .001). The CAARV score also correlated with the Pelli-Robson score (r = 0.353; 95% CI, 0.186-0.499; P = .001), VF mean deviation (r = 0.366; 95% CI, 0.200-0.510; P < .001), and VA (r = −0.326, 95% CI = −0.476 to −0.157; P = .003) in the better eye. There were more statistically significant correlations between contrast sensitivity tests and VF mean deviation with VRQoL measurements than with other clinical measures (visual acuity, intraocular pressure, Disc Damage Likelihood Scale, and mean retinal nerve fiber layer thickness). The MGSS scores were lower (worse) in women compared with men (P = .03 for binocular, P = .01 for better eye, and P = .05 for the worse eye). Structural measures (eg, Disc Damage Likelihood Scale, and retinal nerve fiber layer thickness) were generally not informative with respect to VRP or VRQoL.

CONCLUSIONS AND RELEVANCE Contrast sensitivity tests and VF mean deviation were associated with both objective measures of the ability to act and subjective measurements of VRQoL. The strongest correlation was between SPARCS score (contrast sensitivity) in the better eye and total CAARV score. Therefore, measurement of contrast sensitivity should be considered when evaluating patients' VRQoL. The results of this study were limited by the patient population and apply only within the bounds of the tested cohort.

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Glaucoma is a leading cause of irreversible blindness worldwide. In 2010, about 60.5 million individuals in the world had glaucoma; prevalence is expected to increase to 79.6 million by 2020.[1] Although most affected patients do not report any specific symptoms or vision loss initially, glaucoma can adversely affect patients' quality of life (QoL) and ability to perform visually related activities, even when they are unaware of their diagnosis.[2-5]

The impact of glaucoma on individuals can be assessed in 3 different ways: (1) clinical measures (eg, visual acuity [VA], contrast sensitivity, and visual field [VF]), (2) self-reported measurements of subjective well-being and QoL, and (3) performance-based assessments of daily activities.[6,7] Self-reported questionnaires, both specific to glaucoma and general visual function, are widely used to assess how vision ability affects QoL.[8,9] However, to eliminate patients' personal, emotional, and psychological differences, objective performance-based tools are also needed.[10] Performance-based measures have the advantage of allowing for an objective assessment of patients' abilities using standardized criteria.[11,12] Previous studies have used performance-based measures in a clinical setting for assessing patients' ability to perform activities of daily living.[12-15] Richman et al[10] examined the relationship between clinical measures of vision, health-related QoL (HRQoL), and the ability to perform vision-related activities. The performance-based Assessment of Disability Related to Vision (ADREV) correlated more strongly with clinical measures than the self-reported National Eye Institute Visual Function Questionnaire 25 (NEI-VFQ-25).[10] Although each approach provides a unique and important perspective in understanding the lives of patients with glaucoma, research that integrates all 3 methods is limited.[10,16]

Previous studies have investigated the associations between visual function and both vision-related QoL (VRQoL) and general HRQoL.[5,17-19] Vision-related QoL is a person's satisfaction with his or her visual function and how visual ability impacts his or her life.[20] Past research has focused primarily on clinical measurements of VF and VA. Visual deficits, as determined by these factors, have been found to negatively influence patients' self-reported VRQoL.[2,19,21-23] Previous studies have found that binocular VF loss is associated with lower self-reported VRQoL scores than monocular loss.[16,17] In people aged 65 years or older, the severity of self-reported visual impairment strongly correlates with poor HRQoL.[24] Other studies examining the relationship between clinical visual measurements and performance-based assessments have found that binocular VA scores, binocular VF scores, and VA in the better eye are strongly associated with ADREV scores.[12,14,16]

A clinician's ultimate goal is to address patients' concerns, which usually are centered on improving or at least maintaining their QoL and their ability to function. With the help of both objective and subjective measures of VRQoL, clinicians can obtain a good understanding of an individual's activity limitations and psychological changes and assess the impact of glaucoma on patients' QoL. Meanwhile, assessment of the relationship between VRQoL and visual clinical characteristics can help link subjective patient appraisals of their QoL with objective assessments of vision function and glaucoma severity.[7,12,25] This ongoing prospective cohort study investigates the relationship between the visual clinical characteristics of patients with moderate glaucoma and their self-reported QoL and vision-related performance (VRP) ability. The current study described these relationships at baseline. The ultimate goal was to study these relationships over 4 years, making it one of the largest studies, to our knowledge, to include extended follow-up to assess QoL and VRP in patients with glaucoma.

At a Glance

- We aimed to explore the relationships between clinical visual assessments, vision-related performances, and subjective vision-related quality of life.
- The strongest correlation was found between contrast sensitivity and an objective measure of the ability to perform vision-related activities.
- Contrast sensitivity and visual field were associated with both objective measures of ability to act and subjective measurements of vision-related quality of life.

Methods

Study Design

This present report obtained cross-sectional data from the baseline visit of an ongoing and ultimately prospective, longitudinal, observational cohort being conducted at Wills Eye Hospital in Philadelphia, Pennsylvania, in accordance with the Declaration of Helsinki and with approval from the institutional review board at Wills Eye Hospital. Informed consent was obtained from all participants. Full details of the study design and methods have been described elsewhere.[26]

Participants

There were 161 study participants recruited from the Glaucoma Service at Wills Eye Hospital, one of the largest tertiary glaucoma referral centers in the United States, from May 2012 to May 2014. Inclusion criteria included a 2-year minimum diagnosis of open-angle glaucoma, chronic angle-closure glaucoma, glaucomatous optic neuropathy with a Disc Damage Likelihood Scale (DDLS) of stage 5 through 8 in at least 1 eye and characteristic VF loss, age between 21 and 85 years, and the ability to understand and speak English. Patients with DDLS stages 1 through 4 often do not exhibit VF loss due to glaucoma, while patients with DDLS stages 9 and 10 have extensive disc and field damage, which makes detection of optic rim deterioration difficult. Therefore, DDLS stages 1 through 4 and 9 and 10 have been excluded from this study. Other exclusion criteria included neurological and musculoskeletal diseases that would influence performances, cognitive impairment, low availability for annual ocular examinations, incisional eye surgery within the past 3 months, laser therapy within the previous month, causes for visual impairment other than glaucoma, or any medical condition that would preclude the patient from providing reliable and valid data.

After examining NextGen electronic medical health records for eligibility criteria, patients were recruited through telephone calls or contacted in the clinic. Demographic information was collected, and baseline measurements were obtained at the time of enrollment by the Wills Eye Glaucoma Research Center.

Clinical Evaluation

Patients' current symptoms, health problems, medications, and ocular comorbidities were recorded during their visit. The complete ocular examination consisted of the Early Treatment Diabetic Retinopathy Study best-corrected VA (BCVA) test, an intraocular pressure (IOP) measurement (Goldmann applanation tonometry), a slitlamp examination of the anterior segment, and evaluation of the ocular fundus. The DDLS was used to evaluate the extent of optic disc damage caused by glaucoma (a 10-point scale).[27-31] Two VFs were obtained for each eye during the baseline visit using a Humphrey 24-2 SITA Standard perimeter (Carl Zeiss Meditec Inc). The individual VF scores for each eye were averaged to calculate a composite baseline VF score. Cirrus HD-optical coherence tomography (Spectral Domain Technology with Optic Disc Cube 200 × 200; Carl Zeiss Meditec Inc) was used to evaluate the retinal nerve fiber layer thickness (RNFLT). The Pelli-Robson and the Spaeth-Richman Contrast Sensitivity (SPARCS, a novel, internet-based test) tests were used to measure contrast sensitivity. The SPARCS test features multiple answer choices and a bracketing technique to determine the contrast threshold of patients' central and peripheral vision. The results of SPARCS testing have been shown to be highly reproducible and reliable.[32]

Measures of Quality of Life

Objective and subjective methods were used to assess 3 measures. The Compressed Assessment of Ability Related to Vision (CAARV) test is an instrument that correlates strongly with the more extensive ADREV task test, while only requiring between 10 and 15 minutes to complete.[25,26] The 4 CAARV items include (1) computerized motion detection, (2) recognizing facial expressions, (3) reading street signs, and (4) finding objects in a room. Participants completed CAARV subtests with both eyes open and used their own appropriate refractive correction to simulate normal function. Participants completed 2 subtests in ambient lighting and 2 subtests in a dark room. Each item was scored from 0 to 7, with 7 being perfect performance. The cumulative CAARV score was calculated as an aggregate of the scores from the 4 subtests.

The NEI-VFQ-25 includes a series of 42 questions (25 primary questions) pertaining to vision or feelings about a visual condition. Answers are selected among a numbered list of possible responses. Subscales include general health, general vision, near vision, distance vision, driving, peripheral vision, color vision, ocular pain, role difficulties, dependency, social functioning, and mental health. Composite scores range from 0 to 100, with higher scores indicating better visual functioning.[33]

The Glaucoma Symptom Scale (GSS) includes 10 ocular symptoms (eg, burning/smarting/stinging, tearing, dryness, itching, and hard to see in dark places) often experienced by patients with glaucoma. This study implemented a modified GSS (MGSS) questionnaire involving an initial 4-level score (1 = very bothersome; 2 = somewhat bothersome, 3 = a little bothersome, and 4 = no/not at all bothersome). This initial score was then converted to a 0 to 100 scale where zero signifies the presence of a very bothersome problem and 100 signifies the absence of a problem. The final MGSS score was computed as an unweighted average of the responses to all 10 symptoms, averaged between the 2 eyes.[34]

Table 1. Baseline Demographic Characteristics of the 161 Patients Enrolled in the Study

Variable	No. (%)
Age, mean (range), y	64.6 (30-83)
Female	86 (53.4)
Race/ethnicity	
White	94 (58.4)
African American	52 (32.3)
Asian	13 (8.1)
Hispanic	2 (1.2)
Education, mean (range), y	15.1 (5-25)
Glaucoma diagnosis	
Primary open angle	125 (77.6)
Normal tension	23 (14.3)
Pseudoexfoliation	7 (4.4)
Angle closure	6 (3.7)

Statistical Analysis

Demographics, clinical information, VRQoL scores, and MGSS values were summarized using means, medians, and ranges or as frequencies and percentages when appropriate. For continuous variables, groups were compared using the nonparametric Kruskal-Wallis test owing to skewed data. Comparisons were made for VRQoL measurements between sexes, age groups, diagnoses, and race/ethnicity, as well as for clinical measurements between sexes. Spearman correlation coefficients were calculated for all pairs of VRQoL outcome variables and clinical characteristics from each participant's baseline visit. For analysis of measures within individual eyes, better eye vs worse eye was determined based on the mean deviation (MD) of the VF.

Owing to the large number of clinical measures, *P* values for the set of comparisons within each table were adjusted using the false discovery rate where noted to control for multiple comparisons.[35] Outcome variables with $P \leq .05$, 2-sided, were considered to be statistically significant. Data were analyzed using SAS system version 9.4 (SAS Institute).

Results

Demographics and Outcome Variables

This study examined 322 eyes of 161 enrolled participants (75 men and 86 women). Baseline demographics and clinical characteristics of the study participants appear in **Table 1** and **Table 2**. When examining VRQoL scores, significant differences between sexes were found for the binocular MGSS

Table 2. Baseline Clinical Characteristics of the Patients Enrolled in the Study

Variable	Mean (SD)	Median (Range)
Visual acuity, LogMAR		
Better	0.05 (0.14)	0.02 (−0.20 to 0.86)
Worse	0.24 (0.27)	0.14 (−0.18 to 1.64)
Difference	0.19 (0.24)	0.10 (−0.04 to 1.52)
IOP, mm Hg		
Eye with higher IOP	15.55 (3.94)	15.00 (8.5 to 36.0)
Eye with lower IOP	13.32 (3.86)	13.00 (1.0 to 31.0)
Difference	2.23 (3.0)	1.00 (−3.0 to 14.0)
DDLS		
Higher	6.65 (1.22)	7.00 (3.0 to 9.0)
Lower	5.30 (1.56)	5.00 (1.0 to 8.0)
Difference	1.35 (1.42)	1.00 (0.0 to 7.0)
MD		
Better	−6.80 (6.49)	−4.44 (−30.36 to 1.51)
Worse	−13.70 (8.84)	−12.72 (−32.97 to −0.23)
Difference	6.92 (7.02)	4.66 (−30.5 to 0.0)
RNFLT, μm		
Thicker	71.89 (13.28)	71.00 (23.0 to 110.0)
Thinner	60.62 (13.03)	59.00 (14.0 to 103.0)
Difference	11.20 (11.43)	7.00 (−67.0 to 0.0)
Pelli-Robson test (log contrast sensitivity)		
Better	1.27 (0.22)	1.35 (0.15 to 1.50)
Worse	1.10 (0.31)	1.20 (0.00 to 1.50)
Difference	0.17 (0.25)	0.15 (−1.20 to 1.05)
SPARCS test		
Better	61.85 (13.95)	64.00 (0.0 to 87.0)
Worse	49.10 (19.4)	54.00 (0.0 to 86.0)
Difference	12.82 (13.88)	8.00 (−66.0 to 4.0)

Abbreviations: DDLS, Disc Damage Likelihood Scale; IOP, intraocular pressure; MD, mean deviation; RNFLT, retinal nerve fiber layer thickness; SPARCS, Spaeth-Richman Contrast Sensitivity.

(*P* = .03), MGSS in the better eye (*P* = .01), and MGSS in the worse eye (*P* = .05), as well as the driving subscore of the NEI-VFQ-25 (*P* = .04), with men reporting better VRQoL (higher score) compared with women for all of these measures.

CAARV and Clinical Measurements

The total CAARV score significantly correlated with SPARCS score (*r* = 0.398; 95% CI, 0.235-0.537; *P* < .001), Pelli-Robson score (*r* = 0.353; 95% CI, 0.186-0.499; *P* = .001), MD (*r* = 0.366; 95% CI, 0.200-0.510; *P* < .001), and VA (*r* = −0.326; 95% CI, −0.476 to −0.157; *P* = .003) in the better eye (**Table 3**). All CAARV subtests, except for reading street signs, were statistically correlated with SPARCS score, Pelli-Robson score, and MD. The CAARV motion detection subtest was the only score to correlate significantly with RNFLT in the better eye (Table 3). The CAARV scores were not found to be correlated with IOP (*r* = −0.023; 95% CI, −0.200 to 0.156; *P* > .99). The total CAARV and all CAARV subtests, except for reading street signs, correlated significantly with SPARCS score in the worse eye (**Table 4**).

NEI-VFQ-25 and Clinical Measurements

The NEI-VFQ-25 composite scores were statistically correlated with MD in both the better (*r* = 0.289; 95% CI, 0.116-0.443; *P* = .008) and worse eye (*r* = 0.348; 95% CI, 0.180-0.494; *P* = .001), as well as with VA, Pelli-Robson score, and SPARCS score in the worse eye (Table 3 and Table 4). In addition to the NEI-VFQ-25 composite score, 9 of the 12 NEI-VFQ-25 subscales significantly correlated with the SPARCS score and MD in the worse eye, and 8 of the subscales were statistically associated with the Pelli-Robson score in the worse eye (Table 4). The NEI-VFQ-25 general vision and peripheral vision subscales correlated significantly with the DDLS score in the worse eye. The DDLS scores in the better eye did not correlate significantly with any VFQ measures. Additionally, NEI-VFQ-25 scores did not correlate with IOP or RNFLT measurements of either eye. There were no statistically significant correlations between MGSS score and any clinical measure.

Discussion

The ultimate goal of treating patients with glaucoma is to preserve or even improve their VRQoL and their ability to perform visually related tasks. Clinical tests performed in the office are often useful in estimating the severity of the disease, but provide limited information about VRQoL or VRP.

In the current study, several clinical measures of vision showed statistically significant correlations with both an objective test of VRP and subjective tests assessing VRQoL. The CAARV, an objective test used to determine aspects of vision that influence the activities of daily living of patients with glaucoma, was correlated with contrast sensitivity for both the better and worse eyes. We used 2 distinct tests to measure contrast sensitivity: the Pelli-Robson chart and the SPARCS, a novel computer-based test. While both tests significantly correlated with the CAARV total score for both the better and worse eyes, the SPARCS had stronger correlations for the better eye subscores. Measuring contrast sensitivity by the SPARCS test may provide useful information on the ability of patients to perform daily activities. These findings are in line with previous studies, which highlighted the impact of contrast sensitivity on the VRQoL and VRP of patients with glaucoma.[14] The correlations between clinical measures and the SPARCS test, which separately tests 5 individual areas in the VF, were greater than correlations of clinical measures with the Pelli-Robson test, which only assesses the central field. The only positive correlation between RNFLT and any of the subsets of CAARV, NEI-VFQ-25, or MGSS was with motion detection in CAARV.

Measures of contrast sensitivity and VF MD had more significant correlations with CAARV scores compared with other clinical measures including VA, IOP, and structural measures (DDLS and mean RNFLT) in the better eye. It is possible that even patients with relatively good VA may have low CAARV scores owing to profound VF defect or loss of contrast sensitivity.

Subjective VRQoL measures, as assessed with the NEI-VFQ-25 questionnaire, showed significant correlations with contrast sensitivity and VF MD compared with other clinical

Table 3. Spearman Correlation Coefficients (*P* Values[a]) With Better Eye (N = 161)

VRQoL Variable	VA	IOP	DDLS	MD	RNFLT	Pelli-Robson	SPARCS
CAARV total							
ρ (95% CI)	−0.326 (−0.476 to −0.157)	−0.023 (−0.200 to 0.156)	−0.226 (−0.388 to −0.050)	0.366 (0.200 to 0.510)	0.201 (0.023 to 0.365)	0.353 (0.186 to 0.499)	0.398 (0.235 to 0.537)
P value	.003	>.99	.07	<.001	.16	.001	<.001
Facial recognition							
ρ (95% CI)	−0.235 (−0.396 to −0.058)	−0.018 (−0.195 to 0.161)	−0.225 (−0.387 to −0.048)	0.284 (0.111 to 0.439)	0.223 (0.046 to 0.385)	0.241 (0.065 to 0.401)	0.298 (0.126 to 0.452)
P value	.05	>.99	.07	.009	.08	.04	.007
Finding objects							
ρ (95% CI)	−0.191 (−0.356 to −0.013)	0.001 (−0.177 to 0.179)	−0.144 (−0.313 to 0.036)	0.270 (0.096 to 0.427)	0.073 (−0.107 to 0.247)	0.292 (0.120 to 0.446)	0.295 (0.122 to 0.449)
P value	.22	>.99	.79	.02	>.99	.007	.007
Motion detection							
ρ (95% CI)	−0.232 (−0.393 to −0.055)	0.103 (−0.077 to 0.276)	−0.277 (−0.433 to −0.103)	0.298 (0.125 to 0.451)	0.248 (0.072 to 0.407)	0.320 (0.150 to 0.471)	0.345 (0.177 to 0.492)
P value	.06	>.99	.01	.007	.04	.003	.001
Street signs							
ρ (95% CI)	−0.295 (−0.449 to −0.123)	−0.010 (−0.187 to 0.169)	−0.159 (−0.327 to 0.021)	0.205 (0.027 to 0.369)	0.129 (−0.050 to 0.300)	0.202 (0.024 to 0.366)	0.200 (0.022 to 0.364)
P value	.007	>.99	.55	.14	>.99	.16	.17
NEI-VFQ-25 Total							
ρ (95% CI)	−0.180 (−0.347 to −0.002)	0.011 (−0.168 to 0.189)	−0.146 (−0.315 to 0.033)	0.289 (0.116 to 0.443)	0.186 (0.008 to 0.352)	0.192 (0.014 to 0.357)	0.151 (−0.028 to 0.320)
P value	.30	>.99	.75	.008	.26	.22	.66
Color vision							
ρ (95% CI)	−0.139 (−0.309 to 0.040)	0.029 (−0.150 to 0.206)	−0.058 (−0.234 to 0.121)	0.258 (0.083 to 0.416)	0.137 (−0.043 to 0.307)	0.202 (0.024 to 0.366)	0.251 (0.076 to 0.410)
P value	.89	>.99	>.99	.03	.95	.16	.03
Dependency							
ρ (95% CI)	−0.214 (−0.377 to −0.036)	0.038 (−0.141 to 0.214)	−0.215 (−0.378 to −0.037)	0.236 (0.060 to 0.397)	0.080 (−0.100 to 0.254)	0.217 (0.040 to 0.380)	0.143 (−0.037 to 0.313)
P value	.11	>.99	.10	.05	>.99	.10	.81
Distance activities							
ρ (95% CI)	−0.228 (−0.390 to −0.052)	0.009 (−0.169 to 0.187)	−0.169 (−0.336 to 0.010)	0.304 (0.133 to 0.457)	0.192 (0.013 to 0.357)	0.187 (0.009 to 0.353)	0.157 (−0.022 to 0.326)
P value	.07	>.99	.42	.005	.22	.25	.57
Driving							
ρ (95% CI)	−0.238 (−0.409 to −0.050)	−0.006 (−0.196 to 0.184)	−0.091 (−0.277 to 0.101)	0.314 (0.131 to 0.475)	0.111 (−0.082 to 0.294)	0.224 (0.034 to 0.397)	0.145 (−0.047 to 0.326)
P value	.08	>.99	>.99	.007	>.99	.12	.97
General health							
ρ (95% CI)	−0.141 (−0.311 to 0.039)	−0.136 (−0.306 to 0.043)	−0.045 (−0.221 to 0.135)	0.111 (−0.069 to 0.283)	−0.005 (−0.183 to 0.174)	0.102 (−0.078 to 0.275)	0.061 (−0.119 to 0.236)
P value	.85	.96	>.99	>.99	>.99	>.99	>.99
General vision							
ρ (95% CI)	−0.163 (−0.331 to 0.016)	0.002 (−0.176 to 0.180)	−0.201 (−0.366 to −0.024)	0.230 (0.053 to 0.391)	0.161 (−0.018 to 0.329)	0.247 (0.072 to 0.407)	0.146 (−0.033 to 0.316)
P value	.50	1.00	.16	.06	.53	.04	.74
Mental health							
ρ (95% CI)	−0.126 (−0.297 to 0.054)	−.011 (−0.189 to 0.168)	−0.159 (−0.328 to 0.020)	0.169 (−0.010 to 0.337)	0.015 (−0.164 to 0.192)	0.133 (−0.046 to 0.304)	0.080 (−0.099 to 0.255)
P value	>.99	>.99	.54	.42	>.99	>.99	>.99
Near activities							
ρ (95% CI)	−0.147 (−0.317 to 0.032)	−0.078 (−0.252 to 0.102)	−0.100 (−0.273 to 0.079)	0.198 (0.020 to 0.362)	0.152 (−0.028 to 0.321)	0.196 (0.018 to 0.361)	0.108 (−0.072 to 0.281)
P value	.73	>.99	>.99	.18	.65	.18	>.99
Ocular pain							
ρ (95% CI)	0.025 (−0.154 to 0.202)	0.040 (−0.139 to 0.217)	0.095 (−0.085 to 0.268)	−0.012 (−0.189 to 0.167)	0.008 (−0.171 to 0.186)	−0.089 (−0.263 to 0.091)	−0.052 (−0.228 to 0.127)
P value	>.99	>.99	>.99	>.99	>.99	>.99	>.99

(continued)

Table 3. Spearman Correlation Coefficients (*P* Values[a]) With Better Eye (N=161) (continued)

VRQoL Variable	VA	IOP	DDLS	MD	RNFLT	Pelli-Robson	SPARCS
Peripheral vision							
ρ (95% CI)	−0.100 (−0.273 to 0.079)	−0.048 (−0.224 to 0.132)	−0.117 (−0.288 to 0.063)	0.309 (0.137 to 0.461)	0.177 (−0.002 to 0.344)	0.073 (−0.107 to 0.248)	0.118 (−0.062 to 0.290)
P value	>.99	>.99	>.99	.005	.34	>.99	>.99
Role difficulties							
ρ (95% CI)	−0.124 (−0.295 to 0.055)	0.018 (−0.161 to 0.195)	−0.055 (−0.231 to 0.125)	0.144 (−0.035 to 0.314)	0.129 (−0.050 to 0.300)	0.186 (0.008 to 0.352)	0.083 (−0.097 to 0.257)
P value	>.99	>.99	>.99	.78	>.99	.25	>.99
Social functioning							
ρ (95% CI)	−0.181 (−0.348 to −0.003)	−0.004 (−0.182 to 0.174)	−0.113 (−0.285 to 0.067)	0.289 (0.116 to 0.443)	0.160 (−0.019 to 0.329)	0.147 (−0.032 to 0.317)	0.290 (0.117 to 0.445)
P value	.29	>.99	>.99	.008	.53	.73	.008
MGSS: binocular							
ρ (95% CI)	−0.094 (−0.268 to 0.085)	0.100 (−0.080 to 0.273)	0.064 (−0.116 to 0.239)	0.045 (−0.135 to 0.221)	0.121 (−0.058 to 0.293)	0.098 (−0.082 to 0.271)	−0.067 (−0.242 to 0.113)
P value	>.99	>.99	>.99	>.99	>.99	>.99	>.99
Better eye							
ρ (95% CI)	−0.176 (−0.343 to 0.002)	0.104 (−0.075 to 0.277)	−0.013 (−0.191 to 0.165)	0.056 (−0.124 to 0.231)	0.130 (−0.050 to 0.300)	0.137 (−0.043 to 0.307)	−0.055 (−0.231 to 0.124)
P value	.34	>.99	>.99	>.99	>.99	.95	>.99
Worse eye							
ρ (95% CI)	−0.036 (−0.213 to 0.143)	0.102 (−0.077 to 0.275)	0.100 (−0.080 to 0.273)	0.044 (−0.135 to 0.220)	0.110 (−0.070 to 0.282)	0.073 (−0.106 to 0.248)	−0.063 (−0.238 to 0.117)
P value	>.99	>.99	>.99	>.99	>.99	>.99	>.99

Abbreviations: CAARV, Compressed Assessment of Ability Related to Vision; DDLS, Disc Damage Likelihood Scale; IOP, intraocular pressure; MD, mean deviation; MGSS, Modified Glaucoma Symptom Scale; NEI-VFQ-25, National Eye Institute Visual Function Questionnaire 25; RNFLT, retinal nerve fiber layer thickness; SPARCS, Spaeth-Richman Contrast Sensitivity; VA, visual acuity; VRQoL, vision-related quality of life.

[a] *P* values adjusted for multiple comparisons (false discovery rate).

visual measures, especially in the worse eye. These findings differ from those of previous studies, which typically found stronger correlations between VRQoL scores and measurements in the better eye.[2,16,23] This disparity in findings may be attributed, at least partially, to individual bias. Patients may be more aware or bothered by the loss of vision in their worse eye, which could result in higher correlations between worse eye measurements and subjective (self-report) VRQoL. On the other hand, the better eye may compensate for some degree of vision loss in the worse eye, thereby being the ultimate factor in affecting function in daily activities (objective VRP). However, other research has also suggested that the worse eye may have a stronger influence on VRQoL than has been previously assumed, especially if peripheral vision is the primary impairment (as opposed to central vision).[36,37] In addition, patients may also have different VF defect patterns between the worse and better eyes. These variations in VF defect patterns can have largely different effects on visual abilities and VRQoL.[22,36,38]

It is difficult to determine whether objective or subjective measures can be accurately applied to a particular individual. Previous studies have shown good reproducibility and stability over time of the CAARV test.[25] However, long-term studies have not been reported with any of the performance-based or QoL-based measures. Patients may have low scores when performing objective tasks but may also think and report that their VRQoL is relatively good and vice versa. We believe the clinician should take both types of measures into consideration. One of the strengths of this study was that it evaluated the relationship between clinical measures and both objective and subjective tests, which both provide valuable information regarding patients' VRQoL and their visually related ability to function.

Women had significantly worse (lower) MGSS scores compared with men. The MGSS score included a number of symptoms that can be attributed to dry eye and blepharitis (eg, blurry/dim vision, itching, feeling of something in the eye, and dryness), and these results are in line with others who showed higher rates of dry eye and blepharitis in women.[39-41] Surprisingly, the clinical measures used in this study were not significantly correlated with any of the MGSS scores. This is in contrast to other studies, which reported significant correlations between the severity of glaucoma on VF MD and the degree of dry eye symptoms.[42] Because this study had a homogeneous population of patients with moderate-stage glaucoma, differences in the severity of dry eye syndrome may be smaller and more difficult to detect and, therefore, the correlations between clinical measures and MGSS were less significant.

Finally, although many correlations between clinical measures and VRQoL tests were significant, they were not strongly correlated (Spearman correlation coefficient were typically between 0.2-0.4). This result may be owing to the inevitable variability that characterizes individuals even within a relatively homogeneous population, as different individuals consider their vision and its impact on activities of daily life differently. It is also plausible, even likely, that the precision of CAARV, NEI-VFQ-25, and MGSS is limited.

Table 4. Spearman Correlation Coefficients (*P* Values[a]) With Worse Eye (N = 161)

VRQoL Variable	VA	IOP	DDLS	MD	RNFLT	Pelli-Robson	SPARCS
CAARV total							
ρ (95% CI)	−0.388 (−0.529 to −0.224)	−0.059 (−0.235 to 0.120)	−0.243 (−0.403 to −0.067)	0.315 (0.144 to 0.466)	0.115 (−0.065 to 0.287)	0.330 (0.160 to 0.479)	0.326 (0.156 to 0.475)
P value	<.001	>.99	.04	.004	>.99	.003	.003
Facial recognition							
ρ (95% CI)	−0.324 (−0.474 to −0.154)	0.016 (−0.163 to 0.193)	−0.156 (−0.324 to 0.023)	0.198 (0.020 to 0.363)	0.121 (−0.059 to 0.293)	0.202 (0.024 to 0.367)	0.245 (0.069 to 0.404)
P value	.003	>.99	.58	.18	>.99	.15	.04
Finding objects							
ρ (95% CI)	−0.226 (−0.388 to −0.049)	−0.095 (−0.269 to 0.084)	−0.255 (−0.413 to −0.080)	0.287 (0.114 to 0.442)	0.086 (−0.094 to 0.260)	0.279 (0.105 to 0.435)	0.286 (0.112 to 0.440)
P value	.07	>.99	.03	.009	>.99	.01	.009
Motion detection							
ρ (95% CI)	−0.229 (−0.391 to −0.053)	0.011 (−0.168 to 0.189)	−0.156 (−0.324 to 0.024)	0.264 (0.089 to 0.421)	0.158 (−0.022 to 0.327)	0.213 (0.035 to 0.376)	0.277 (0.103 to 0.433)
P value	.06	>.99	.58	.02	.57	.11	.01
Street signs							
ρ (95% CI)	−0.304 (−0.457 to −0.133)	−0.001 (−0.179 to 0.177)	−0.156 (−0.325 to 0.023)	0.207 (0.029 to 0.370)	0.018 (−0.161 to 0.196)	0.189 (0.011 to 0.355)	0.159 (−0.021 to 0.327)
P value	.005	>.99	.58	.14	>.99	.23	.55
NEI-VFQ-25 total							
ρ (95% CI)	−0.314 (−0.465 to −0.143)	0.094 (−0.085 to 0.268)	−0.162 (−0.330 to 0.017)	0.348 (0.180 to 0.494)	0.071 (−0.110 to 0.246)	0.321 (0.150 to 0.471)	0.353 (0.186 to 0.499)
P value	.004	>.99	.51	.001	>.99	.003	.001
Color vision							
ρ (95% CI)	−0.161 (−0.329 to 0.018)	0.089 (−0.091 to 0.263)	−0.035 (−0.212 to 0.144)	0.259 (0.084 to 0.417)	0.021 (−0.158 to 0.199)	0.291 (0.118 to 0.445)	0.288 (0.115 to 0.443)
P value	.53	>.99	>.99	.03	>.99	.008	.008
Dependency							
ρ (95% CI)	−0.255 (−0.414 to −0.080)	0.094 (−0.085 to 0.268)	−0.101 (−0.274 to 0.079)	0.246 (0.070 to 0.405)	−0.021 (−0.199 to 0.158)	0.254 (0.079 to 0.413)	0.268 (0.094 to 0.425)
P value	.03	>.99	>.99	.04	>.99	.03	.02
Distance activities							
ρ (95% CI)	−0.296 (−0.450 to −0.123)	0.076 (−0.103 to 0.251)	−0.111 (−0.284 to 0.068)	0.313 (0.142 to 0.465)	0.049 (−0.131 to 0.225)	0.286 (0.112 to 0.441)	0.341 (0.172 to 0.488)
P value	.007	>.99	>.99	.004	>.99	.009	.001
Driving							
ρ (95% CI)	−0.239 (−0.410 to −0.051)	0.099 (−0.093 to 0.284)	0.019 (−0.172 to 0.209)	0.240 (0.051 to 0.411)	0.076 (−0.116 to 0.262)	0.185 (−0.006 to 0.362)	0.220 (0.031 to 0.394)
P value	.08	>.99	>.99	.08	>.99	.37	.14
General health							
ρ (95% CI)	−0.084 (−0.258 to 0.096)	−0.069 (−0.244 to 0.111)	−0.086 (−0.260 to 0.094)	0.113 (−0.067 to 0.285)	0.017 (−0.162 to 0.195)	0.083 (−0.096 to 0.257)	0.100 (−0.080 to 0.273)
P value	>.99	>.99	>.99	>.99	>.99	>.99	>.99
General vision							
ρ (95% CI)	−0.356 (−0.502 to −0.189)	0.027 (−0.152 to 0.204)	−0.265 (−0.422 to −0.090)	0.283 (0.109 to 0.438)	0.070 (−0.111 to 0.245)	0.329 (0.160 to 0.478)	0.303 (0.131 to 0.456)
P value	.001	>.99	.02	.01	>.99	.003	.005
Mental health							
ρ (95% CI)	−0.231 (−0.392 to −0.054)	0.100 (−0.079 to 0.273)	−0.156 (−0.325 to 0.023)	0.239 (0.063 to 0.399)	0.020 (−0.159 to 0.198)	0.235 (0.059 to 0.396)	0.259 (0.085 to 0.418)
P value	.06	>.99	.58	.047	>.99	.05	.03
Near activities							
ρ (95% CI)	−0.277 (−0.433 to −0.103)	−0.056 (−0.232 to 0.124)	−0.135 (−0.306 to 0.044)	0.248 (0.072 to 0.407)	0.014 (−0.165 to 0.192)	0.318 (0.147 to 0.469)	0.294 (0.122 to 0.448)
P value	.01	>.99	.97	.04	>.99	.003	.007
Ocular pain							
ρ (95% CI)	−0.027 (−0.204 to 0.152)	0.157 (−0.022 to 0.326)	−0.022 (−0.200 to 0.156)	0.124 (−0.056 to 0.295)	0.011 (−0.168 to 0.189)	0.035 (−0.144 to 0.212)	0.088 (−0.091 to 0.262)
P value	>.99	.57	>.99	>.99	>.99	>.99	>.99

(continued)

Table 4. Spearman Correlation Coefficients (*P* Values[a]) With Worse Eye (N = 161) (continued)

VRQoL Variable	VA	IOP	DDLS	MD	RNFLT	Pelli-Robson	SPARCS
Peripheral vision							
ρ (95% CI)	−0.297 (−0.450 to −0.124)	0.067 (−0.113 to 0.242)	−0.247 (−0.406 to −.071)	0.375 (0.210 to 0.517)	0.062 (−0.119 to 0.237)	0.306 (0.134 to 0.458)	0.372 (0.207 to 0.515)
P value	.007	>.99	.04	<.001	>.99	.005	<.001
Role difficulties							
ρ (95% CI)	−0.324 (−0.474 to −0.154)	0.078 (−0.102 to 0.252)	−0.134 (−0.305 to 0.045)	0.299 (0.127 to 0.452)	0.024 (−0.156 to 0.201)	0.295 (0.122 to 0.449)	0.293 (0.120 to 0.447)
P value	.003	>.99	.99	.007	>.99	.007	.007
Social functioning							
ρ (95% CI)	−0.294 (−0.448 to −0.121)	0.037 (−0.142 to 0.214)	−0.189 (−0.355 to −0.011)	0.346 (0.178 to 0.493)	−0.057 (−0.234 to 0.123)	0.306 (0.134 to 0.458)	0.347 (0.179 to 0.493)
P value	.007	>.99	.23	.001	>.99	.005	.001
MGSS: binocular							
ρ (95% CI)	−0.093 (−0.266 to 0.087)	0.182 (0.003 to 0.348)	−0.018 (−0.196 to 0.160)	0.148 (−0.032 to 0.317)	0.096 (−0.084 to 0.270)	0.161 (−0.018 to 0.329)	0.086 (−0.094 to 0.260)
P value	>.99	.29	>.99	.72	>.99	.53	>.99
Better eye							
ρ (95% CI)	−.036 (−0.212 to 0.143)	0.162 (−0.017 to 0.330)	0.052 (−0.127 to 0.228)	0.051 (−0.129 to 0.226)	0.081 (−0.099 to 0.256)	0.114 (−0.066 to 0.286)	0.006 (−0.172 to 0.184)
P value	>.99	.51	>.99	>.99	>.99	>.99	>.99
Worse eye							
ρ (95% CI)	−0.108 (−0.280 to 0.072)	0.192 (0.014 to 0.357)	−0.056 (−0.232 to 0.123)	0.196 (0.018 to 0.361)	0.101 (−0.079 to 0.274)	0.173 (−0.006 to 0.340)	0.123 (−0.057 to 0.294)
P value	>.99	.22	>.99	.19	>.99	.37	>.99

Abbreviations: CAARV, Compressed Assessment of Ability Related to Vision; DDLS, Disc Damage Likelihood Scale; IOP, intraocular pressure; MD, mean deviation; MGSS, Modified Glaucoma Symptom Scale; NEI-VFQ-25, National Eye Institute Visual Function Questionnaire 25; RNFLT, retinal nerve fiber layer thickness; SPARCS, Spaeth-Richman Contrast Sensitivity; VA, visual acuity; VRQoL, vision-related quality of life.

[a] *P* values adjusted for multiple comparisons (false discovery rate).

There were several limitations of this current report. First, the data reported here are cross-sectional in nature. Second, this study focused only on patients with moderate glaucoma, and the population was primarily white and African American (Table 1). Therefore, any associations and results from this study apply only to the cohort population examined and may not correlate with advanced glaucoma or other demographics. Future directions of this ongoing study are to evaluate prospectively a VRP-based measure and 2 VRQoL assessments in a cohort of patients with glaucoma over a 4-year period to search for factors that may influence the progression of clinical measures of glaucoma and to establish how clinical measures longitudinally relate to patients' VRQoL and VRP.

Conclusions

Although MD and VA affect VRQoL, the present study suggests that contrast sensitivity may also play an important role in its effects on the daily functioning and activities of patients with glaucoma. Therefore, measurement of contrast sensitivity, particularly using the SPARCS test, should be considered when investigating patients' VRQoL. In addition, owing to the influence of worse eye VF and contrast sensitivity, clinicians should also aim to improve visual abilities in the worse eye rather than focusing all efforts solely on the better eye.

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REFERENCES

1. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. *Br J Ophthalmol*. 2006;90(3):262-267.

2. Qiu M, Wang SY, Singh K, Lin SC. Association between visual field defects and quality of life in the United States. *Ophthalmology*. 2014;121(3):733-740.

3. McKean-Cowdin R, Wang Y, Wu J, Azen SP, Varma R; Los Angeles Latino Eye Study Group. Impact of visual field loss on health-related quality of life in glaucoma: the Los Angeles Latino Eye Study. *Ophthalmology*. 2008;115(6):941-948.e1.

4. Altangerel U, Spaeth GL, Rhee DJ. Visual function, disability, and psychological impact of glaucoma. *Curr Opin Ophthalmol*. 2003;14(2):100-105.

5. Nelson P, Aspinall P, Papasouliotis O, Worton B, O'Brien C. Quality of life in glaucoma and its relationship with visual function. *J Glaucoma*. 2003;12(2):139-150.

6. Magacho L, Lima FE, Nery AC, Sagawa A, Magacho B, Avila MP. Quality of life in glaucoma patients: regression analysis and correlation with possible modifiers. *Ophthalmic Epidemiol*. 2004;11(4):263-270.

7. Spaeth G, Walt J, Keener J. Evaluation of quality of life for patients with glaucoma. *Am J Ophthalmol*. 2006;141(1)(suppl):S3-S14.

8. Odberg T, Jakobsen JE, Hultgren SJ, Halseide R. The impact of glaucoma on the quality of life of patients in Norway, I: results from a self-administered questionnaire. *Acta Ophthalmol Scand*. 2001;79(2):116-120.

9. Mills RP, Janz NK, Wren PA, Guire KE. Correlation of visual field with quality-of-life measures at diagnosis in the Collaborative Initial Glaucoma Treatment Study (CIGTS). *J Glaucoma*. 2001;10(3):192-198.

10. Richman J, Lorenzana LL, Lankaranian D, et al. Relationships in glaucoma patients between standard vision tests, quality of life, and ability to perform daily activities. *Ophthalmic Epidemiol*. 2010;17(3):144-151.

11. Skalicky S, Goldberg I. Quality of life in glaucoma patients. *US Ophthalmic Rev*. 2013;6(1):6-9.

12. Altangerel U, Spaeth GL, Steinmann WC. Assessment of function related to vision (AFREV). *Ophthalmic Epidemiol*. 2006;13(1):67-80.

13. Warrian KJ, Lorenzana LL, Lankaranian D, Dugar J, Wizov SS, Spaeth GL. The assessment of disability related to vision performance-based measure in diabetic retinopathy. *Am J Ophthalmol*. 2010;149(5):852-860.e1.

14. Richman J, Lorenzana LL, Lankaranian D, et al. Importance of visual acuity and contrast sensitivity in patients with glaucoma. *Arch Ophthalmol*. 2010;128(12):1576-1582.

15. Lorenzana L, Lankaranian D, Dugar J, et al. A new method of assessing ability to perform activities of daily living: design, methods and baseline data. *Ophthalmic Epidemiol*. 2009;16(2):107-114.

16. Kulkarni KM, Mayer JR, Lorenzana LL, Myers JS, Spaeth GL. Visual field staging systems in glaucoma and the activities of daily living. *Am J Ophthalmol*. 2012;154(3):445-451.e3.

17. Lisboa R, Chun YS, Zangwill LM, et al. Association between rates of binocular visual field loss and vision-related quality of life in patients with glaucoma. *JAMA Ophthalmol*. 2013;131(4):486-494.

18. Patino CM, Varma R, Azen SP, Conti DV, Nichol MB, McKean-Cowdin R; Los Angeles Latino Eye Study Group. The impact of change in visual field on health-related quality of life the Los Angeles Latino Eye Study. *Ophthalmology*. 2011;118(7):1310-1317.

19. McKean-Cowdin R, Varma R, Wu J, Hays RD, Azen SP; Los Angeles Latino Eye Study Group. Severity of visual field loss and health-related quality of life. *Am J Ophthalmol*. 2007;143(6):1013-1023.

20. Asaoka R, Crabb DP, Yamashita T, Russell RA, Wang YX, Garway-Heath DF. Patients have two eyes!: binocular versus better eye visual field indices. *Invest Ophthalmol Vis Sci*. 2011;52(9):7007-7011.

21. Wu P, Xi S, Xia H, Lu H, Guo W. Survey on vision-related quality of life and self-management among patients with glaucoma. *J Glaucoma*. 2014;23(2):75-80.

22. Murata H, Hirasawa H, Aoyama Y, et al. Identifying areas of the visual field important for quality of life in patients with glaucoma. *PLoS One*. 2013;8(3):e58695.

23. van Gestel A, Webers CA, Beckers HJ, et al. The relationship between visual field loss in glaucoma and health-related quality-of-life. *Eye (Lond)*. 2010;24(12):1759-1769.

24. Crews JE, Chou CF, Zhang X, Zack MM, Saaddine JB. Health-related quality of life among people aged ≥65 years with self-reported visual impairment: findings from the 2006-2010 behavioral risk factor surveillance system. *Ophthalmic Epidemiol*. 2014;21(5):287-296.

25. Wei H, Sawchyn AK, Myers JS, et al. A clinical method to assess the effect of visual loss on the ability to perform activities of daily living. *Br J Ophthalmol*. 2012;96(5):735-741.

26. Waisbourd M, Parker S, Ekici F, et al. A prospective, longitudinal, observational cohort study examining how glaucoma affects quality of life and visually-related function over 4 years: design and methodology. *BMC Ophthalmol*. 2015;15:91.

27. Henderer JD, Liu C, Kesen M, et al. Reliability of the Disk Damage Likelihood Scale. *Am J Ophthalmol*. 2003;135(1):44-48.

28. Bayer A, Harasymowycz P, Henderer JD, Steinmann WG, Spaeth GL. Validity of a new disk grading scale for estimating glaucomatous damage: correlation with visual field damage. *Am J Ophthalmol*. 2002;133(6):758-763.

29. Danesh-Meyer HV, Ku JY, Papchenko TL, Jayasundera T, Hsiang JC, Gamble GD. Regional correlation of structure and function in glaucoma, using the Disc Damage Likelihood Scale, Heidelberg retina tomograph, and visual fields. *Ophthalmology*. 2006;113(4):603-611.

30. Hornova J, Kuntz Navarro JB, Prasad A, Freitas DG, Nunes CM. Correlation of Disc Damage Likelihood Scale, visual field, and Heidelberg retina tomograph II in patients with glaucoma. *Eur J Ophthalmol*. 2008;18(5):739-747.

31. Spaeth GL, Henderer J, Liu C, et al. The disc damage likelihood scale: reproducibility of a new method of estimating the amount of optic nerve damage caused by glaucoma. *Trans Am Ophthalmol Soc*. 2002;100:181-185.

32. 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*. 2015;99(1):16-20.

33. Mangione CM, Lee PP, Gutierrez PR, Spritzer K, Berry S, Hays RD; National Eye Institute Visual Function Questionnaire Field Test Investigators. Development of the 25-item National Eye Institute Visual Function Questionnaire. *Arch Ophthalmol*. 2001;119(7):1050-1058.

34. Lee BL, Gutierrez P, Gordon M, et al. The Glaucoma Symptom Scale: a brief index of glaucoma-specific symptoms. *Arch Ophthalmol*. 1998;116(7):861-866.

35. Westfall PHTR, Rom D, Wolfinger RD, Hocjberg Y. *Multiple Comparisons and Multiple Tests Using SAS*. Cary, NC: SAS Institute Inc; 1999.

36. Hirneiss C. The impact of a better-seeing eye and a worse-seeing eye on vision-related quality of life. *Clin Ophthalmol*. 2014;8:1703-1709.

37. Chan EW, Chiang PP, Wong TY, et al. Impact of glaucoma severity and laterality on vision-specific functioning: the Singapore Malay eye study. *Invest Ophthalmol Vis Sci*. 2013;54(2):1169-1175.

38. Park SC, De Moraes CG, Teng CC, Tello C, Liebmann JM, Ritch R. Initial parafoveal versus peripheral scotomas in glaucoma: risk factors and visual field characteristics. *Ophthalmology*. 2011;118(9):1782-1789.

39. Truong S, Cole N, Stapleton F, Golebiowski B. Sex hormones and the dry eye. *Clin Exp Optom*. 2014;97(4):324-336.

40. Paulsen AJ, Cruickshanks KJ, Fischer ME, et al. Dry eye in the Beaver Dam Offspring Study: prevalence, risk factors, and health-related quality of life. *Am J Ophthalmol*. 2014;157(4):799-806.

41. Schaumberg DA, Uchino M, Christen WG, Semba RD, Buring JE, Li JZ. Patient reported differences in dry eye disease between men and women: impact, management, and patient satisfaction. *PLoS One*. 2013;8(9):e76121.

42. Fernandez Lopez E, Karaca EE, Ekici F, Waisbourd M, Spaeth GL. Symptoms reported by patients with varying stages of glaucoma: review of 401 cases. *Can J Ophthalmol*. 2014;49(5):420-425.