Glaucoma

Impact of Glaucoma on Visual Functioning in Indians

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Purpose. To evaluate the impact of glaucoma on visual functioning in Indians.

Methods. Patients attending the glaucoma service who had undergone a comprehensive glaucoma evaluation were recruited. Better mean deviation (MD, using Humphrey Field Analyzer program 24-2) between two eyes was used to classify participants into mild, moderate, and severe visual field (VF) loss groups. Participants were administered the Glaucoma Quality of Life-15 (GQL-15) questionnaire. Rasch analysis was used to validate the GQL-15 and its four subscales. Linear regression was used to determine associations between GQL-15 scores and VF loss after adjusting for sociodemographic variables.

Results. A total of 198 patients (mean age ± SD, 59.8 ± 12.3 years; 67% male) were recruited. Participants with severe VF loss (39%) followed by mild loss (35%) comprised the largest group. Rasch analysis resulted in a 10-item reliable and valid questionnaire: the Glaucoma Activity Limitation-10 (GAL-10). Although a single subscale, "peripheral vision," met requirements of the Rasch model, it could not be preserved in the GAL-10. In multivariate analyses, the middle-income group (compared with higher income) and severe VF-loss (compared with mild VF-loss) participants reported significantly poorer functioning on GAL-10 ([β = 0.84; 95% confidence interval (CI), 0.16–1.52; $P = 0.02$] and [$\beta = 1.19$; 95% CI, 0.61–1.78; $P < 0.000$], respectively). None of these associations were, however, clinically significant.

Conclusions. Glaucoma patients in India, especially those with severe VF loss, face significant challenges in performing daily tasks and in mobility. It is important to prevent progression such that activity limitation is minimized in glaucoma patients. (*Invest Ophthalmol Vis Sci.* 2012;53:6081–6092) DOI: 10.1167/iovs.12-9885

Glaucoma is a progressive optic neuropathy that results in irreversible loss of the visual field (VF). It is the world's second leading cause of irreversible blindness.[1–3] Recent population-based studies from India have reported the prevalence of glaucoma blindness in those aged 40 years and older to range between 1.5% and 20% depending upon the type of glaucoma and location of residence.[4–10] Furthermore increased prevalence from primary angle-closure glaucoma (PACG) and those living in rural areas than primary open-angle glaucoma (POAG) and those living in urban areas.[4] Given the increased risk of glaucoma with age (i.e., especially those over 40 years),[1,5–7] there are serious economic and public health concerns associated with this chronic disease.[11]

The impact of glaucoma on a person is wide ranging. Early stages of the disease are characterized by a relatively intact central VF, so the disease often goes unnoticed.[9,10] By contrast, progressive loss of the peripheral VF occurs with advancing glaucoma, thereby resulting in difficulty in performing day-to-day activities (i.e., activity limitation) that involve use of peripheral vision or contrast, such as independent navigation, reading, driving, and so forth.[12] Given that clinical measurements are made under controlled clinic conditions, they fail to capture all the aspects of vision functioning that are important from a patient's perspective.[13] The patient's perception is, therefore, as important as the extent of the disease in assessing the severity of glaucoma.

Recently, two systematic reviews of the questionnaires used to assess the impact of glaucoma from the patient's perspective have been published.[14,15] The Glaucoma Quality of Life-15 (GQL-15) is one such questionnaire.[16] It is glaucoma specific in that it includes questions relevant to patients with glaucoma, so it is intuitively appealing to patients and researchers alike and is expected to be more responsive to interventions for glaucoma. The GQL-15 has been shown to be strongly associated with both activity limitation (visual disability) and various psychophysical tests such as contrast sensitivity, glare disability, dark adaptation, stereopsis, and Esterman VF score in Western populations.[16] Furthermore, significantly greater perceived activity limitation among glaucoma patients with mild VF loss compared with control group was reported in the same cohort, suggesting that early glaucomatous loss is readily discernible to patients, which belies the argument that glaucoma is an asymptomatic condition in its early stages.[16]

Strong psychometric properties have been reported for the GQL-15, albeit using the classical test theory (CTT).[16] However, the limitations of CTT are well recognized.[17,18] Modern test theories, such as item response theory (IRT), provide several potential advantages over CTT.[19–21] For this reason, the Rasch measurement model, one of the IRT models, is increasingly used in questionnaire development, and several legacy questionnaires in ophthalmology, developed using CTT, have been revalidated.[22–24] Recently, the GQL-15 was investigated using Rasch analysis in two glaucoma populations—German and Singaporean.[25,26] The GQL-15 demonstrated marginally suboptimal psychometric properties in the Singapore population but was still retained in its original form. By comparison, a revised nine-item version, with superior

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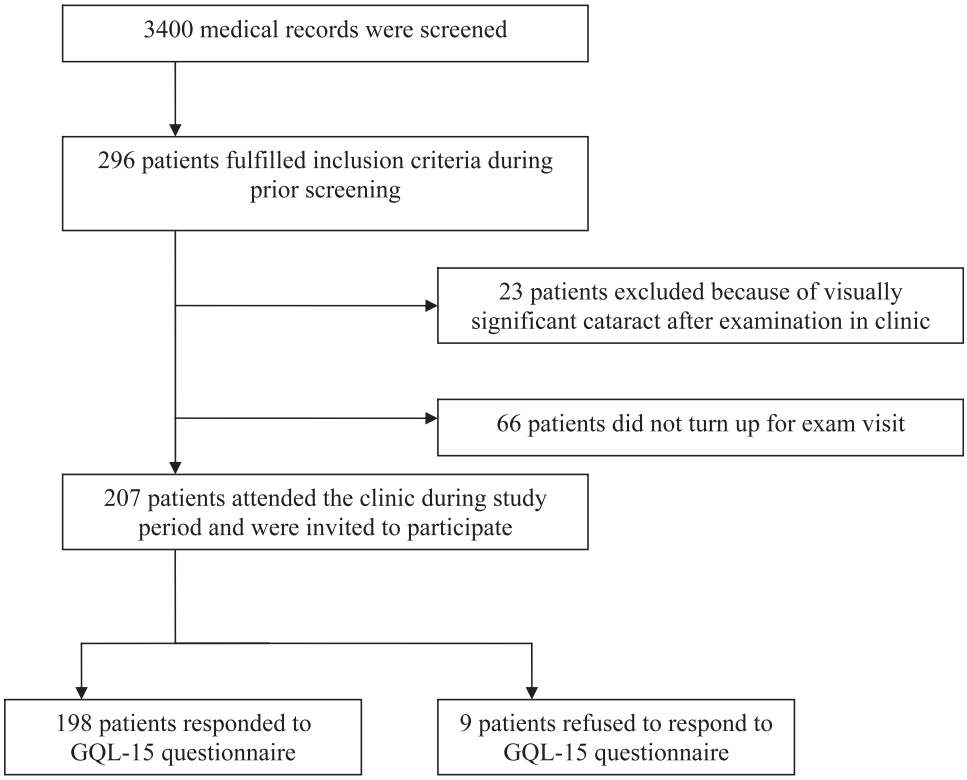

Figure 1. Study design schema.

psychometric properties was proposed—the Glaucoma Activity Limitation-9 (GAL-9)—in the German population.[25] As all the items included in the GQL-15 relate to activity limitation, the investigators suitably renamed it the GAL. However, neither of these investigations contained an assessment of validity of the subscales of the GQL-15.

While considerable literature exists regarding the prevalence of different types of glaucoma in India,[4,5,7,8] to the best of our knowledge, there have been no studies to assess the impact of glaucoma from the patient's perspective using glaucoma-specific questionnaires. Given the differences in literacy rates, socioeconomic status, lifestyle, and the cultural contexts between developing (such as India) and developed countries, the results from the latter populations may not be directly transferable to those in developing countries. Thus, the aim of the present study was to evaluate the impact of glaucoma using a glaucoma-specific questionnaire; namely, the GQL-15. In addition, we determined the relationship between the severity of VF loss, activity limitation (using GQL-15), and objective measures (clinical measures of visual function) in this cohort.

Patients and Methods

Participants were recruited during their routine follow-up visit to the L V Prasad Eye Institute (LVPEI), Hyderabad, India, between November 2010 and January 2011. Ethics approval was provided by the Ethics Committee for human research at the LVPEI and all consenting patients signed an informed consent form. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

Participants with established diagnosis of primary glaucoma who underwent glaucoma evaluation in the past 6 months at the glaucoma clinic and who had at least two reliable automated VFs (using Humphrey Automated Field analyzer, 24-2 Swedish Interactive Threshold Algorithm – Standard; Carl Zeiss Meditec, Inc., Dublin, CA), one of which was performed in the past 6 months were eligible. Reliable VFs were defined as those with <20% fixation losses and <33% false-positive and false-negative response rates. Medical records of all eligible patients were screened a day prior to their appointment, and they were invited to participate by either the research coordinator or the attending glaucoma specialist. A few potential participants ($n = 9$) refused to participate for various logistical reasons. Although this number was too small, a formal analysis revealed that the demographics of these participants did not substantially differ from those included in the study. The flow chart (Fig. 1) provides details on the enrollment of patients.

Patients included in the study were 18 years of age or older; understood and spoke English, Telugu, or Hindi; and had POAG, PACG, juvenile open-angle glaucoma, or normal-tension glaucoma. Given that age-related visually insignificant cataract (i.e., better eye visual acuity >20/40) has a relatively higher prevalence in patients with glaucoma, such patients were also eligible. However, patients with visually significant cataract (such that the patient had been advised to have surgery in any eye) were excluded. Glaucoma patients with pseudophakia in one or both eyes were included. Other criteria for exclusion were the presence of other impairments (e.g., physical, cognitive) that could influence their responses, having had intraocular surgery within the past 3 months, having had laser therapy within the previous 2 weeks, and the presence of coexisting ocular morbidity, such as diabetic retinopathy and/or maculopathy of any etiology.

All the patients underwent a comprehensive clinical assessment and completed the 15-item GQL. Participants were provided verbal instructions prior to filling out the GQL-15. While a little over one-third (65%) self-administered the GQL-15, trained interviewers administered it to the remaining

participants. In addition to the administration of the GQL-15, certain demographic details were also recorded from the patients, including age, marital status, location of residence, literacy, occupation, employment status, family history of glaucoma, systemic comorbidity, and monthly family income (in Indian Rupees, INR). The following information was extracted from patients' medical records: number of years since first diagnosis of glaucoma, number and type of glaucoma medications, history of previous glaucoma treatment (surgery or laser), ocular comorbidity, and VF test results using automated perimeter. Visual field testing was performed with appropriate refractive correction, and mean deviation (MD) was taken as the main global index of severity of VF loss. A VF was labeled glaucomatous by the glaucoma specialist based on two reliable threshold-VF examinations of the central 24° or 30° (Swedish interactive threshold algorithm Standard 24-2 or 30-2), if the patient had a glaucoma hemifield test result that was outside the normal limits or if the pattern SD was flagged at $P < 0.05$ on at least two consecutive baseline VF tests.[27,28] Additionally, the pattern of VF abnormality had to correspond with the disc findings for inclusion in the study.

Clinical Assessment

Snellen visual acuity (VA) was recorded monocularly and converted to logarithm of minimum angle of resolution (logMAR) for analysis.[29] Visual impairment was defined as presenting VA in better eye <20/60. Monocular contrast sensitivity (CS) was recorded using the Pelli-Robson contrast sensitivity chart and a standardized protocol.[30]

Severity of Visual Field Loss

The severity of VF defects was graded using a standard grading system: Hodapp–Anderson–Parrish (HAP) grading scale.[31–34] In brief, the MD was used as VF measurement representing overall VF loss, and the better MD between the two eyes (better MD) was used to classify the severity of the VF loss. More important, when viewing binocularly, the better eye will usually determine the degree of functional impairment.[35] Consequently, patients were categorized into three groups of clinical stages: (1) mild, an MD of no worse than −6 dB; (2) moderate, an MD of 6 to 12 dB; and (3) severe, an MD worse than 12 dB. These categories of VF loss were used in the primary analysis. However, the better MD and the MD of worse eye (worse MD) were also used as continuous variables during statistical analysis in the study.

Glaucoma Quality of Life-15 Questionnaire

The GQL-15 consists of 15 items, and these items are grouped into four subscales: (1) central and near vision (two items); (2) peripheral vision (six items); (3) dark adaptation and glare (six items); and (4) and outdoor mobility (one item)[16] (Table 1). Thus, the total number of items across the four subscales is 15. Participants rate the amount of difficulty in performing a given activity using five response options ranging from 1 (no difficulty) to 5 (severe difficulty). An item is coded as "not applicable" if the participant does not perform the activity owing to nonvisual reasons. Using standard procedures, local language versions were obtained using forward–backward translations of the GQL-15.

Rasch analysis was used to determine whether the total GQL-15 and subscale scores were valid, reliable, and possessed measurement characteristics. Subscales were included in the GQL-15 to provide a comprehensive assessment of activities that typically affect a glaucoma patient. Furthermore, performance of the overall questionnaire cannot ensure adequate functioning of its subscales, so we investigated the psychometric properties of the each of the subscales of the GQL-15. If we found flaws in the GQL-15 or its subscales, we attempted to create reengineered versions of these. Rasch analysis[36] was conducted using the Andrich rating scale model,[37] with Winsteps software (Version 3.68.0; Winsteps, Chicago, IL).[38] The Rasch measurement model has been described elegantly by Massof.[39] Four fundamental indicators were used to evaluate questionnaire quality. These included (1) fit, or the extent that items in the GQL-15 and its subscales measured a single construct (i.e., unidimensionality); (2) item difficulty; (3) targeting, or the extent to which the set of items is of appropriate difficulty for the level of the participant's visual abilities; and (4) measurement precision, using person separation reliability (PSR; minimum acceptable value 0.80), or the extent to which the items distinguish distinct levels of visual functioning in the participants.

Table 1. Item Content of the GQL-15 Questionnaire

Item No.	Item Description
1*	Reading newspapers
2†‡	Walking after dark
3†‡	Seeing at night
4†§	Walking on uneven ground
5‡	Adjusting to bright lights
6†‡	Adjusting to dim lights
7†‡	Going from light to dark room or vice versa
8†§	Tripping over objects
9†§	Seeing objects coming from the side
10†‖	Crossing the road
11†§	Walking on steps/stairs
12§	Bumping into objects
13§	Judging distance of foot to step/curb
14‡	Finding dropped objects
15*†	Recognizing faces

* Item belongs to central and near vision subscale.
† Item retained in the revised GQL-15.
‡ Item belongs to glare and dark adaptation subscale.
§ Item belongs to peripheral vision subscale.
‖ Item belongs to outdoor mobility.

Rasch analysis allows estimates of item difficulty (i.e., how difficult the items are) and person measures ("person ability," representing the extent to which participants or persons possess the construct being examined) to be made along postulated constructs; visual functioning in the present case. Two values are used throughout the analysis: logits (log-odds-units) and fit statistics (infit mean square). Rasch analysis estimates measures (interval-level scores) from raw ordinal data (assigned to response categories), and the unit of Rasch measurement is logits. In Rasch analysis, both persons (participants) and items are placed along a hierarchy on this logit scale. The logit (or log-odds unit) is the natural logarithm of the odds of a participant being successful at a specific task or an item being successfully carried out. Conventionally, zero (0) logit is ascribed to denote item difficulty. For the person category, logit measures indicate whether one person is more able than another (e.g., does one person have better visual functioning than another?). For items, logit measures indicate whether one item is more difficult than another (e.g., is reading newspapers more difficult than recognizing faces?). For the GQL-15 and its subscales, a positive person logit score indicates more activity limitation (worse visual functioning), and a positive item logit score indicates a less difficult item. Conversely, a negative person logit score indicates less activity limitation (better visual functioning), and a negative item logit score indicates a more difficult item. In simpler terms, higher

positive person scores indicate worse visual functioning, whereas higher negative person scores indicate better visual functioning.

Because the Rasch model is probability based, some amount of deviation of the scores of items can be expected. When an item does not perform as expected, the fit statistics (i.e., the infit mean-square statistic) flag the unexpected behavior of an item. The fit of items to the model was assessed using the fit statistics, specifically the infit statistic. The ideal value of the infit mean-square statistic is 1.0, and items with values outside the range of 0.7 to 1.3 were considered to be misfitting. However, recent studies suggested that fit statistics alone are inadequate to determine unidimensionality. Therefore, principal components analysis (PCA) of the residuals was also used in combination with Rasch fit statistics to test the unidimensionality of the GQL-15 and its subscales. The details of Rasch analysis have been described elsewhere.[23,24]

Statistical Analysis

Data analysis was performed with SPSS 16.0 for Windows (SPSS Inc., Chicago, IL). We used the overall (total) questionnaire score, linearly estimated using Rasch analysis in univariate and multivariate regression analysis, and used *t*-based 95% CI for the regression coefficients. The purpose of these analyses was to examine the relationships between self-reported activity limitation (i.e., questionnaire scores) and demographic and clinical measures of visual function. All *P* values were two-sided and were considered significant when the values were <0.05. Additionally, independent significant predictors were considered clinically meaningful if the 95% CI limits of their β coefficients were either more or less than half the SD of the mean questionnaire score.[40,41]

Results

A total of 198 patients responded to the GQL-15 questionnaire (response rate, 96%). Tables 2 and 3 summarize the sociodemographic and clinical characteristics of these participants. The majority had presenting VA $\geq$20/30 in the better eye ($n =$ 162, 82%); only 3% ($n = 7$) were visually impaired (VA $<$20/60 in better eye). Forty-seven participants (24%) had a worse eye VA of light perception or no light perception. Participants with POAG (47%) and PACG (41%) were almost equally distributed and formed the largest group. Based on better MD, participants with severe VF loss (39%) comprised the largest group.

Overview of Rasch Analyses of Psychometric Properties of GQL-15 Questionnaire

Entire GQL-15. There was no evidence of disordered thresholds, implying that participants used the rating scale was intended. The PSR was 0.88, which implied acceptable reliability and established the questionnaire's ability to differentiate among at least three distinct strata of participants' abilities. Targeting was –0.96 logits. Two items exhibited misfit (infit mean square 1.4 and 1.6) and thus were not contributing towards the measurement of the underlying construct. Unidimensionality (i.e., if all 15 items measured a single construct) by PCA of residuals was assessed and revealed that the unexplained variance by the first contrast was 2.1 eigenvalue units (remaining contrasts were $<$2.0 eigenvalue units), indicating a minor departure from unidimensionality being caused by three items (loading $>$0.4). Two of these three items belonged to the peripheral vision subscale and one to glare and dark adaptation. Two items ("going from light to dark room or vice versa" and "tripping over objects") showed differential item functioning (DIF), albeit minimal (0.50–1.00 logits), by age group and location. The presence of DIF indicated that these subgroups do not display the same probability of endorsing the item. Both of these items were rated 0.53 and 0.65 logits easier, relative to other items, by younger participants and urban residents, respectively.

Multidimensionality is critical to measurement because in its absence, the user cannot be certain of the nature of the construct under measurement. In order to optimize its measurement properties, it was essential that the questionnaire be segregated into several unidimensional constructs. The first dimension contained items from the peripheral vision domain; the second dimension contained glare and dark adaptation items.

The way forward to restore unidimensionality in the GQL-15 was to delete the three multidimensionality-causing items; once deleted, the remaining 12 items constituted a unidimensional measure. However, two items misfit (infit mean square 1.4 and 1.5) and were deleted iteratively. Consequently, the revised 10-item questionnaire was unidimensional, consisting of items that all fit the Rasch model (Table 1). The PSR was 0.86,which implied acceptable reliability and established the revised questionnaire's ability to differentiate between at least three distinct strata of participants' activity limitations. By comparison, the PSR of the GQL-15 was 0.88, indicating that the shortening to 10 items did not affect its reliability. More important, the 10-item scale consisted of items that all measured the same construct, so the use of a summary or total questionnaire score is valid. The underlying construct of the 10 items is vision-related activity limitation rather than quality of life (QOL), so we renamed the revised version the Glaucoma Activity Limitation-10 or GAL-10 (Table 1). Similar suggestions have been made by previous investigators in favor of renaming the revised Rasch version of the GQL-15 to GAL-9.[25]

Hence, for the remainder of this article, we refer to the reengineered version of the GQL-15 as the GAL-10, and we present all our analyses related to this version. The GAL-10 score has interval level properties, implying that it is appropriate for use in parametric statistics in further analyses. Figure 2 is a histogram of the GAL-10 person scores in logits ($P =$ 0.03, Kolmogorov–Smirnov test). Lower scores represent better visual functioning (i.e., reduced activity limitation). The mean ($\pm$SD) overall glaucoma participants' GAL-10 score was –0.81 ($\pm$1.33) logits, indicating that the revised 10 items in the GAL were reasonably matched to the participants' activity limitations (Fig. 3). Furthermore, the negative value for the mean score indicates that overall the participants had good glaucoma-specific visual functioning. The three most difficult activities reported included "walking after dark," "seeing at night," and "walking on uneven ground." The three least difficult activities were "adjusting to dim light," "tripping over objects," and "recognizing faces." Considering that the SD of the mean GAL-10 score was 1.33 logits, significant independent predictors were also deemed to be clinically significant if the CI limits of their β coefficients were greater than 0.66 or less than –0.66. These two values are approximately half the SD of the mean, which is generally considered to be a useful estimate of a clinically meaningful difference.

Although the underlying construct is activity limitation in the GAL-10 (present study) as well as in the GAL-9 proposed by Khadka et al.,[25] and both have been demonstrated to possess superior psychometric properties as compared with the original GQL-15 in the population assessed, there is a minor difference: the GAL-10 has 10 items, whereas there are nine in the GAL-9. Nonetheless, the two versions share seven common items. Furthermore, the items in the GAL-10 were better targeted to participant ability than those in the GAL-9.

Table 2. Sociodemographic and Clinical Characteristics of the Participants Who Responded to the GQL-15 Questionnaire ($n = 198$)

Participant Characteristic	Result
Mean age, y ± SD	59.8 ± 12.34
Range, y	20 to 87
Sex, *n* (%)	
Male	132 (67)
Female	66 (33)
Mean duration of glaucoma, y ± SD	8.0 ± 6.8
Range, y	8 mo to 58 y
Work status, *n* (%)	
Working	66 (33)
Not working	132 (67)
Retired	77 (39)
Homemaker	49 (25)
Visual reasons	6 (3)
Presenting VA in the better eye, mean ± SD	
LogMAR (Snellen)	0.15 ± 0.18 ($20/32^{+2}$)
Range	
LogMAR (Snellen)	0.0 to 0.9 (20/20 to 20/160)
Median logMAR (Snellen)	0.10 (20/25)
Presenting VA in the worse eye, mean ± SD	
LogMAR (Snellen)	0.74 ± 0.86 ($20/125^{+3}$)
Range	
LogMAR (Snellen)	0.0 to 2.5 (20/20 to no LP)
Median logMAR (Snellen)	0.30 (20/40)
Presenting Pelli-Robson CS in the better eye, LogCS	
Mean ± SD	1.12 ± 0.27
Range	0.15 to 1.50
Presenting Pelli-Robson CS in the worse eye, LogCS	
Mean ± SD	0.96 ± 0.40
Range	0.0 to 1.50
Category of VF loss*, *n* (%)	
Mild	69 (35)
Moderate	52 (26)
Severe	77 (39)
Better MD score, dB	
Mean ± SD	−12.03 ± 9.35
Range	0.38 to −32.44
Median	−8.68
Worse MD score, dB	
Mean ± SD	−19.37 ± 8.30
Range	−6.11 to −33.02
Median	−19.01

LP, light perception.

* Based on better mean deviation (using Humphrey Field Analyzer program 24-2).

However, targeting is sample dependent, so it is possible that GQL-9 may have performed differently in our population and vice versa.

Subscales. Of the four subscales, the three multi-item subscales were analyzed using Rasch analysis. Only a single subscale, "peripheral vision," was found to meet the requirements of the Rasch measurement model. The PSR was 0.80, and all the items fit the Rasch model well (infit mean square, 0.84–1.17). PCA of residuals indicated unidimensionality (unexplained variance by first contrast was 1.6 eigenvalue units). The mean (±SD) overall participants' peripheral vision score was −1.02 (±1.47) logits, indicating slight mistargeting. That is, the participants had a lower activity limitation (better peripheral vision functioning) than what could be captured by the items. However, this subscale could not be retained in its entirety in GAL-10, so there is no role for subscales in the revised 10-item questionnaire (GAL-10). The remaining two subscales ("central and near vision" and "glare and dark adaptation") had PSR values significantly below the minimum accepted value of 0.80. Given that these subscales lacked the fundamental requirement of measurement precision, these were considered dysfunctional and were not analyzed further.

Relationship between Activity Limitation and Sociodemographic Characteristics, and Severity of Visual Field Loss from Glaucoma

Univariate analysis (Table 3) demonstrated that rural dwellers and those whose monthly family income ranged from 5000 to 10,000 INR per month reported significantly greater activity limitation on the GAL-10 ($P < 0.05$). Participants did not vary in their GAL-10 scores by other sociodemographic variables assessed.

We examined the data to determine if increments of VF loss (severity of glaucoma) were associated with a corresponding increase in activity limitation (i.e., if there was a dose–response relationship between the severity of VF loss and the GAL score). Table 4 displays this relationship. In each case,

Table 3. Summary (Logit) Scores of GAL-10 Questionnaire (i.e., Revised Version of GQL-15) Stratified by Participant Characteristics ($n = 198$)

Participant Characteristic	No. (%)	Glaucoma Activity Limitation-10 Summary Logit Score* (Mean ± SD)
All subjects		
Mean ± SD (range)	198 (100)	−0.81 ± 1.33 (−3.71–2.41)
Median age, y		
<61	96 (48)	−1.37 ± 1.94
≥61	102 (52)	−1.20 ± 1.71
Sex		
Male	132 (67)	−1.16 ± 1.81
Female	66 (33)	−1.54 ± 1.83
Area		
Urban	167 (84)	−1.45 ± 1.82†
Rural	31 (16)	−0.38 ± 1.53
Median duration of glaucoma, y‡		
<6.5	97 (50)	−1.35 ± 1.63
≥6.5	97 (50)	−1.26 ± 1.98
Marital status		
Not married	6 (3)	−1.31 ± 1.40
Married	176 (89)	−1.25 ± 1.82
Widowed	16 (8)	−1.68 ± 1.98
Level of education		
No formal education	20 (11)	−1.17 ± 2.04
Primary school	71 (38)	−1.14 ± 1.66
Secondary school	77 (42)	−1.59 ± 1.88
Higher degree	16 (9)	−1.25 ± 1.91
Work status		
Working	66 (33)	−1.37 ± 1.79
Not working	132 (67)	−1.25 ± 1.84
Monthly income (Indian rupees)‡		
<5000	23 (12)	−1.00 ± 1.60
5000 to 10,000	33 (17)	−0.48 ± 1.80§
>10,000	138 (71)	−1.48 ± 1.81
Systemic Comorbidity‖		
Absent	93 (47)	−1.37 ± 1.92
Present	104 (53)	−1.19 ± 1.73
Family history of glaucoma‡		
Yes	39 (20)	−1.17 ± 2.03
No	159 (80)	−1.31 ± 1.77
Type of glaucoma		
POAG	94 (48)	−1.55 ± 1.93
PACG	82 (41)	−0.98 ± 1.61
Juvenile open-angle glaucoma	12 (6)	−1.68 ± 2.33
Normal tension glaucoma	10 (5)	−0.81 ± 1.42
Glaucoma treatment category‡		
Laser alone	2 (1)	−2.76 ± 3.06
Pharmacologic therapy alone	67 (34)	−1.62 ± 1.81
Surgery alone	14 (7)	−1.00 ± 1.42
Combination therapy (medical & surgery/ medical & laser/surgical and laser)	114 (58)	−1.09 ± 1.84
Number of glaucoma medications¶		
1	94 (54)	−1.43 ± 1.88
>1	79 (46)	−1.14 ± 1.81
Lens status		
Pseudophakia		
1 eye	33 (17)	−1.09 ± 1.91
Both eyes	26 (13)	−1.19 ± 2.16
Cataract		
None	23 (12)	−2.05 ± 1.97
1 eye	9 (5)	−0.88 ± 2.05
Both eyes	103 (53)	−1.27 ± 1.63

* GAL-10 questionnaire (revised GQL-15 using Rasch analysis); higher negative values for GAL-10 summary logit score indicate lower activity limitation.

† Denotes a significant statistical difference between the mean GAL-10 overall scores across the categories for that characteristic ($P < 0.05$).

‡ Data not available for a few patients (ranging from 1–15).

§ A significant difference between the GAL-10 scores of participants whose monthly income ranged between 5000 and 10,000 as compared with those whose income was >10,000 Indian Rupees ($P < 0.05$).

‖ Includes diabetes, hypertension, coronary artery disease, and asthma.

¶ Twenty-five patients did not require any medications for glaucoma.

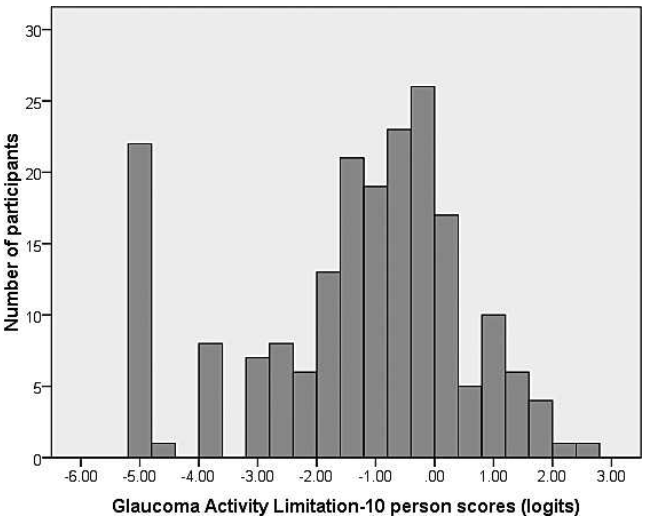

Figure 2. Histogram showing distribution of person scores using Rasch analysis of the GAL-10 questionnaire estimated from participants' ratings of the difficulty of 10 items. Person scores are expressed in logits. A positive person logit score indicates greater activity limitation (worse function), whereas a negative person logit score indicates lower activity limitation (better function).

univariate analysis revealed a significant reduction in the score (i.e., increased activity limitation) with worsening glaucoma levels. Participants with mild VF loss had significantly better glaucoma-specific visual functioning as compared with those with moderate or severe VF loss. Participants with severe VF loss had reductions in GAL-10 score of 72% (95% CI, 64.7–79.3) and 61% (95% CI, 52.6–69.4) when compared with those with mild and moderate VF loss, respectively (Table 4). However, there was no difference in functioning between those with mild and moderate VF loss using the GAL-10 ($P = 0.07$).

In the multivariate model, after controlling for potential confounders, only income and severity of VF loss remained independently associated with glaucoma-specific visual functioning using the GAL-10. Compared with patients with higher monthly income, those in the middle-income group had significantly poorer functioning ($\beta = 0.84$; 95% CI, 0.16–1.52; $P = 0.02$). Also, compared with patients with mild VF loss, those with severe VF loss had significantly poorer visual functioning ($\beta = 1.19$; 95% CI, 0.61–1.78; $P < 0.0001$). However, none of these independent associations were clinically significant.

Relationship between Activity Limitation and Clinical Measures of Visual Function in Glaucoma

All of the clinical measures of visual function (visual acuity, contrast sensitivity, and mean deviation) demonstrated significant, albeit moderate correlations ($r = 0.36$–0.49) with the GAL-10 score (Table 5). However, considerable scatter was observed in the correlations, and an example of such scatter for better MD is depicted in Figure 4. Given the results from previous studies, we expected to find higher correlations between activity limitation (GAL-10 scores) and clinical measures of visual function of better eye, compared with those of worse eye. We found the GAL-10 scores to be statistically significantly correlated with the clinical measures and of similar magnitude for both better and worse eye.

Conversion of Raw to Rasch-Scaled Scores

The results of the present study are likely to be generalizable to other populations, but population samples vary, so it is always best to implement Rasch measurement properties by actually performing Rasch analysis. However, other investigators may wish to use the GAL-10 and also gain the interval-scoring benefits of Rasch analysis without performing Rasch analysis themselves. For the benefit of such investigators, we have developed a series of Excel (Microsoft, Redmond, WA) spreadsheets, which convert raw (ordinal) GAL-10 scores to Rasch measurement estimates. These spreadsheets can be obtained by contacting the corresponding author.

Discussion

This cross-sectional study from a South Indian glaucoma population demonstrates a consistent pattern of worsening of functioning (poorer GAL-10 scores) with increasing amounts of VF loss across the disease spectrum. This is consistent with outcomes reported by similar such studies in the Western glaucoma populations.[16,42–44] Patients with severe VF loss reported significantly worse functioning due to glaucoma. However, those with mild and moderate VF loss also reported functioning difficulties, providing evidence of the impact of VF loss and of a dose–response relationship: increasing severity of VF loss in the eye with better MD was associated consistently and independently with increasing activity limitation (i.e., lower negative logit scores on the GAL-10). Participants with severe VF loss had reductions in GAL-10 score of 72% (as compared with mild VF loss) and 61% (as compared with moderate VF loss). These findings are consistent with those of Nelson et al. who developed and used the GQL-15.[16]

Our results are in accordance with those from developed countries that have demonstrated the deleterious effects of VF loss on vision-specific functioning in glaucoma.[16,43–48] For example, the population-based Los Angeles Latino Eye Study (LALES) used the National Eye Institute-Visual Function Questionnaire (NEI-VFQ) and reported that greater VF loss in patients with OAG impacts on the vision-related QOL.[47] Parrish et al. demonstrated that perceived difficulty with driving increases with worsening VF damage in the better eye of glaucoma patients.[49] Using the same GQL-15 as in the present study, Goldberg et al. reported that the GQL-15 scores differ significantly among patients with mild, moderate, and severe glaucoma, demonstrating a trend of poorer functioning with increasing severity in an Australian clinic-based sample.[44] In a recent study of a Singapore hospital-based glaucoma sample that also used the GQL-15, Wang et al. demonstrated a significant and independent association between the severity of bilateral glaucoma and functioning.[26] They reported that the deterioration in functioning is clinically significantly worse in those with bilateral moderate/severe glaucoma. Taken together, these findings suggest that glaucoma impacts functioning transcending all barriers such as ethnicity, race, and culture.

Until now, all four studies that used the GQL-15 had been conducted in Western populations (United Kingdom, Australia, Germany, and Singapore).[16,25,26,44] Two of the four studies used the raw (Likert) scores from the GQL-15, but the recent two studies in the German and Singaporean populations have performed Rasch analysis of the GQL-15. Our results of the GAL-10 are unique given that there is a lack of literature regarding the use of glaucoma-specific questionnaires such as the GQL-15 from India.

While other studies have reported variables such as age[44] and a history of surgery for glaucoma to be related to visual functioning,[50] we failed to find such associations. In our study,

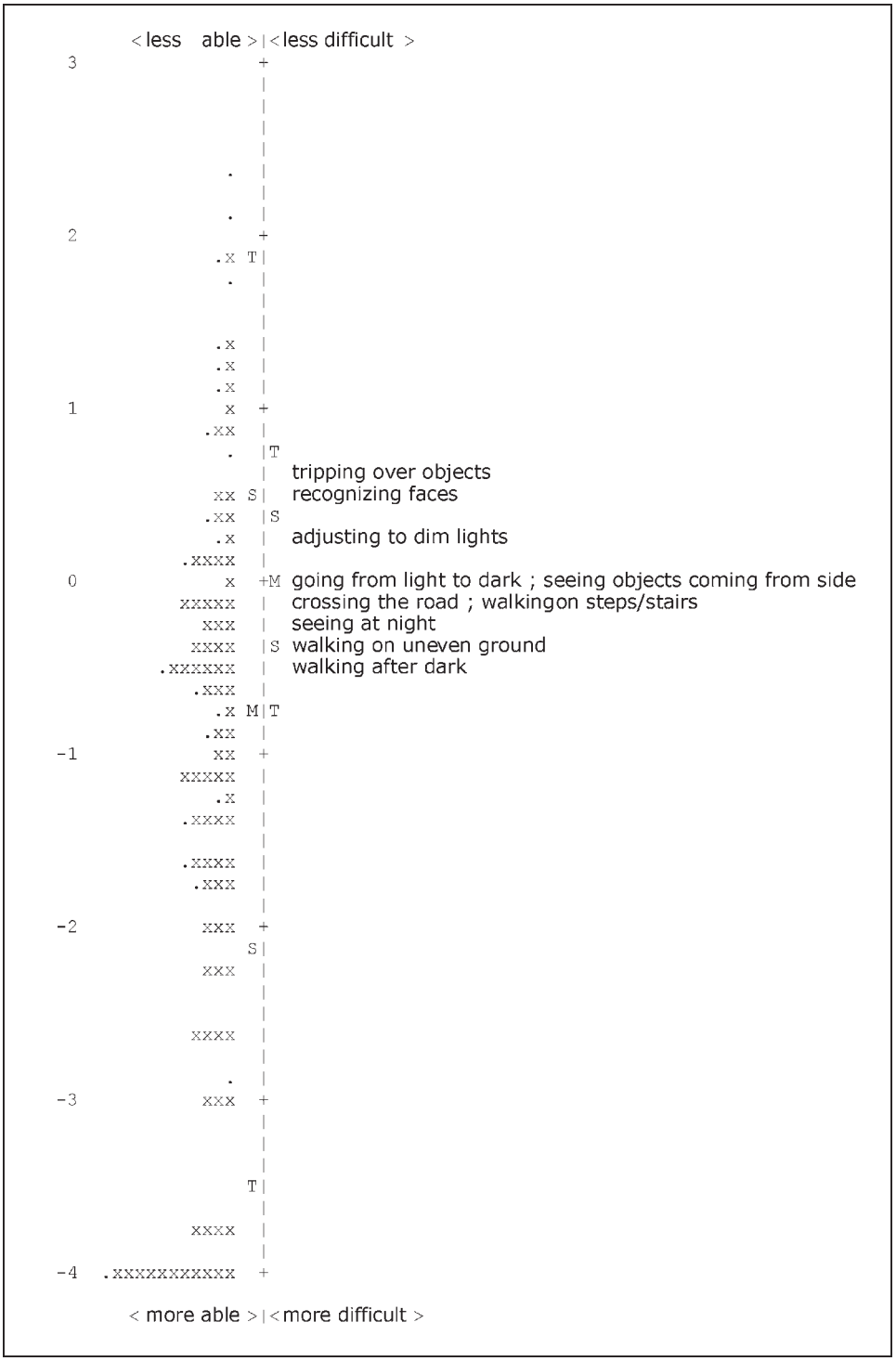

Figure 3. Person item map of the GAL-10 questionnaire. *Left of the dashed line*: participants represented by "x." *Right of the dashed line*: items denoted by their content. *Top of the map*: participants with lower ability and least difficult items. On the whole, the item difficulty matches the ability of the participants, which is represented by the x's being concentrated where the items are located and the means of the two distributions, denoted by M, being close to each other. Each "**x**" and "**.**" represent two and one participant, respectively. M, mean; S, 1 SD from the mean; T, 2 SD from the mean.

the median duration since diagnosis of glaucoma was 6.5 years, and 58% were on combination therapy for glaucoma, so it is unlikely that our participants were unaware of their diagnosis/status of glaucoma (although this information was not collected by us). Nonetheless, the knowledge of the diagnosis and information about the status of glaucoma in patients under periodic follow-up could potentially influence their responses to items on the GAL-10.[51] The mean GAL-10 score in the present study was –0.81 ± 1.33 logits, indicating that our participants did experience activity limitation regardless of the duration of glaucoma. Therefore, the knowledge or history of glaucoma would have had a negligible impact (if any in terms

Table 4. Relationship between Severity of Visual Field Loss and the GAL-10 Questionnaire Score

Category of VF Loss*	GAL-10 Score (Mean ± SD, Range)†	Visual Performance (%)‡	*P* Value§
Mild	−1.98 ± 1.82 (−4.93 to 0.82)	–	–
Moderate	−1.43 ± 1.66 (−4.93 to 1.91)	28% ↓ (vs. mild)	0.253
Severe	−0.56 ± 1.67 (−4.93 to 2.41)	72% ↓ (vs. mild)	<0.0001
		61% ↓ (vs. moderate)	0.014

* Mean deviation of better eye used for classification (mild VF loss – mean deviation no worse than 6 dB in better eye; moderate VF loss – mean deviation between 6 and 12 dB in better eye; severe VF loss – mean deviation worse than 12 dB in better eye).

† GAL-10 score (in logits); higher negative values indicate better score and lower activity limitation.

‡ Visual performance compared for moderate and severe VF loss categories against mild.

§ Using ANOVA with post-hoc analysis (Tukey); $P < 0.05$ indicates statistically significant.

of underreporting) on the responses to the GQL-15. Our belief is further supported by the LALES, which comprised 75% newly diagnosed glaucoma patients and 25% patients with a history of glaucoma, who were found to have differences in QOL scores (using NEI-VFQ and Short-form 12 [SF-12]) by VF loss status despite adjusting or excluding those with history of glaucoma and/or treatment history from the analyses.[47] In the present study, using multivariate analysis, we found that patients in the middle-income group reported statistically worse functioning than those in the higher income group; this was not clinically significant. This finding is perhaps not surprising given their socioeconomic status; patients in the middle-income group could have had an advanced stage of the disease at presentation and may have lacked compliance and adherence to medications resulting in uncontrolled intraocular pressures. Other variables not included in our study, such as psychological factors (presence of depression, mood state, anxiety) and family support systems, could all have hypothetically affected responses to the GQL-15. These factors require investigation in future studies.

As mentioned in the Results section, other investigators who wish to use the GAL-10 can use either the Excel spreadsheets developed by us to obtain the interval-level scores for their raw data (if their sample is similar to that of present study) or perform Rasch analysis on their own data. In the latter case, it is likely that a new study of GQL-15 in a different population could result in another Rasch version of the questionnaire.

A number of studies that have used questionnaires have revealed aspects of vision that most influence patients' beliefs about their vision.[16,43,45,47,49,51–54] However, the relationship between vision and performance of daily activities is much more complex than can be gleaned from questionnaires on self-reported functioning. Aspects of vision include the ability to detect motion, recognize patterns (acuity), distinguish borders (contrast sensitivity), appreciate color, and notice objects in different parts of the VF.[55] Given the results of previous studies using questionnaires in glaucoma patients, some correlation between clinical measures of vision and the GAL-10 score would be expected in our sample. The relationship between activity limitation and all clinical measures of vision used in the present study was equally strong. Nonetheless, the role of contrast sensitivity—the not-so-commonly recorded clinical measure—deserves mention. We found VA and contrast sensitivity to be moderately correlated with each other ($r = -0.63$, $P < 0.0001$). Correlations in the range of 0.5 to 0.6 with VA have been reported previously,[56] so our findings are as expected. This relationship perhaps suggests that contrast sensitivity is less likely to provide any new information at higher spatial frequencies as has also been demonstrated in the work by Elliott and Hurst.[57] However, Pelli-Robson contrast sensitivity provides information concerning low to medium spatial frequencies only, and this is the region that is most closely associated with activity limitation in glaucoma patients for tasks such as reading, face recognition, and mobility.[16] Therefore, in accordance with other investigators,[58,59] we believe that the Pelli-Robson contrast sensitivity test is likely to provide important information about the difficulties faced by glaucoma patients in performing daily activities, especially in those with near-normal VA.

While the pattern of these correlations was in the expected direction, all of these relationships possessed considerable scatter (Fig. 4), which also appears to be consistent with several earlier studies.[16,43,60–63] In addition, the correlations were not significantly different in the better or worse eye for any of the clinical measures of vision. Other studies have also reported a lack of distinct difference in the correlation of visual functions of better or worse eye with self-reported visual functioning.[42,43,45] In our study, the worse eye acuity followed by better MD showed the strongest correlation with the GAL-10 score. This finding is similar to that by Jampel et al., albeit using a different questionnaire, the NEI-VFQ, in an American population.[60] As proposed by Jampel et al., the reason that worse eye acuity and better MD relate more closely to patient's perspective could be due to the difference in the psychophysical measurement of VA and VF, which reveals aspects of inter-eye performance that differ from VF testing.[60]

The use of questionnaires in the assessment of activity limitation has pitfalls because they are, by their nature, subjective and are affected by various factors; for example, culture, language, education, social desirability, and so forth.[64–66] These nonvisual variables could be the reason for the scatter observed in patients' responses to questionnaires. Given the limitations of questionnaires, performance-based measures (PBMs), which involve testing what a person can

Table 5. Spearman Rank Correlation for the GAL-10 Questionnaire Overall Score with Clinical Measures of Visual Function*

	VA		Pelli- Robson CS		Perimetric MD	
Questionnaire	Better Eye	Worse Eye	Better Eye	Worse Eye	Better Eye	Worse Eye
GAL-10†	0.35	0.49	−0.38	−0.36	−0.40	−0.35

* $P < 0.0001$ for association with all clinical measures.

† GAL-10 - revised version using Rasch analysis of the Glaucoma Quality of Life-15 questionnaire.

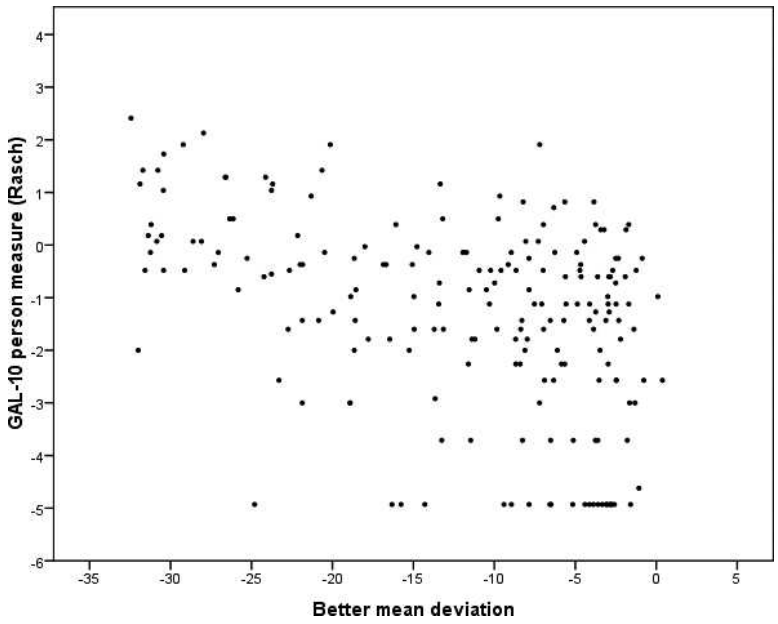

FIGURE 4. Scatterplot of the relationship between better MD and GAL-10 Rasch person measure ($r = -0.40$; $P < 0.0001$).

and cannot do by actually observing the person attempting to perform specified tasks, have received increased attention.[67–69] Assessment of disability related to vision is one such PBM that has been developed recently in ophthalmology and has been shown to be a valid and reproducible method for assessing glaucoma patients.[61,68]

The strengths of our study are the relatively large sample size and the inclusion of participants with mild to severe VF loss. The use of a glaucoma-specific questionnaire and Rasch analysis to validate it, so as to produce an estimated linear interval overall measure of activity limitation, is another significant strength of this study. To our knowledge, this is the first time that GQL-15 and its subscales have been subjected to Rasch analysis in a South Indian glaucoma population, and it has resulted in a valid unidimensional measure of activity limitation (GAL-10) in these patients. However, our study has some limitations. There was a male preponderance (67%), a higher proportion were literates (89%), and the majority were from urban areas (84%); however, this was perhaps expected given the tertiary eye care centre–based sample, so our sample may not be fully representative of the population, and the results cannot be generalized to glaucoma patients in a community setting. Furthermore, the cross-sectional design of our study has to be considered while interpreting the reduction in glaucoma functioning (GAL-10 scores) across subgroups of participants. The reduced scores are based on comparison between participants categorized into different groups and do not necessarily indicate a longitudinal shift in the activity limitation with a change in the VA or VF or the status of glaucoma. We studied the VA, CS, and VF in better and worse eye separately, but not binocularly. One could argue for the need to include binocular data. We did not explore the potential effects of loss of color vision and other psychophysical measures, including disability glare, dark adaptation, and stereopsis on activity limitation. These psychophysical measures have been reported to be compromised in glaucoma.[16] The potential effects of these measures on activity limitation need further exploration in futures studies.

In conclusion, our study provided evidence of the impact of glaucoma on visual functioning (activity limitation) as measured by GAL-10 in glaucoma patients. With superior measurement properties, the GAL-10 can be used in place of the original GQL-15 as a summary index of activity limitation for glaucoma patients, and its brevity may make clinical application simpler. By using Rasch analysis to generate an overall score with interval characteristics for the GAL-10, our data showed a dose-related gradient relationship between the severity of VF loss and activity limitation in a South Indian glaucoma population. Nonetheless, the limitations of questionnaires, including the GAL-10, in the assessment of activity limitation should be considered when interpreting the results. Given the potential advantages of PBMs of visual function, for example, the Assessment of Disability Related to Vision (ADREV) PBMs are likely to play an important role in the assessment of impact of glaucoma on patients. Nonetheless, PBMs have only recently been introduced in ophthalmology, and their relationship with questionnaires and clinical measures of vision is still being studied. Until PBMs gain wide acceptance, the results of studies using reliable and valid questionnaires, such as the GAL-10 in our study, would offer clinicians a reasonably good understanding of activity limitation from the glaucoma patient's perspective and serve as a guide in referral to low vision rehabilitation services at the appropriate time.

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