Evaluation of Fear of Falling in Patients with Primary Open-Angle Glaucoma and the Importance of Inferior Visual Field Damage

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Purpose. To evaluate fear of falling using the Fall Efficacy Scale-International (FES-I) in glaucoma patients and investigate its association with glaucomatous visual field loss.

Methods. This study included 273 patients (160 men and 113 women, average age 64.2 years) with primary open-angle glaucoma. Participants were requested to answer the FES-I questionnaire, translated into Japanese, in a face-to-face interview. The relationship between total FES-I score and the following variables was analyzed using multivariable linear regression: age, sex, better and worse best corrected visual acuity, total deviation (TD) in four visual field areas, body mass index (BMI), minutes walked per day, history of diabetes mellitus, history of systemic hypertension, number of previous falls.

Results. Univariate analysis suggested that total FES-I score increased with age and in woman, whereas other variables were not significantly associated with total FES-I score. However, age (coefficient, 0.23; standard error [SE], 0.04; $P < 0.001$), sex (coefficient, 1.79 for women; SE, 0.84; $P = 0.034$), mean TD in the inferior central area (coefficient, 0.92; SE, 0.22; $P < 0.001$), and mean TD in the inferior peripheral area (coefficient, –0.86; SE, 0.21; $P < 0.001$) were included in the optimal model for total FES-I score.

Conclusions. Inferior peripheral visual field damage and preserved inferior central visual field sensitivity were associated with increased fear of falling assessed with FES-I in glaucoma.

Keywords: QoL, fall, fear of falling

Considering that aging is one of the most important risk factors for glaucoma,[1] the number of glaucoma patients is significantly increasing in our ageing population. Many studies have shown that glaucomatous vision loss can deteriorate patients' quality of life (QoL). Sumi et al.[2] reported that visual field damage in the lower hemifield within 5° of fixation is the most important area for vision-related QoL, whereas other studies have suggested the importance of other visual field regions for specific tasks, such as driving,[3] postural stability,[4] hand-eye coordination,[5] the possibility of causing or being involved in a motor vehicle accident,[6–12] the risk of fractures,[13] and also the likelihood of falling.[6] Deterioration of QoL in glaucoma patients can lead to depression,[14] anxiety,[14,15] sleep disturbance,[15] suicidal ideation,[15] and fear of falling.[16,17] Consequently, the QoL of glaucoma patients is an important public health issue.[18]

Fear of falling is psychologically damaging and is related to lower QoL. It can lead to decreased physical functioning,[19] reduced activities in daily living,[20] increased depressive symptoms,[21] impaired balance,[22,23] and low mobility.[24] Previous studies have investigated the relationship between glaucomatous visual field damage and fear of falling,[17,25] however, fear of falling was assessed in an arbitrary manner using nonvalidated tools, such as a single questionnaire.[24] The Fall Efficacy Scale (FES)-International (FES-I) is a validated questionnaire that assesses fear of falling, defining it as low perceived self-efficacy at avoiding falls during essential, nonhazardous activities of daily living.[20] The tool was developed by the Prevention of Falls Network Europe, a European committee focused on fall prevention and the psychology of falling.[26] This questionnaire has been widely used in many research fields, especially in geriatric science,[27,28] being validated in different populations.[29,30] Greenberg[24] reviewed measurement tools of fear of falling, and recommended FES-I to measure fear of falling because it is a short, easily administered tool, with understandable scoring categories that include both physical and social activities in and out of the home, whether or not the person actually conducts the activity. Despite this, to the best of our knowledge, no study has investigated the fear of falling—using FES-I—in patients with glaucoma.

The aim of our study was to evaluate the fear of falling in glaucoma patients using the FES-I, and to investigate the association with FES-I score and glaucomatous visual field loss.

Subjects and Methods

The study procedures conformed to the tenets of the Declaration of Helsinki and to national (Japanese) and institutional (Keio University School of Medicine) regulations. The study was approved by the ethics committee of the Keio University School of Medicine (#2010293). All study subjects gave a written informed consent prior to being enrolled. The study was preregistered in the University Hospital Medical Information Network (UMIN) Clinical Trial Registry (UMIN000005574, http://www.umin.ac.jp/ctr/index.htm).

Study Design and Subject Enrollment

This was a cross-sectional observational study. Details of the patient recruitment are given elsewhere[17]; in short, all patients between ages 40 and 85 years who visited Keio University Hospital (Tokyo, Japan), the Iidabashi Eye Clinic (Tokyo, Japan), or the Tanabe Eye Clinic (Yamanashi, Japan) between the period of May 1, 2011 and November 30, 2011 were screened for eligibility in this study.

Baseline Evaluation of Subjects with Glaucoma

Glaucoma patients studied underwent a battery of ophthalmic examinations, including slit-lamp biomicroscopy, funduscopy, gonioscopy, intraocular pressure measurements by Goldmann applanation tonometry, and visual field examination with the Humphrey Field Analyzer (HFA; the 24-2 Swedish Interactive Threshold Algorithm Standard Strategy, Carl Zeiss Meditec, Dublin, CA). The findings were analyzed by TS and KY, both of whom subspecialize in glaucoma. The reliability of the visual field was confirmed to be less than a 20% fixation loss rate and less than a 15% false-positive rate; the false-negative rate was not applied as a reliability criteria because it has been shown to be positively correlated with the level of visual field damage rather than patient attentiveness.[31]

Diagnostic Criteria for Primary Open-Angle Glaucoma (POAG)

POAG was diagnosed according to the presence of the following three findings: (1) glaucomatous optic disc cupping, represented by notch formation, generalized cup enlargement, a senile sclerotic or myopic disc, or nerve-fiber layer defects; (2) glaucomatous visual field defects, defined according to the Anderson and Patella[32] criteria (a cluster of three or more points in the pattern deviation plot within a single hemifield [superior or inferior] with a P value <5%, one of which must have a P value <1%); and (3) an open angle observed on gonioscopy. Gonioscopy was performed by a glaucoma specialist. During the enrolment period, 10 POAG patients did not agree to participate in the study. The percentage of POAG patients who agreed to participate in the study was 96.3%. We excluded 62 patients with secondary glaucoma, and 16 patients with angle closure glaucoma. We included glaucoma patients after experiencing visual field testing at least two times. Therefore no patient was perimetrically naive.

Evaluation of Fall-Related Self-Efficacy

All participants answered the FES-I questions, translated into Japanese, in a face-to-face interview. The original FES-I has excellent internal and test–retest reliability (Cronbach's α, 0.96; interclass correlation coefficient, 0.96).[29] The original FES-I can be downloaded from this website (https://www.health.qld.gov.au/__data/assets/pdf_file/0026/426635/33346.pdf). The Japanese version of FES-I also has excellent internal and test–retest reliability (Cronbach's α, 0.95; interclass correlation coefficient, 0.79).[33] The level of concern about falling when carrying out each activity is evaluated using a four-response category (1 = not at all concerned, 2 = somewhat concerned, 3 = fairly concerned, 4 = very concerned). Individuals are instructed to rate each activity regardless of whether they actually perform it. The total FES-I score ranges from 16 to 64 and is calculated by adding points from all question responses. The 16 questions concerned the following activities:

1. Cleaning the house (e.g., sweep, vacuum, or dust)
2. Getting dressed or undressed
3. Preparing simple meals
4. Taking a bath or shower
5. Going to the shop
6. Getting in or out of a chair
7. Going up or down stairs
8. Walking around outside
9. Reaching up or bending down
10. Answering the telephone
11. Walking on a slippery surface (e.g., wet or icy)
12. Visiting a friend/relative
13. Going to a place with crowds
14. Walking on an uneven surface (e.g., rocky ground, poorly maintained pavement)
15. Walking up or down a slope
16. Going out to a social event (e.g., religious service, family gathering, or club meeting)

In addition, demographic information was recorded from participants, including age, sex, height, weight, alcohol intake, smoking history, current illnesses including past history of depression, usage of cane, and medical history (including medications taken orally, such as sedatives and tranquilizers).

Integrated Binocular Visual Field

A binocular integrated visual field (IVF) was calculated for each patient by merging the patient's monocular HFA visual fields, using the "best sensitivity" method, in which the IVF total deviation (TD) at each point was calculated using the maximum TD (least negative) value from each of the two overlapping points, as if the subject was viewing the field binocularly.[34] The IVF mean deviation was calculated as the mean of 52 TD values across the whole visual field, whereas the means of TD values in the superior peripheral (mTD_{SP}), superior central (mTD_{SC}), inferior central (mTD_{IC}), and inferior peripheral (mTD_{IP}) areas were also calculated, following the areas indicated in Figure 1; thus the visual field was divided outside and within the central 10° (these areas follow the mapping in the 24-2 and 10-2 visual field of the HFA).

Statistical Analyses

The relationship between total FES-I score and the following variables were analyzed using multivariable linear regression: age, sex, better best corrected visual acuity (BCVA),

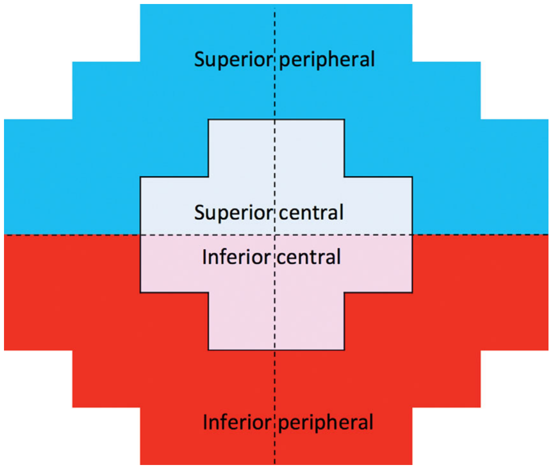

Figure 1. Mapping of the superior peripheral, superior central, inferior central, and inferior peripheral areas. The visual field was divided outside and within the central 10°. These areas follow mappings in the 24-2 and 10-2 visual field of the HFA.

worse BCVA, mTD_{SP}, mTD_{SC}, mTD_{IC}, mTD_{IP}, BMI, average minutes walked per day, history of diabetes mellitus, history of systemic hypertension, usage of tranquilizers, and number of previous falls. We included these variables as surrogate measures for frailty and mobility problems to control for confounding. The optimal linear model was then selected among all possible combinations of the 13 predictors (2^{13} total combinations) using the second order bias corrected Akaike Information Criterion (AICc) index. The degrees of freedom in a multivariate regression model decreases when the number of variables is large and it is therefore recommended to use model selection methods to improve model fit by removing redundant variables.[35,36] The AICc statistics of different models were compared using the ANOVA test. Finally, in the optimal model, to assess whether the effect of a variable on total FES-I score was independent from other variables, three correlation analysis was conducted. Partial correlation measures the correlation between two variables while controlling for other variables.[37] All data were analyzed with the statistical programming language R (R version 3.1.3; The Foundation for Statistical Computing, Vienna, Austria).

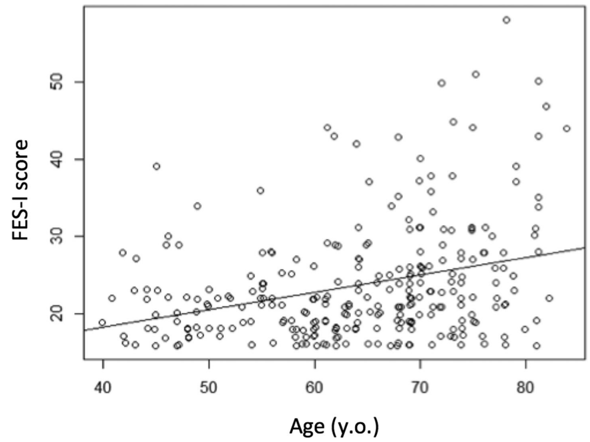

Figure 2. The relationship between FES-I total score and age. FES-I score increased with increasing age ($P < 0.001$).

Results

Patients' demographic data are shown in Table 1. As shown in Figure 2, FES-I score increased with increasing age (coefficient, 0.23 per year; standard error [SE], 0.042; $P < 0.001$, linear model). As shown in Figures 3–7, mTD, mTD_{SP}, mTD_{SC}, mTD_{IC}, and mTD_{IP} were not significantly associated with FES-I score (P = 0.43, 0.13, 0.069, 0.50, 0.61, linear model). Similarly, BMI ($P = 0.46$), average minutes walked per day ($P = 0.59$), and number of previous falls ($P = 0.68$) were not significantly associated with total FES-I score. The total FES-I score was not significantly different between patients with and without a history of diabetes ($P = 0.62$, unpaired t-test), or systemic hypertension ($P = 0.37$, unpaired t-test). In contrast, there was a significant difference in the total FES-I score between men and women (significantly higher in women, $P = 0.023$, unpaired t-test).

Among the 13 variables of age, sex, better BCVA, worse BCVA, mTD_{SP}, mTD_{SC}, mTD_{IC}, mTD_{IP}, BMI, average minutes

Table 1. Demographic Characteristics of the Subjects

	Mean	SD	Range		
Age, y	**64.2**	**10.3**	**40**	**to**	**84**
Sex, male:female			160:113		
Better BCVA	0.0028	0.015	0.00	to	0.15
Worse BCVA	0.016	0.039	0.00	to	0.15
MD in the better eye, dB	−3.2	4.7	−29.0	to	2.2
MD in the worse eye, dB	−7.8	7.0	−31.0	to	0.9
IVF mTD, dB	−2.1	3.9	−18.40	to	5.3
mTD_{SP}, dB	−2.9	5.4	−24.5	to	6.0
mTD_{SC}, dB	−2.7	5.8	−31.7	to	5.3
mTD_{IC}, dB	−0.93	3.5	−29.2	to	6.2
mTD_{IP}, dB	−1.6	3.6	−20.9	to	4.3
BMI, %	22.3	3.0	15.6	to	32.7
Average walk minutes per day, minutes	87.9	95.6	0.0	to	600
History of diabetes mellitus, (yes:no)			40:233		
History of systemic hypertension, (yes:no)			81:192		
Number of previous falls, times	0.21	0.67	0	to	6

dB, decibel.
MD: mean deviation

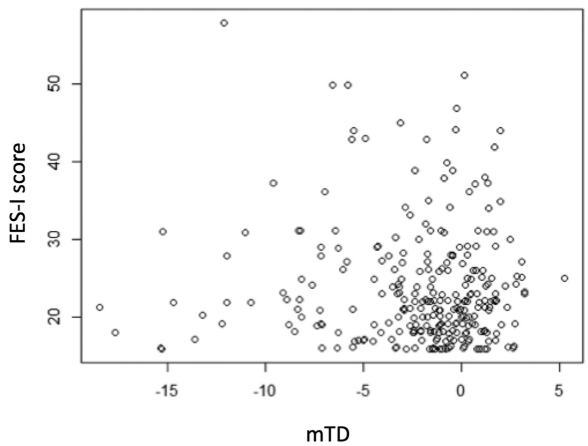

Figure 3. The relationship between FES-I total score and mTD. mTD was not associated with FES-I score ($P = 0.43$). mTD: mean of 52 TD values across the whole visual field.

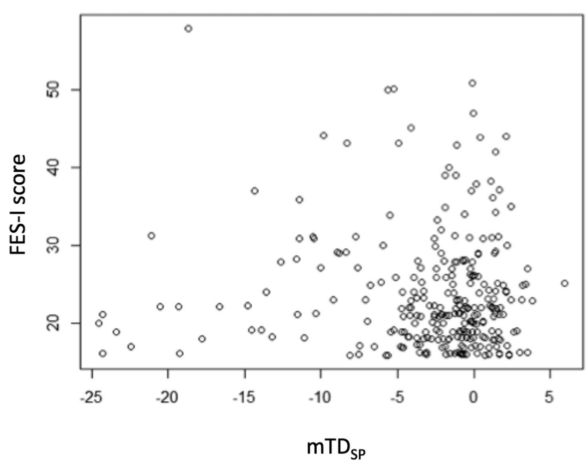

Figure 4. The relationship between FES-I total score and mTD_{SP}. mTD_{SP} was not associated with FES-I score ($P = 0.13$).

walked per day, history of diabetes mellitus, history of systemic hypertension, history of systemic and orthopedic disease (such as rheumatic arthritis, osteoporosis, spinal stenosis, and Parkinson disease, number of previous falls, usage of tranquilizer) only four were included in the optimal model for total FES-I score: age (coefficient, 0.23; SE, 0.04; $P < 0.001$), sex (coefficient, 1.79 for women; SE, 0.84; $P = 0.034$), mTD_{IC} (coefficient, 0.92; SE, 0.22; $P < 0.001$), and mTD_{IP} (coefficient, –0.86; SE, 0.21; $P < 0.001$); this model had an AICc value of 1832.7 (Table 2). As shown in Table 3, removing mTD_{IC} and mTD_{IP} from this model (leaving only age and sex as the dependent variables) resulted in a significant decrease in the goodness of fit of the model (AICc, 1847.6; $P < 0.001$, ANOVA). The goodness of fit of the model with age and sex only was not improved by separately adding mTD_{IC} or mTD_{IP} (AICc, 1847.9 and 1848.3; $P = 0.57$ and 0.72, with Bonferroni's correction for multiple comparisons, respectively). The optimal model was significantly better than an equivalent model that included (1) mTD_{SC} (AICc, 1849.7), (2) mTD_{SP} (AICc, 1847.9), and (3) mTD_{SC} and mTD_{SP} (AICc, 1846.0), instead of mTD_{SC} and mTD_{SP} (ANOVA, all $P < 0.001$, with Bonferroni's correction for multiple comparisons, respectively).

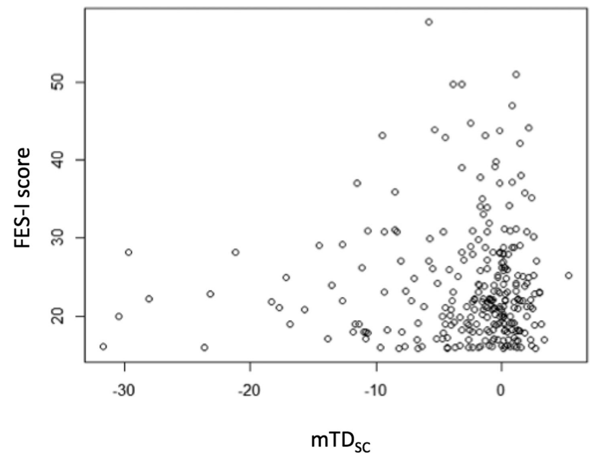

Figure 5. The relationship between FES-I total score and mTD_{SC}. mTD_{SC} was not associated with FES-I score ($P = 0.07$).

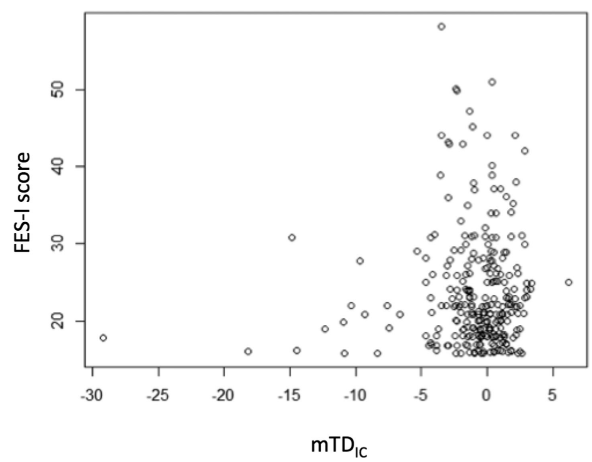

Figure 6. The relationship between FES-I total score and mTD_{IC}. mTD_{IC} was not associated with FES-I score ($P = 0.50$).

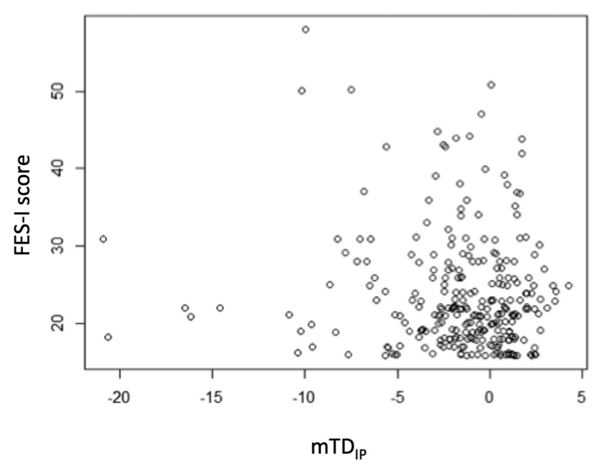

Figure 7. The relationship between FES-I total score and mTD_{IP}. mTD_{IP} was not associated with FES-I score ($P = 0.61$).

Partial correlation analysis suggested that all variables included in the optimal model (age, sex, mTD_{IC}, and mTD_{IP}) were significantly related to total FES-I score independently (coefficient values were: 0.34, 0.13, 0.25, and –0.25, and P values were: < 0.001, 0.035, < 0.001, and < 0.001, respectively).

Table 2. Variables Included in the Optimal Model for FES Score

	Coefficient	SE	*P* Value
Age, y	0.23	0.04	<0.001
Sex	1.79	0.84	0.034
Better BCVA (LogMar)		N.S.	
Worse BCVA (LogMar)		N.S.	
mTD_{SP}, dB		N.S.	
mTD_{SC}, dB		N.S.	
mTD_{IC}, dB	0.92	0.22	<0.001
mTD_{IP}, dB	−0.86	0.21	<0.001
BMI, %		N.S.	
Average walk minutes per day, minutes		N.S.	
History of diabetes mellitus		N.S.	
History of systemic hypertension		N.S.	
Number of previous falls, times		N.S.	

dB, decibel; LogMar, logarithmic minimum angle of resolution; N.S., not selected.

Table 3. Comparisons of Models for Total FES-I Score with and Without Visual Field Parameters

Parameters Included in the Model	AICc	*P* Value
Age, sex, mTD_{IC}, mTD_{PC}	1832.7	<0.001
Age, sex	1847.6	
Age, sex, mTD_{IC}	1847.9	0.57
Age, sex, mTD_{PC}	1848.3	0.72

P value was obtained by comparing to the model only with age and sex.

Discussion

In this study, fear of falling was evaluated using the FES-I questionnaire in 273 patients with POAG. This questionnaire has been widely used in many research fields[27,28] being validated in different populations,[29,30] however, to our knowledge, no previous study has investigated the fear of falling using FES-I in glaucoma. The importance of visual field damage on total FES-I score was investigated using linear modelling. It was suggested that older age, being a woman, reduced inferior peripheral visual field sensitivity, and increased inferior central visual field sensitivity were associated with a lower FES-I score (an increased fear of falling). Visual field sensitivity in the superior hemifield was not related to total FES-I. Partial correlation analysis also revealed that the effect of each of the variables of age, sex, mTD_{IC}, and mTD_{IP} was independent from the other three variables (sex, mTD_{IC}, and mTD_{IP} in the case of age). Thus it was suggested that inferior peripheral visual field damage and preserved inferior central visual field sensitivity were associated with increased fear of falling in glaucoma.

In previous studies, older age was shown to be a significant risk factor for increased fear of falling.[38–41] Friedman et al.[38] reported that age was a predictor of developing a fear of falling in individuals without a fear of falling (odds ratio, 1.04 [95% confidence interval (CI), 1.01–1.07] per year). Similarly, Murphy et al.[40] reported that women older than age 80 years were 1.5 times more likely to have a fear of falling compared with those younger than 80 years. Female sex has also been reported as a risk factor for fear of falling in previous studies.[38–41] Oh-Park et al.[41] reported that being a woman was a significant predictor for developing a fear of falling (adjusted hazard ratio, 1.55 [95% CI, 1.08–2.23]). Ramulu et al.[16] also reported that female sex (β, −0.55 logits; 95% CI, −1.03 to −0.06; $P = 0.03$) is associated with fear of falling in subjects with glaucoma.

In the current study, it was suggested that inferior peripheral visual field damage was associated with increased fear of falling. Previous studies have shown that inferior visual field damage is associated with falls,[42] fall-related injuries,[42,43] poorer physical function,[43] and posture sway.[4] Black et al.[42] examined falls data of POAG patients prospectively in 71 communities of elderly dwelling; it was suggested that visual field loss in the inferior area was a predictor of falls and injurious falls, even after adjustment for other factors, such as age, sex, multifocal use, number of comorbidities, and self-rated health. Furthermore, in our recent study, we found that visual field damage in the inferior peripheral area was a significant risk factor for an injurious fall in 365 POAG patients.[44] Black et al.[42] also reported that inferior visual field damage in POAG patients is associated with overall reduced physiological function, including lower limb muscle strength, walking speed, and self-reported physical activity.

Interestingly, increased visual field sensitivity in the inferior central area was significantly related to a lower total FES-I score. The inferior central visual field is important for various tasks, including legibility of letters, legibility of sentences, walking, using public transportation, dining, and dressing.[2] In addition, we recently reported that visual field sensitivity in the inferior central area is important for these tasks, even when visual acuity is concurrently considered; however, visual field sensitivity in the inferior peripheral area was only important for walking.[45] This implies that a patient with better sensitivity in the inferior central area is more active in various daily tasks, desires to perform more visually demanding tasks, and also has more opportunities to walk around. Such patients may have a pronounced fear of falling if the inferior peripheral visual field is damaged because this area is related to falls or injurious falls.[4,42–44] This may be the reason why total FES-I score was low when inferior peripheral visual field sensitivity was decreased and inferior central visual field was increased. Supporting this, mTD_{IC} and mTD_{IP} were not significantly related to total FES-I score in the univariate analysis (Fig. 2), however, both were included in the optimal multivariable model. In addition, adding only mTD_{IC} or mTD_{IP} to a model with age and sex did not improve the goodness of fit of the model (Table 2). Furthermore, the results of partial correlation analysis revealed that both mTD_{IC} and mTD_{IP} were significantly related to total FES-I score, independent of each other. Nonetheless, mTD_{IC} and mTD_{IP} are usually closely related to each other (R, 0.83; $P < 0.001$ in the current study; not shown in results), and these values usually decline simultaneously. Thus a future study should examine eyes with visual field damage only in one of these two areas to further investigate the effect of mTD_{IC} on total FES-I score.

In our previous study,[25] visual field damage in the inferior peripheral area was related to fear of falling; however, in contrast to the current study, visual field sensitivity in the inferior central visual field was not related to fear of falling. These contradictory results may be a result of the difference in the assessment of fear of falling. In our previous study,[25] fear of falling was evaluated using a single question, "Are you afraid of falling?" FES-I, however, consists of 16 questions, which enable a more comprehensive assessment. FES-I is a validated international questionnaire[28,30,46–51] with excellent internal and test–retest reliability (Cronbach's α, 0.96; interclass correlation coefficient, 0.88).[30]

In this study, the number of previous falls was not associated with fear of falling. Other studies have suggested that fear of falling can occur in subjects without a history of falls and no association between previous falls and fear of falling, as detailed later.[52–57] Lee et al.[54] investigated fear of falling–related factors in 108 older adults with complex chronic disease, and reported that the number of comorbidities, level of physical activity, activity of daily living, and mobility were associated with fear of falling in the regression model, but a history of falling was not associated with fear of falling. Liu[55] investigated the prevalence of fear of falling in 445 robust community-dwelling older people, and reported that 65% of subjects with fear of falling had no history of falls. Moreira et al.[56] investigated the factors associated with fear of falling using FES-I in 751 community-dwelling older adults with diabetes mellitus, and reported that falls in the previous 12 months were not associated with fear of falling. Lindholm et al.[57] investigated contributing factors to fear of falling among 104 people with idiopathic Parkinson disease, and reported that a previous fall was not associated with a fear of falling.

Our study has several limitations. First, no controls were included in the analyses. It may be of interest to investigate the difference of FES-I score between healthy subjects and patients with glaucoma, although it is beyond the scope of the current study. Furthermore, fear of falling varied according to the pattern of visual field damage and is not identical across glaucoma patients; thus the current results, in glaucoma patients only, may be more relevant for clinical care. Second, because all of the participants knew they had glaucoma (and the disease is inherently associated with anxiety),[23] participants may give somewhat pessimistic answers to the FES-I questions. Third, we measured the history of falls and the number of previous falls through a single nonvalidated questionnaire. Fourth, although the inferior central and peripheral visual field were correlated to fear of falling in the multivariate analysis, it does not appear strongly in the scatterplot. These results should be replicated in the future study. Strengths of the current study include that the diagnosis of POAG was made by glaucoma specialists with a battery of ophthalmic examinations of POAG patients.

Conclusions

Fear of falling was evaluated using the FES-I tool in patients with POAG. It was suggested that older age, female sex, inferior peripheral visual field damage, and preserved inferior central visual field sensitivity were associated with increased fear of falling. In addition to severe glaucomatous visual field loss in the whole field as reported in previous studies,[16,17] the current study suggests that careful attention is needed when there is damage in the inferior peripheral visual field because this is associated with fear of falling.

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