Dry-Eye Screening by Using a Functional Visual Acuity Measurement System: The Osaka Study

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Purpose. We determined whether functional visual acuity (VA) parameters and a dry eyes (DEs) symptoms questionnaire could predict DEs in a population of visual terminal display (VDT) users.

Methods. This prospective study included 491 VDT users from the Osaka Study. Subjects with definite DE, diagnosed with the presence of DE symptoms, tear abnormality (Schirmer test $\leq$ 5 mm or tear breakup time [TBUT] $\leq$ 5 seconds), and conjunctivocorneal epithelial damage (total staining score of $\geq$3 points), or probable DE, diagnosed with the presence of two of them, were assigned to a DE group, and the remainder to a non-DE group. Functional VA was assessed, and DE questionnaires were administered. We assessed whether univariate and discriminant analyses could determine to which group a subject belonged. Sensitivity and specificity were assessed.

Results. Of 491 subjects, 320 and 171 were assigned to the DE and non-DE groups, respectively. No significant differences were observed between DE and non-DE groups in Schirmer test value and epithelial damage, but TBUT value (3.1 $\pm$ 1.5 vs. 5.9 $\pm$ 3.0 seconds). The sensitivity and specificity of single test using functional VA parameters were 59% and 49% in functional VA, 60% and 50% in visual maintenance ratio, and 83% and 30% in frequency of blinking, respectively. According to a discriminant analysis using a combination of functional VA parameters and a DE questionnaire, six variables were selected for the discriminant equation, of which area under the curve (AUC) was 0.735. Sensitivity and specificity of diagnoses predicted by the discriminant equation were 85.9% and 45.6%, respectively.

Conclusions. The discriminant equation obtained using functional VA measurement combined with a symptoms questionnaire may suggest the possibility for the first step screening of DE with unstable tear film. Since the questionnaire has an overall poor sensitivity and specificity, further amelioration may be necessary for the actual utilization of this screening tool.

Keywords: tear break up time, dry eye, functional visual acuity, visual display terminal user, screening

The prevalence of dry eye (DE) disease has increased dramatically in recent decades, and may escalate further in the future as the mean age of many societies is increasing. Current prevalence estimates range between 5% and 35% in people aged older than 50 years.[1–7] A recent study using self-diagnostic questionnaires and objective examinations revealed an even higher prevalence of DE disease (73.5%) on the basis of the Japanese DE diagnostic criteria in Japanese pensioners aged over 60.[8] The DE disease is a major and increasing healthcare problem because of its prevalence.

Dry eye symptoms affect the quality of life. People with DE disease suffer from eye irritation, discomfort, or heaviness, but also have problems performing common daily activities, such as reading, driving, working at the computer, and watching TV.[9–11] The degree of suffering may present with cases as severe as a patient with angina.[12]

Despite raised awareness of DE disease, many people mistakenly attribute DE symptoms to other causes as the symptoms usually are vague and equivocal. Thus, they tend to endure the condition or to self-treat with over-the-counter products, without consulting a physician or obtaining a definitive diagnosis. Therefore, noninvasive screening tests to detect DE at an early stage may facilitate timely medical examination and treatment. The 2005 Gallup Survey showed that nearly 40% of Americans experience DE symptoms, and that 25% of those do not consult a health care professional about their eye condition.[13] The Allergan Dry Eye Survey, which was conducted online in March 2011 by Harris Interactive with 2411 adults (aged 18 and older) responding, showed that 69% of respondents who experience DE symptoms do not visit an eye care professional for DE treatment, and that 19% of respondents use nonprescription eye drops.[14] Given these observations, screening tests for DE may have a helpful role in warning sufferers with DE symptoms of the possibility of DE, and encouraging them to seek appropriate treatment.

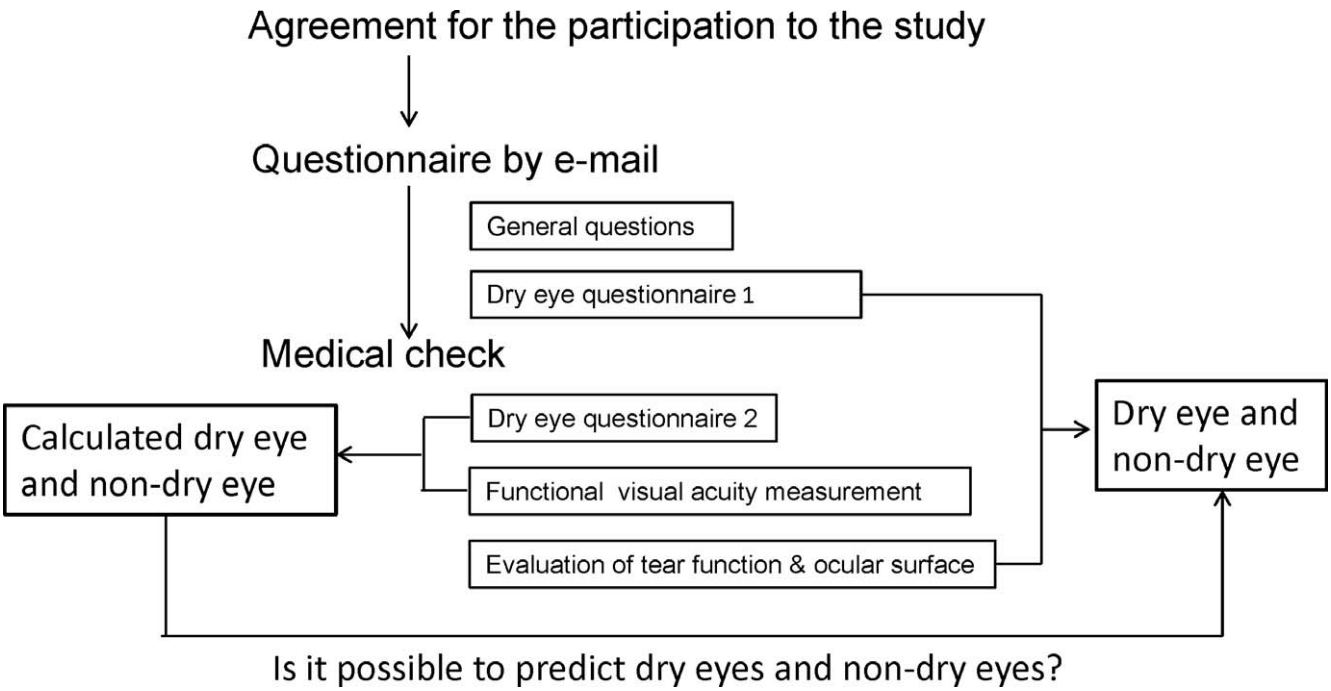

FIGURE 1. Flow chart of dry eye questionnaire and ophthalmic examinations.

Office workers doing video display terminal (VDT) work suffer from severe eye fatigue, which may be brought on by DE. Although there are some screening instruments for DEs, most of them are for discriminating between severe DE with epithelial damage and normal eyes. To our knowledge, there are no screening tools to predict DE in office workers doing VDT work who have the characteristics of severe DE symptom, but mild epithelial damage.

Functional visual acuity (VA) is an index of visual function over time obtained by continuous measurement of the dynamics of VA. It has been reported that functional VA is decreased in DE patients despite them exhibiting normal VA by standard VA testing.[15–20] In accordance with recent reports that DE may cause visual deterioration due to the stability and regularity of the ocular surface,[21–26] we investigated whether functional VA parameters can function as predictors of DEs in a population of VDT users.

METHODS

Participants

The right eyes of 491 subjects (326 men, 165 women; mean age, 43.3 ± 8.9 years; age range, 24–64 years) among the Osaka Study participants who underwent the functional VA examination were included in this study. The Osaka Study is an epidemiological survey that was conducted by the Japanese Dry Eye Society to derive an estimate of the prevalence rate of DE disease in VDT workers. The subjects were classified into 2 groups: a DE group, including the subjects with definite or probable DEs, and a non-DE group, as determined by the Japanese DE diagnostic criteria.[27] Definite DE was diagnosed based on the presence of 3 items: DE symptoms, a Schirmer test score of 5 mm or less or a tear breakup time (TBUT) of 5 seconds or less, and a positive vital staining score exceeding 2 points. Probable DE was concluded if 2 of these 3 criteria were met. Mostly, probable DE denotes short TBUT DE, which is diagnosed by the presence of DE symptoms and a TBUT value of 5 seconds or less with no positive fluorescein staining scores. The cases with short TBUT value, but no symptoms are treated as normal. We administered a questionnaire, including general information, such as age, sex, contact lens use, and DE symptoms, by e-mail, after permission was granted to conduct the study in subjects who were willing to participate. The DE questionnaire (DE questionnaire 1) that we administered has been used widely in Japan.[28,29] It is composed of 12 questions related to DE symptoms, and possible responses to the questions include "constantly," "often," "sometimes," and "never." Subjects who responded to more than one of the 12 questions with "constantly" or "often" were considered positive for subjective symptoms of DE. Figure 1 is a flow chart depicting the sequence of events with regard to the DE questionnaire and ophthalmic examinations. Subjects who had worn or currently wore contact lenses were eligible for inclusion in the study. Subjects who had had external ocular diseases within the previous 6 months were excluded from the study. This research followed the tenets of the Declaration of Helsinki. Informed consent was obtained from all subjects after an explanation of the nature and possible consequences of the study was provided.

Tear Function and Ocular Surface Evaluation

Ophthalmic examinations included conjunctival and corneal vital staining with lissamine green and fluorescein, TBUT, and Schirmer tests that were assessed by DE specialists. These examinations were undertaken at least 1 day after removal of contact lenses in the contact lens users. Keratoconjunctival epithelial damage was evaluated using lissamine green and sodium fluorescein dyes. Two microliters of a preservative-free 1% lissamine green and 1% sodium fluorescein were instilled separately into the conjunctival sac by micropipette. Overall epithelial damage was scored on a scale of 0 to 9 points.[30] Tear stability was assessed by the standard TBUT measurement. To evaluate tear quantity, the Schirmer test without anesthesia was administered following all other examinations, using a sterilized Schirmer strip (Whatman No. 41; Showa, Tokyo, Japan). To avoid the influence of conjunctivocorneal staining

on the Schirmer test, we proceeded with that test after a 10-minute interval.

The Functional VA Measurement System

The Functional VA Measurement System (Kowa, Aichi, Japan) was used to examine the change in continuous VA over time. The outcomes recorded were starting VA, functional VA, visual maintenance ratio, and blink frequency.[31,32] Starting VA was defined as the standard best-corrected VA as measured by the functional VA measurement system. Functional VA was defined as the mean value of time-wise changes in VA during the examination. The visual maintenance ratio was defined as the functional VA divided by baseline VA.[31]

Functional VA was measured during a 60-second period under daily vision correction, without topical anesthesia. Subjects were allowed to blink naturally during the measurement period. Patients delineated the orientation of automatically presented Landolt rings by manipulation of a joystick. Functional VA testing was carried out after tear function testing.

Subjective Eye Symptoms Questionnaire

We administered another DE questionnaire (DE questionnaire 2) on a different day, that included the following items: "eye fatigue," "eye pain," "eye discharge," "foreign-body sensation," "excess tearing," "blurred vision," "eye itching," "heavy eye sensation," "red eye," "uncomfortable sensation," "dry sensation," and "sensitivity to bright light." The responses "yes" or "no" were used for the discriminant analysis.

Statistical Analysis

Student's *t*-test was performed to compare the tear functions and functional VA parameters of each group. The χ^2 test was used to compare the positive and negative ratio of each DE symptom according to DE questionnaire 1. The correlations between the TBUT value and the DE questionnaire 1 were analyzed using Spearman's correlation analysis. The correlation between the TBUT value and visual function was analyzed using Pearson's correlation analysis. We carried out univariate analyses regardless of whether each functional VA parameter was independently able to discriminate definite and probable DEs from non-DEs. The DE and non-DE groups served as the dependent variables, and the functional VA parameters (i.e., functional VA, visual maintenance ratio, and blink frequency) as the independent variables.

Similarly, we carried out a discriminant analysis to investigate whether screening for DEs and probable DEs using a combination of functional VA parameters and a DE questionnaire is valid. Stepwise variable selection was used to determine which independent variables were the best predictors of DE, thereby reducing the number of variables required for screening. The independent variables were general characteristics of the subjects (i.e., sex, age, and presence or absence of contact lens use), the functional VA parameters (i.e., functional VA, visual maintenance ratio, and blink frequency), and the 12 questions of the DE questionnaire.

We performed receiver operating characteristic (ROC) analysis, and calculated sensitivity and specificity based on the functions obtained by univariate and discriminant analyses. ROC curves plot (1-specificity, false-positive rate) on the *x*-axis and the sensitivity (true-positive rate) on the *y*-axis across a series of cut-off points, yielding an area under the curve (AUC). The AUC values ranged from 0 to 1; the larger the AUC, the better the overall performance of the screening test to identify DE and non-DE subjects correctly.

Table 1. Screening Properties Based on the Functions Calculated by Univariate and Discriminant Analysis

	Dry Eye Group	Nondry Eye Group
Profiles		
Age	43.0 ± 8.7	43.8 ± 9.2
Sex, men/women	195/125	131/40
VDT use, h	8.1 ± 2.3	7.6 ± 2.1*
Contact lens use (presence)	99 (30.9%)	45 (26.3%)
Current smoker (presence)	54 (16.9%)	43 (25.1%)
Dry eye questionnaire 1		
Eye fatigue (presence)	211 (65.9%)	29 (17.0%)*
Eye pain (presence)	47 (14.7%)	5 (2.9%)*
Eye discharge (presence)	74 (23.1%)	12 (7.0%)*
Foreign-body sensation (presence)	68 (21.3%)	9 (5.3%)*
Excess tearing (presence)	32 (10.0%)	6 (3.5%)*
Blurred vision (presence)	110 (34.4%)	14 (8.2%)*
Eye itching (presence)	79 (24.7%)	13 (7.6%)*
Heavy eye sensation (presence)	82 (25.6%)	10 (5.9%)*
Red eye (presence)	97 (30.3%)	9 (5.3%)*
Uncomfortable sensation (presence)	100 (31.3%)	10 (5.9%)*
Dry sensation (presence)	142 (44.4%)	19 (11.1%)*
Sensitivity to bright light (presence)	68 (21.3%)	7 (4.1%)*
Tear function parameters and vital staining scores		
Schirmer test value, mm	18.2 ± 12.0	19.3 ± 11.8
TBUT, s	3.1 ± 1.5	5.9 ± 3.0*
Epithelial damage, points	1.4 ± 1.5	0.6 ± 0.8
Functional VA parameters		
Starting VA, logMAR	0.11 ± 0.27	0.12 ± 0.28
Functional VA, logMAR	0.24 ± 0.28	0.22 ± 0.28
Visual maintenance ratio	0.95 ± 0.05	0.96 ± 0.05*
Blink frequency, times	13.0 ± 10.8	10.1 ± 9.7*

The VDT hours, tear function parameters, vital staining scores, and functional VA parameters were assessed using Student's *t*-test. Comparison between the positive and negative ratio of each DE symptom according to DE questionnaire 1 was performed by a χ^2 test.

* $P < 0.05$.

All statistical analyses were performed using JMP software, version 10.0 (SAS Institute, Inc., Cary, CA, USA). A P value of <0.05 was considered statistically significant.

Results

Subjects

Of the 491 subjects enrolled, 320 were assigned to the DE group, and these were comprised of 58 subjects (11.8% of all subjects) with definite DE and 262 subjects (53.4% of all subjects) with probable DE. The non-DE group was comprised of 171 subjects (34.8%). Table 1 shows the general characteristics of the DE and non-DE groups. The mean number of VDT-use hours in the DE group was significantly higher than that of the non-DE group. Table 2 shows the ratio of positive DE symptoms based on DE questionnaire 1, tear function parameters, and vital staining scores in contact lens wearers and noncontact lens wearers.

Tear Function Assessment

The results of tear function testing and the vital staining scores are shown in Table 1. Of the 491 subjects, 17.7% exhibited Schirmer test values of ≤5 mm and 77.7% exhibited TBUT

Table 2. Positive Ratio of DE Symptoms, Tear Function Parameters, and Vital Staining Scores in Contact Lens Wearers and Noncontact Lens Wearers

	Contact Lens Wearers	Noncontact Lens Wearers
Positive ratio of dry eye symptoms, %	76.4	70.0
Schirmer test value, mm	21.9 ± 11.80	17.2 ± 11.68*
TBUT, s	3.9 ± 2.33	4.2 ± 2.59
Epithelial damage, points	1.5 ± 2.57	0.4 ± 1.08*

Positive ratio of DE symptoms was assessed using the χ^2 test ($P > 0.05$). Tear function parameters and vital staining scores were assessed using Student's *t*-test.

* $P < 0.05$.

values of ≤5 seconds. No vital staining or mild vital staining (<3 points) was observed in 84.7% of the subjects, and moderate or severe staining (≥3 points) was observed in 15.3%.

Functional VA Parameters

The results of functional VA parameter testing are shown in Table 1. While there was no significant difference between the DE and non-DE groups with regard to logMAR starting VA or functional VA, the visual maintenance ratio was significantly lower in the DE group than the non-DE group ($P < 0.05$). Conversely, blink frequency was significantly higher in the DE group ($P < 0.05$).

No significant correlation was observed between TBUT values and logMAR starting VA ($r = 0.0148$, $P > 0.05$), logMAR functional VA ($r = -0.0189$, $P > 0.05$), or the visual maintenance ratio ($r = 0.0739$, $P > 0.05$).

Dry Eye Questionnaire

Table 3 shows the outcomes of DE questionnaires 2 between the DE and non-DE groups. A significant correlation was observed between TBUT values and responses in the DE questionnaire 1 ($r = -0.1182$, $P < 0.05$) as well as DE questionnaire 2 ($r = -0.1262$, $P < 0.05$).

Screening Sensitivity, Specificity, and AUC

Table 4 shows the screening properties of the equations calculated by univariate and discriminant analyses. The sensitivity, specificity, and AUC values were low in the equations calculated using each functional VA parameter singly by univariate analysis (Figs. 2a–c). By using a stepwise variable selection method, the best predictors of DE for the explanatory variables selected were "eye fatigue," "uncomfortable sensation," "dry sensation," "sensitivity to bright light," "visual maintenance ratio," and "blink frequency" (Table 5). The group to which the subject was allocated by the analysis was determined by entering the values for each of these variables into the following nonstandardized canonical equation derived from the discriminant analysis: $L = -5.2669 + 4.3840 \times$ (visual maintenance ratio) – $0.0296 \times$ (blink frequency) + (eye fatigue) + (uncomfortable sensation) + (dry sensation) + (sensitivity to bright light). Notably, the coefficient of "eye fatigue" is –0.5771 in the presence of the symptom and +0.5771 in its absence. Likewise, the coefficients of "uncomfortable sensation," "dry sensation," and "sensitivity to bright light" are –0.4064, –0.3710, and –0.4015, respectively, in the presence of those symptoms, and +0.4064, +0.3710, and +0.4015, respectively, in their absence. The obtained *L* value was substituted into the following 2 formulas: $P(DE) = 1/(1 + \text{Exp}$ [–L]) and $P(non\text{-}DE) = 1/(1 + \text{Exp}$]L]). The diagnosis was determined to be DE when the value of *P* was greater in the former formula, and non-DE when it was greater in the latter formula.

Table 3. The Proportion of DE Symptoms in DE and Non-DE Groups

Questionnaire 2	Dry Eye Group	Nondry Eye Group
Eye fatigue, yes	208 (65.0%)	61 (35.7%)
Eye pain, yes	41 (12.8%)	8 (4.7%)
Eye discharge, yes	69 (21.6%)	20 (11.7%)
Foreign-body sensation, yes	47 (14.7%)	9 (5.3%)
Excess tearing, yes	34 (10.6%)	12 (7.0%)
Blurred vision, yes	89 (27.8%)	22 (12.9%)
Eye itching, yes	56 (17.5%)	17 (9.9%)
Heavy eye sensation, yes	50 (15.6%)	10 (5.8%)
Red eye, yes	76 (23.7%)	22 (12.9%)
Uncomfortable sensation, yes	60 (18.7%)	10 (5.8%)
Dry sensation, yes	117 (36.6%)	31 (18.1%)
Sensitivity to bright light, yes	52 (16.3%)	12 (7.0%)

Figure 3 shows the ROC curve. The AUC was 0.735, and the sensitivity and specificity were 85.9% and 45.6%, respectively (Table 4).

Discussion

We conducted this study to assess the effectiveness of discriminating between DEs and non-DEs using functional VA examination. We obtained similar results to previous studies, in that the visual maintenance ratio was significantly worse in the DE group than the non-DE group.[16–19] In contrast, there were no significant differences between the groups with regard to functional VAs. This may be due to the measurement conditions; functional VA examination was performed under daily vision correction, not with the best corrected VA. Our results showed that blink frequency in the DE group was significantly higher than the non-DE group, although it has been shown that blinking is reduced in severe DE.[33,34] Frequent blinking might have induced normalization of the tear film in DE with decreased TBUT. Discriminant analysis has been used previously to predict diagnosis of DE by one or more predictor variables.[35–38] In this study, the results of the tests using each functional VA parameter singly suggested that they were not functional for screening, due to the low sensitivity, specificity, and AUC values. On the other hand, the discriminant equation generated using the combination of functional VA examination and a DE questionnaire may be acceptable as a screening test for DE, with an AUC of 0.735 and sensitivity of 85.9%. The AUC is a measure of how well a parameter can distinguish between two diagnostic groups (i.e., DEs and non-DEs). Sensitivity represents how well a test detects the disease, and negative results from a test with high sensitivity are useful for excluding a potential diagnosis. We obtained low specificity, 45.6%. A test with low specificity diagnoses many patients without the disease as having the disease. Theoretically, the best test for screening is the one with the highest sensitivity and specificity. However, such highly accurate tests often are complex, expensive, and invasive, and, thus, are not practical for screening large numbers of asymptomatic people. Under such circumstances, tests with more false-positives than false-negatives (lower specificity and high sensitivity) may be more preferable.[39]

When we compared 2 types of DE questionnaire, the positive DE symptoms in DE questionnaire 1 did not correspond precisely with the outcomes in DE questionnaire

Table 4. Screening Properties Based on the Functions Calculated by Univariate and Discriminant Analyses

Independent Variables	Cutoff Score	Sensitivity, %	Specificity, %	AUC
Single tests				
Functional VA	0.75	59	49	0.525
Visual maintenance ratio	0.96	60	50	0.553
Blink frequency	3.00	83	30	0.583
Discriminant function				
"Eye fatigue," "eye discomfort," "eye dryness," "increased sensitivity to light," "visual maintenance ratio," and "blink frequency"	–	85.9	45.6	0.735

2. This may be the cause of the relatively low sensitivity and even lower specificity. Obtaining concordant outcomes between questionnaires 1 and 2 may improve sensitivity and specificity.

The explanatory variables selected from the DE questionnaire for the discriminant equation were "eye fatigue," "uncomfortable sensation," "dry sensation," and "sensitivity to bright light." The functional VA parameters selected were "visual maintenance ratio" and "blink frequency." We expected that "age" and "sex" may be important predictors in the discriminant equation.[2,3,5,40,41] However, no age-related trend was observed with regard to the presence of DE in either sex. This result may be due to our study population consisting of relatively young individuals, with few over 60 years, as Uchino et al.[42] suggest in their report. Older subjects should be included in future studies to obtain more valuable data. In addition, while it is known that in postmenopausal women aged over 50 hormone imbalance affects proper tear production and the development of DE,[3] only 14 subjects in this study (2.9% of the total subject-pool) were women aged 50 or over (data not shown). It also is known that contact lens use can contribute to DE disease.[43–45] However, contact lens users were approximately equally represented in the DE and non-DE groups in this study. This may be because the subjects enrolled in the study were office workers. Aspects of the office working environment, such as the duration of VDT usage, temperature, and humidity under air-conditioning, and work tasks may have a much stronger effect than the presence or absence of contact lens use. In fact, Osaka study workers using VDTs for more than 8 hours a day had a significantly increased risk of DE, while no significant association between contact lens use and the risk of DE was observed.[42]

The McMonnies Dry Eye Questionnaire is a screening instrument that is used widely to discriminate subjectively DE subjects from non-DE subjects,[46,47] and its sensitivity ranges from 87% to 98%, and its specificity from 87% to 97%.[35,36] Having high sensitivity and specificity, this instrument is a good predictor for discriminating DEs with Sjögren syndrome and keratoconjunctivitis sicca from subjects without DE. However, it is not as good at identifying marginally dry eyes.[35,48,49] With regard to DE type, most of the subjects diagnosed with DE in this study could be categorized as short TBUT DE rather than aqueous deficiency DE with keratoconjunctivitis sicca. In fact, most subjects in this study had normal lacrimal function, according to Schirmer test results, and Schirmer test values showed hardly any differences between the DE and non-DE groups. The subjects with a TBUT of $\leq$5 seconds accounted for approximately 80% of the total, while those exhibiting a Schirmer test value of $\leq$5 mm accounted for approximately 20%. In addition, the subjects with epithelial staining values of $<$3 points accounted for 85%. Uchino et al.[42] suggested that DE disease in VDT workers starts with a shortened TBUT despite a normal Schirmer value, leading to the development of subjective symptomatology. The DE associated with keratoconjunctivitis sicca, which can be detected effectively by McMonnies Dry Eye Questionnaire, may be relatively infrequent in the office-working population. As compared to results obtained using McMonnies Dry Eye Questionnaire, we obtained lower sensitivity and specificity; however, the discriminant equation calculated in this study may be acceptable for a screening tool for short TBUT DE.

It has been suggested that short TBUT DE represents an early, mild form of DE, since it is associated with little or no corneal epithelial damage.[28] However, short TBUT DE patients often suffer from severe eye fatigue, uncomfortable eye sensations, sensations of eye heaviness, and sensations of dryness or eye pain during daily activities. One of the typical symptoms of short TBUT DE is eye fatigue, which may lead to

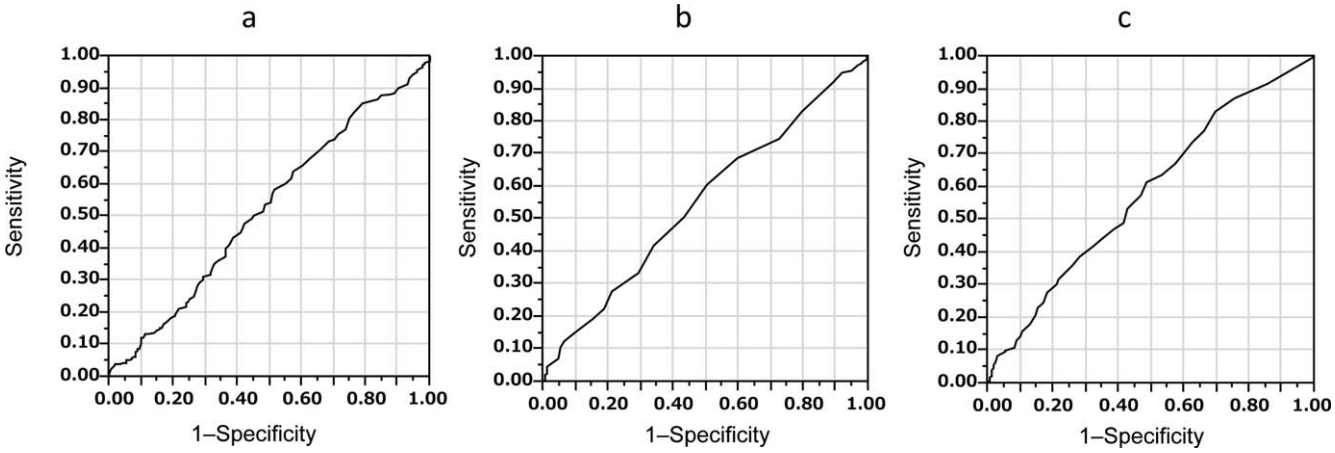

Figure 2. The ROC curve using each functional VA parameter singly. (**a**) Functional VA. (**b**) Visual maintenance ratio. (**c**) Blink frequency.

Table 5. Estimated Parameter Values of the Model

Items	Estimated Values	χ^2	*P* Value
Contact lens use	0	0.7778	0.3778
Eye fatigue	0.5771	29.7458	4.93e-8*
Eye pain	0	1.7427	0.1868
Eye discharge	0	0.9891	0.3200
Foreign body sensation	0	0.0706	0.7905
Excess tearing	0	0.1238	0.7250
Blurred vision	0	3.0128	0.0826
Eye itching	0	0.0665	0.7966
Heavy eye sensation	0	0.8709	0.3507
Red eye	0	3.6976	0.0545
Uncomfortable sensation	0.4064	4.6893	0.0304*
Dry sensation	0.3710	9.2111	0.0024*
Sensitivity to bright light	0.4015	5.0339	0.0249*
Sex	0	3.0477	0.0809
Age	0	0.0323	0.8574
Visual maintenance ratio	4.3840	4.567	0.0326*
Blink frequency	−0.0296	7.8899	0.0050*

patients being misdiagnosed or underdiagnosed. The fact that "eye fatigue" was selected as one of the predictors in the discriminant equation is encouraging with regard to the potential ability of this instrument to discriminate short TBUT DE subjects from normal subjects. Reportedly, the incidence of short TBUT DE has increased recently in office workers who do VDT work, and contact lens users.[29] Therefore, it is rather important to distinguish this short TBUT DE from the normal. It has not been revealed yet that the short TBUT DE is either a mild case of DE or another type of DE. In this study, we eventually came to seek the screening method of this vague type of DE, which is not easily differentiated, since TBUT value alone cannot identify either DEs or non-DEs. Although the screening test showed the low specificity, this screening tool may be applicable for the first step screening of short TBUT DE.

A screening instrument should be demonstrably simple, quick to administer, sensitive and specific, and reliable. The discriminant equation obtained in this study was derived from 4 questions relating to dry eye symptoms, and 2 functional VA parameters. The response-options for the dry eye symptom questions are simply "yes" or "no." Functional VA examination takes only 60 seconds under daily vision correction, in other words, when the subject undergoes the examination using their own eye glasses or contact lenses. Correcting visual errors anew is not required. This screening test can be used in subjects who wear contact lenses, and those who do not. Contact lens users do not need to remove them during the functional VA measurement. The contact lens DE questionnaire (CLDEQ) is a screening test for contact lens-related DE, that Nichols et al.[50] has suggested is efficacious for discriminating contact lens-related DE. Although the equation obtained in this study may be useful for detecting DEs independently of contact lens use, a further study should be conducted to assess specifically the efficacy of this screening tool with regard to diagnosing contact lens–related DEs.

Major limitation remains in this study. Since the questionnaire has an overall poor sensitivity and specificity, the value of this tool still is questionable for screening purposes of milder forms of DE. Further amelioration may be necessary for the actual utilization of this screening tool, Whether this discriminant equation also can yield acceptable results in the context of other DE types requires further investigation.

In conclusion, the discriminant equation obtained using functional VA measurement combined with a symptoms questionnaire may suggest the possibility for the first step screening of short TBUT DE. Functional VA measurement can evaluate visual performance in DEs. Additionally, this measurement may be used as a screening tool in conjunction with a simple DE questionnaire. To confirm the validity of the discriminant equation, it should be applied in another cohort study that is unrelated to the current study, in the future.

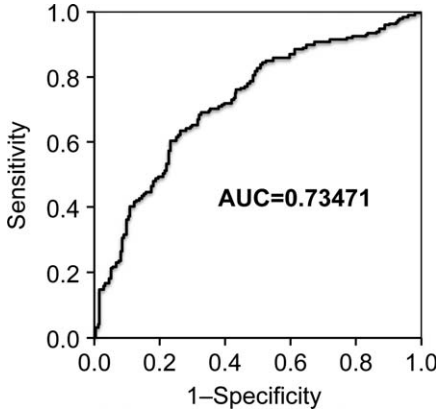

Figure 3. The ROC curve using the combination of functional VA parameters and a DE questionnaire.

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