USABILITY AND VALIDATION OF EYE QUESTIONNAIRE-BASED VISION SCREENING (EYEQVS)

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Abstract

Eye: Questionnaire-based Vision Screening (EyeQVS) is a 21-item questionnaire designed to screen for reduced vision, visual field defects, binocular disorders, dry eye, postural ergonomic problems and computer vision syndrome. EyeQVS offer an online and equipment-free vision screening option. The purpose of this research is evaluating both usability and validity of EyeQVS. The testability was surveyed using grading scales and the experience was investigated using structured and open-ended questions. Each target ocular condition of EyeQVS was compared to the full eye examination. Method: In the usability investigation of EyeQVS, two modes were employed [self-administration (fifty-two self-respondents cum patients) and proxy-administration (ten proxy-respondents for sixty-two patients) modes] in screening for vision problems. In the validation investigation, fifty-two subjects were recruited using convenient sampling to check the accuracy of EyeQVS. Each subject was screened with EyeQVS before undergoing a comprehensive eye examination. Results: All respondents indicated high confidence towards EyeQVS with an average of more than 8 points on the Likert scale score. The majority found it easy to use and navigate. Respondents also adored the short duration required to complete the vision screening. The Chi-square of the Independence Test revealed that the designated components of EyeQVS had a good relationship with respective clinical tests ($p < 0.05$). Conclusion: EyeQVS exhibits workable user satisfaction and operative validation from the full eye examination findings. EyeQVS provides alternative online easy access to preventive eye care. EyeQVS is pragmatic for vision screening implementation in locations where equipment-based screening is not feasible. It is also suitable for vulnerable communities needing special care, support or protection because of age, disability, poverty or accessibility issues.

Keywords: Usability, Validity, Vision Screening, Questionnaire, Underprivileged Community

Introduction

Public eye health care has an impact on the quality of life. Unfortunately, it remains a significant challenge to deliver comprehensive eye care in most countries (1). Financial constraints and a shortage of professional eye care practitioners are among the main hindrances to implementing comprehensive eye care in most countries. Due to the feasibility constraint of providing a full eye examination, vision screening is initiated to detect potential vision problems, paving referral pathways towards a full eye examination. Vision screening plays an important role in preventive eye care. However, inconsistencies in what constitutes an appropriate vision screening method persist. Ensuring that at-risk populations are linked to appropriate health care is a responsibility of the public health sector. Providing comprehensive eye examinations to every person by evidence-based guidelines is difficult without adequate resources.

The availability of vision screening is also restricted due to the need for more screeners and the dependency on expensive screening equipment (2). Therefore, the quest for an alternative technique is inevitable. Questionnaires

are well-liked because they are cost-effective, quick, cover a broad spectrum of contents, are versatile, and can reach a large target population (3). This study aimed to report the usability and validity of a new questionnaire-based vision screening tool named EyeQVS (Eye: Questionnaire-based Vision Screening). The testability was surveyed using grading scales. The user's experience was recorded using structured and open-ended questions. Each target ocular condition of EyeQVS was compared to the full eye examination.

Methods

Study design

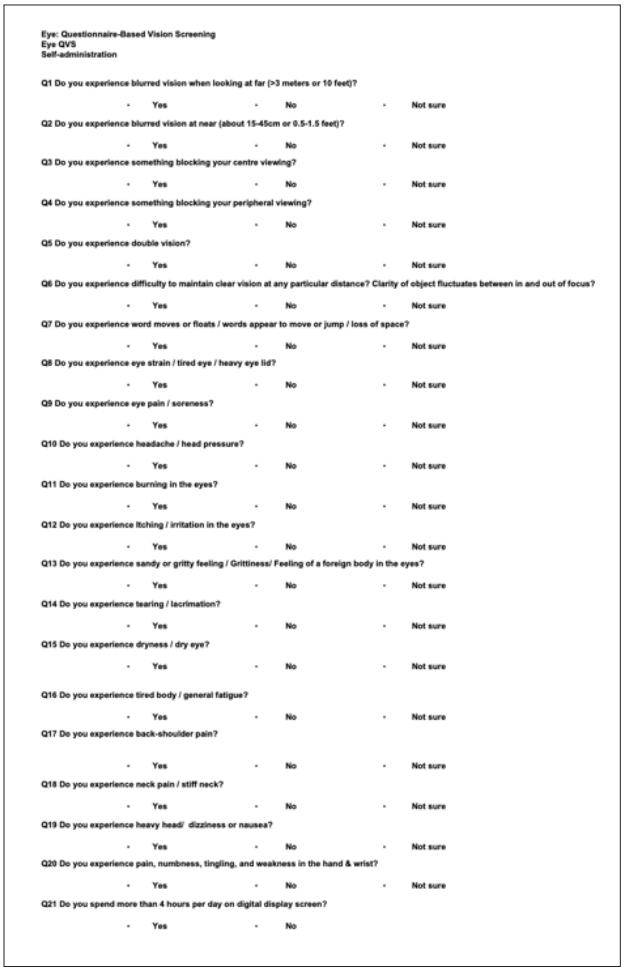
This cross-sectional research project obtained ethical approval from the UiTM Research Ethics Committee [approval code: REC/09/2021 (MR/803)]. Informed consent was obtained from the subjects, parents or legal guardians, and all research procedures adhered to the tenets of the Declaration of Helsinki.

About eye: Questionnaire-based Vision Screening (EyeQVS)

Eye: Questionnaire-based Vision Screening (EyeQVS) is a 21-item questionnaire (Figure 1) designed to screen for reduced vision (two items – Questions 1-2), visual field defect (two items – Questions 3-4), binocular disorders (six items – Questions 5-10), dry eyes (five items – Questions 11-15), postural ergonomic problems (five items – Questions 16-20) and computer vision syndrome (17 items – Questions 5-21). The EyeQVS aims to offer an online and equipment-free alternative for vision screening. EyeQVS harbours upon the convenience and cost-efficiency appeals of a questionnaire-based screening concept and eliminates the dependence of vision screening on expensive equipment. EyeQVS is designed to complete in less than ten minutes. EyeQVS consists of self-administered and proxy-administered options to cater for different literacy levels of the population. Individuals with sufficient English proficiency and literacy level can use self-administration. Vision screeners or caretakers can proxy-administer for people who cannot answer the questionnaire themselves. Proxy administration is subdivided into proxy-assisted reporting and proxy-respondent reporting to gain inclusiveness for people with more diverse cognitive and communication abilities.

Sample Size Calculation

An appropriate sample size is required for sensitivity and specificity study of a screening tool. A sample size of at least 50-100 subjects is generally recommended (4). We



Eye: Questionnaire-Based Vision Screening
Eye QVS
Self-administration

Q1 Do you experience blurred vision when looking at far (>3 meters or 10 feet)?
Yes No Not sure
Q2 Do you experience blurred vision at near (about 15-45cm or 0.5-1.5 feet)?
Yes No Not sure
Q3 Do you experience something blocking your centre viewing?
Yes No Not sure
Q4 Do you experience something blocking your peripheral viewing?
Yes No Not sure
Q5 Do you experience double vision?
Yes No Not sure
Q6 Do you experience difficulty to maintain clear vision at any particular distance? Clarity of object fluctuates between in and out of focus?
Yes No Not sure
Q7 Do you experience word moves or floats / words appear to move or jump / loss of space?
Yes No Not sure
Q8 Do you experience eye strain / tired eye / heavy eye lid?
Yes No Not sure
Q9 Do you experience eye pain / soreness?
Yes No Not sure
Q10 Do you experience headache / head pressure?
Yes No Not sure
Q11 Do you experience burning in the eyes?
Yes No Not sure
Q12 Do you experience itching / irritation in the eyes?
Yes No Not sure
Q13 Do you experience sandy or gritty feeling / Grittiness/ Feeling of a foreign body in the eyes?
Yes No Not sure
Q14 Do you experience tearing / lacrimation?
Yes No Not sure
Q15 Do you experience dryness / dry eye?
Yes No Not sure
Q16 Do you experience tired body / general fatigue?
Yes No Not sure
Q17 Do you experience back-shoulder pain?
Yes No Not sure
Q18 Do you experience neck pain / stiff neck?
Yes No Not sure
Q19 Do you experience heavy head/ dizziness or nausea?
Yes No Not sure
Q20 Do you experience pain, numbness, tingling, and weakness in the hand & wrist?
Yes No Not sure
Q21 Do you spend more than 4 hours per day on digital display screen?
Yes No

Eye: Questionnaire-Based Vision Screening
Eye QVS
Proxy-administration

Q1 Does the person experience blurred vision when looking at far (>3 meters or 10 feet)?
Yes No Not sure
Q2 Does the person experience blurred vision at near (about 15-45cm or 0.5-1.5 feet)?
Yes No Not sure
Q3 Does the person experience something blocking your centre viewing?
Yes No Not sure
Q4 Does the person experience something blocking your peripheral viewing?
Yes No Not sure
Q5 Does the person experience double vision?
Yes No Not sure
Q6 Does the person experience difficulty to maintain clear vision at any particular distance? Clarity of object fluctuates between in and out of focus?
Yes No Not sure
Q7 Does the person experience word moves or floats / words appear to move or jump / loss of space?
Yes No Not sure
Q8 Does the person experience eye strain / tired eye / heavy eye lid?
Yes No Not sure
Q9 Does the person experience eye pain / soreness?
Yes No Not sure
Q10 Does the person experience headache / head pressure?
Yes No Not sure
Q11 Does the person experience burning?
Yes No Not sure
Q12 Does the person experience itching / irritation?
Yes No Not sure
Q13 Does the person experience sandy or gritty feeling / Grittiness/ Feeling of a foreign body?
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Q15 Does the person experience dryness / dry eye?
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Q18 Does the person experience neck pain / stiff neck?
Yes No Not sure
Q19 Does the person experience heavy head/ dizziness or nausea?
Yes No Not sure
Q20 Does the person experience pain, numbness, tingling, and weakness in the hand & wrist?
Yes No Not sure
Q21 Does the person spend more than 4 hours per day on digital display screen?
Yes No

Figure 1: Eye: Questionnaire-based Vision Screening (21-item *EyeQVS*).

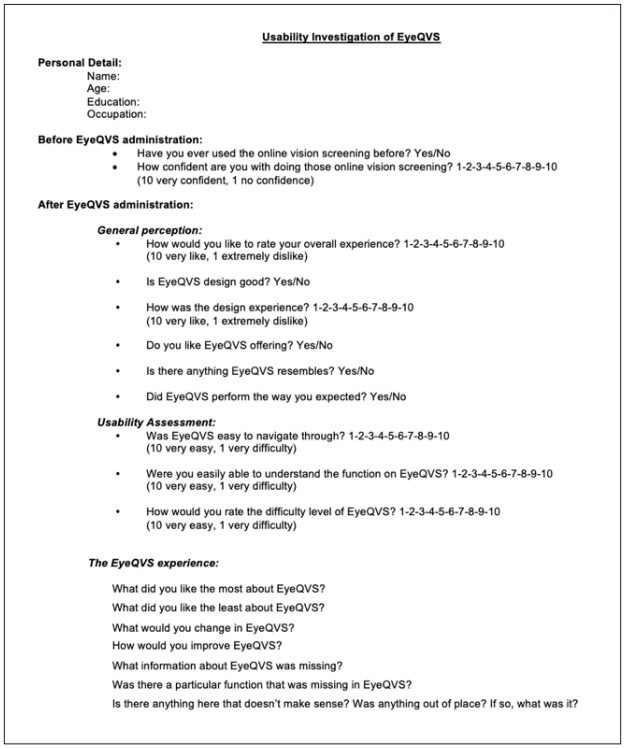
used the sample size calculator for sensitivity/specificity estimation (http://wnarifin.github.io) to calculate the sample size of this study (5). Using a recent report of 35% myopia prevalence in Malaysia (6), our sample size was estimated as 53 at a precision of 0.10 with 95% confidence interval (1-α) value.

Subject recruitment

Respondents and patients were recruited using convenient sampling. The inclusion criteria for respondents were individuals with sufficient English proficiency and literacy level. In the usability investigation of EyeQVS, two modes were employed [self-administration (fifty-two self-respondents cum patients) and proxy-administration (ten proxy-respondents for sixty-two patients) modes] in screening for vision problems. The respondents were university students for self-administration mode and social workers for proxy-reporting mode. The university students were recruited from one local public university in Klang Valley, Selangor, Malaysia. The social workers from two community welfare centres in Klang Valley, Selangor, Malaysia were recruited as respondents to proxy-administer EyeQVS on people with disabilities, orphans and old folks at their respective work places. The two distinct crowds were identified to represent the target population of the respective design. Self-administration mode of EyeQVS is designed for individuals with sufficient English proficiency and literacy level to administer the test by themselves. University students are appropriate representative of this category. The proxy-administration mode of EyeQVS is designed to help underprivileged population. The community welfare centres consist of people with disabilities, orphans and old folks who fit well under this category.

Usability investigation of EyeQVS

Usability investigation aimed to probe how well the application met the user's requirement (intuitive, easy to navigate, and overall user experience). Both proxy and self-administration modes were examined for its usability. Every screener under the proxy-administration category was required to proxy-administer EyeQVS on at least five patients before answering the usability survey. Every screener under self-administration category was only required to self-administer EyeQVS on himself/herself before answering the usability survey. All the responses were included in the usability analysis. The usability assessment of the EyeQVS experience was tested via interviews using structured questionnaires in both self-administration and proxy administration sets (Figure 2). Each respondent was interviewed with two items before and sixteen items after the EyeQVS administration.



Usability Investigation of EyeQVS

Personal Detail:
Name:
Age:
Education:
Occupation:

Before EyeQVS administration:
- Have you ever used the online vision screening before? Yes/No
- How confident are you with doing those online vision screening? 1-2-3-4-5-6-7-8-9-10 (10 very confident, 1 no confidence)

After EyeQVS administration:

General perception:
- How would you like to rate your overall experience? 1-2-3-4-5-6-7-8-9-10 (10 very like, 1 extremely dislike)
- Is EyeQVS design good? Yes/No
- How was the design experience? 1-2-3-4-5-6-7-8-9-10 (10 very like, 1 extremely dislike)
- Do you like EyeQVS offering? Yes/No
- Is there anything EyeQVS resembles? Yes/No
- Did EyeQVS perform the way you expected? Yes/No

Usability Assessment:
- Was EyeQVS easy to navigate through? 1-2-3-4-5-6-7-8-9-10 (10 very easy, 1 very difficulty)
- Were you easily able to understand the function on EyeQVS? 1-2-3-4-5-6-7-8-9-10 (10 very easy, 1 very difficulty)
- How would you rate the difficulty level of EyeQVS? 1-2-3-4-5-6-7-8-9-10 (10 very easy, 1 very difficulty)

The EyeQVS experience:

What did you like the most about EyeQVS?
What did you like the least about EyeQVS?
What would you change in EyeQVS?
How would you improve EyeQVS?
What information about EyeQVS was missing?
Was there a particular function that was missing in EyeQVS?
Is there anything here that doesn't make sense? Was anything out of place? If so, what was it?

Figure 2: The usability survey.

Validity Investigation of EyeQVS

The validity investigation aimed to inspect the ability of EyeQVS to detect vision problems (underlying outcome of interest). Fifty-two young Malay adults were recruited using convenient sampling to assess how accurately EyeQVS can detect vision problems, compared to comprehensive eye examination as the "gold standard". Each subject was required to complete a vision screening using the EyeQVS first. Then, the optometrists performed a comprehensive eye examination per standard clinical practice. To minimise potential bias, the optometrists were blinded from the EyeQVS screening results until the full eye examination was completed. The distant visual acuity was tested using a LogMAR letter chart. The near visual acuity was examined using the Malay language reading chart. The refractive status was inspected using dry retinoscopy and subjective refraction. Slit lamp biomicroscopy and ophthalmoscopy examined the anterior and posterior ocular health, respectively. The central and peripheral visual fields were tested using the Amsler test and the 24-2 Humphrey Visual Field, respectively. The binocular status was dissected using eight tests. The ocular symmetry and alignment were tested using Hirschberg Test & Cover Test to detect tropia. The simultaneous perception and suppression of binocularity were assessed using Worth-4-Dot. The near vergence function was examined from

three aspects: the near point of convergence using the RAF rule; heterophoria using the near Howell phoria card (33 cm), and stereopsis using the Random Dot Test. The accommodation system was tested from two facets: the near point of accommodation using the RAF rule and the near accommodative response using the Monocular Estimated Method (MEM) at the working distance of 40 cm. The dry eye status was assessed using non-invasive tear break-up time (NIBUT) and the Schirmer test (ST). Non-invasive tear break-up time is the estimation of tear stability (7). NIBUT had significantly higher sensitivity and specificity (7). We measured NIBUT with a handheld Placido disc as a projected image on the anterior surface of the eyes. Schirmer Test determines if the tear volume is enough tears to keep the eye moist and healthy (8). In this study, we used a 5 x 35 mm Schirmer strip of filter paper to measure basic and reflex tear secretion for 5 mins without anaesthesia. The computer vision syndrome was examined using Segui Computer Vision Questionnaire that evaluated the frequency and intensity of sixteen symptomatology related to digital usage (9, 10). The scopes of vision investigation and their respective referral criteria in the present study are summarised in Table 1.

Table 1: The scopes of vision investigation and the respective referral criteria

Scope of Investigations	Parameters	Apparatus	Referral Criteria
Visual acuity & refractive error Investigation	Distant visual acuity	LogMAR Letter Chart	Fail if ≥ 6/12
	Near visual acuity	BCMRC Reading Chart	Fail if ≥ N10
	Refraction (SE = Spherical Equivalent)	Dry Retinoscopy & Subjective Refraction	Hyperopia, SE ≥ 2.50 D; Astigmatism, Cylinder ≥ 1.50 D; Myopia, SE ≤ -1.50 D; Anisometropia, ≥ 1.00 D (difference in SE).
Ocular Health Investigation	Peripheral Visual Field	24-2 Humphrey Visual Field	Fail if any abnormality detected
	Central Visual Field	Amsler Test	Fail if any abnormality detected
	Anterior Segment	Slit Lamp Biomicroscopy	Fail if any abnormality detected
	Posterior Segment	Ophthalmoscope	Fail if any abnormality detected
Binocular investigation	Ocular symmetry	Hirschberg Test	Fail if any tropia detected
	Ocular alignment	Cover Test	Fail if any tropia detected
	Suppression	Worth-4-dot	Fail if detect any suppression (2 lights/ 3 lights) or diplopia (5 lights)
	Near point of Convergence	RAF rule	Fail if ≥ 10cm
	Near Phoria	Howell Card (33cm)	Fail if outside the normal range: ORTHO TO 10 EXO PD
	Stereopsis	Random Dot test	Fail if > 40 seconds of arc
	Near point of Accommodation	RAF rule	Fail if worse than the age norm using the minimum amplitude of accommodation age formula as 15 - (0.25 x patient's age in years)
	Accommodation Response at near	Monocular estimated method	Fail if not within the normal range of +0.50D to +0.75D
Dry Eye Investigation	Tear stability	Non-Invasive Tear Breakup Time	Fail if < 6 seconds
	Tear volume	Schirmer Test	Fail if < 10 mm
Computer Vision Syndrome Investigation	Symptom, frequency, and intensity assessment	Segui Computer Vision Questionnaire	Fail if ≥ 6 points

Results

Socio-demographic data of patients

A total of 114 patients (52 from self-administration mode and 62 from proxy administration set) were screened using EyeQVS by two groups of screeners (fifty-two screeners from self-administration group and ten screeners from proxy administration group). All data were used in the usability investigation. Only self-administration group proceeded to full eye examination for sensitivity and specificity investigation.

There was a total of fifty-two Malay patients in the self-administration mode testing. The total number of male and female were 14 and 38 respectively. The age range was between 20-24 years old. All of them are university students with tertiary education level.

Meanwhile, sixty-two patients from underprivileged communities were tested under proxy-administration mode by ten social workers. The ethnicity proportion of Malay, Indian, Chinese was 79%, 18% and 3%, respectively. The total number of male and female were 25 and 37 respectively. They aged from three to 86 years old. The education level varied from no education to tertiary education.

Usability of EyeQVS

The analysis was divided into four sections. The first analysis was about the previous experience with online vision screening. The second analysis was constructed by depleting structured questions on the EyeQVS experience. The third analysis was about the usability grading using a Likert Scale of 10-point. Forth analysis was about the EyeQVS experience using open-ended questions.

Lay-persons self-screening category

The mean age for fifty-two laypersons was 21.108 (± 1.048) years old. Approximately 85% (44/52) had never used online vision screening before. Among the 15% with previous online vision, screening experience graded confidence level of 5.153 ± 4.236. The average overall experience of EyeQVS was 9.173 ± 0.901. About 96.15% (50/52) graded EyeQVS as a good design with an average of 8.596 ± 1.361 on a Likert 10-point scale. All (100%) like the product offering. The report of tool resemblance with EyeQVS was only 1.9% (1/51). The majority (94% or 49/52) stated that the EyeQVS performed the way they expected.

Social worker as a proxy-screener category

The mean age for ten social workers was 34.00 ± 16.20 years old. Approximately 90% (9/10) had never used online vision screening before. Among the 10% with previous online vision, screening experience graded confidence level of 1.000 ± 3.162. Their overall experience of EyeQVS was 6.500 ± 2.718 on Likert 10-point scale. All [100% (10/10)] graded EyeQVS as a good design with an average = 7.800 ± 2.098 on Likert 10-point scale. Approximately 80% (8/10) like what EyeQVS offers. Only 10% (1/10) reported tool resemblance with EyeQVS. About 60% (6/10) stated that the EyeQVS performed the way they expected.

The usability assessment and EyeQVS experience are summarised in Table 2 and Table 3, respectively. Relatively, all scored above 7-point on the Likert scale, which indicated the well-acceptability of EyeQVS. Positive feedback from open-ended questions included user-friendly, easy, simple and short duration. One request to add information on nearby eye care practitioners might not be feasible due to dynamic practices. Comments on design were mixed. Some enjoyed the subtle design, but some preferred a more colourful design. The demand for bigger fonts might complicate the scrolling process. The request for a more appealing design for children was irrelevant because we used proxy administration.

Table 2: Summary of usability assessment. The number indicates the average score with a standard deviation of 10-point Likert scale (10 very easy, 1 very difficult)

Three items were assigned to assess usability	Lay-person self-screening	Social worker as proxy-screener
Was EyeQVS easy to navigate through?	9.288 ± 1.109	9.700 ± 0.483
Were you easily able to understand the function of EyeQVS?	9.212 ± 1.109	9.400 ± 0.699
How would you rate the difficulty level of EyeQVS?	9.096 ± 1.660	9.500 ± 0.707

Table 3: The summary of the EyeQVS experience

Items for EyeQVS experience	Lay-person as self-screener	Social worker as proxy-screener
What did you like the most about EyeQVS?	• Easy to use and navigate • Easy to select the answer • Able to understand the question given easily • Friendly interface • It can give a summary diagnosis • It allows the user to know about the eye problem before meeting an optometrist. • Less time spent • Result is satisfying	• Easy to use and navigate • Easy to select the answer

Table 3: The summary of the EyeQVS experience (continued)

Items for EyeQVS experience	Lay-person as self-screener	Social worker as proxy-screener
What did you like the least about EyeQVS?	• The colour is not very attractive. • Too simple. • Doesn't have a detailed question. • It doesn't have the option sometimes. • The term in English is a bit difficult.	• Age needs to key in manually
What would you change in EyeQVS?	• Improve colour. • More entertaining • Make it attractive with a good combination of bright colours. • Use a bigger font size. • Can add opinion. • More infographic	• No remark
How would you improve EyeQVS?	• More question. • Elaborate further on the answer options. • Make it easier for children • Add information on the nearest verified/registered optometrist. • Maybe could add a Malay or other language version. • Tutorial in the beginning before answering. • Animation.	• Maybe could add a Malay or other language version.
What information about EyeQVS was missing?	• Rate level of pain • Contact details	• Immediate family medical history detail • Timeline of symptoms occur.
Was there a particular function that was missing in EyeQVS?	• Race, General Health History • Information about disease	• No remark
Is there anything here that doesn't make sense? Was anything out of place? If so, what was it?	• No remark	• No remark

Validity of EyeQVS

Reduced Vision and Refractive Error Screening (Q1-Q2):

Two items were used in the visual acuity and refractive error (VARX) screening of EyeQVS. One item for reduced vision / refractive error screening at far (Q1) and one for reduced vision / refractive error screening at near (Q2). The formulas used to calculate the failure rate are listed in Appendix I. The failure criteria for both investigations were 0% (pass) & 100% (fail). The Chi-square test of independence was performed on the total count of pass-fail in each vision test (Table 4). The Chi-square test of independence is a statistical hypothesis test used to determine whether two categorical variables are likely related. Items Q1 and Q2 were significantly related to distant and near visual acuity, respectively. Both items did not correlate well with subjective refraction.

Table 4: The comparison of Eye: Questionnaire-based Vision Screening (reduced vision and refractive error investigation component) with clinical tests of visual acuity and subjective refraction

Eye: Questionnaire-based Vision Screening EyeQVS	Distance visual acuity test using LogMAR Letter chart	Near visual acuity test using BCMRC Reading chart	Subjective refraction
VARX at far	$\chi^2 = 8.851$ $p = 0.003$	NA*	$\chi^2 = 1.866$ $p = 0.172$
VARX at near	NA*	$\chi^2 = 5.920$ $p = 0.015$	$\chi^2 = 0.228$ $p = 0.633$

*NA – not applicable

#VARX – visual acuity & refractive error

The information on accuracy, sensitivity, specificity, positive predictive value, negative predictive value and balanced accuracy in reduced vision and refractive error screening by EyeQVS are summarised in Appendix II & III. The EyeQVS had high sensitivity (100%) and specificity (68.08%) to detect reduced vision problems at a distance. EyeQVS also had high specificity (80.77%) to detect reduced vision problems at near. The sensitivity to detect reduced vision problems near was unable to generate due to none of the respondents having reduced near vision problems. The sensitivity of item Q1 dropped to 45.45%, but specificity remained high at 73.68% in detecting refractive error. The accuracy of item Q1 to correctly classify observation was high for reduced far vision (71.15%) but low for refractive error (55.77%). The sensitivity of item Q2 was low (21.21%), but specificity remained high at 84.21% in detecting refractive error. The accuracy of item Q2 to correctly classify observation was high for reduced near vision (80.77%) but lower for refractive error (44.23%). EyeQVS has high positive (70-75%) and negative (74-84%) predictive values for refractive error. EyeQVS has low positive (25%) but high negative (68-81%) predictive values for reduced vision. The

balanced accuracy was the highest in screening for reduced vision at far but relatively low for refractive error screening and reduced near vision screening (40-56%).

Visual Field Defect Screening (Q3-Q4):

Two items of EyeQVS were used in the visual field defect screening. One item for central visual field defect screening (Q3) and one for peripheral visual field defect screening (Q4). The formulas used to calculate the failure rate are listed in Appendix I. The fail criteria for both investigations were 0% (pass) & 100% (fail). Only two subjects failed the central and peripheral visual field defect screening. All subjects passed the Amsler test, Humphrey visual field test, and anterior and posterior segment ocular assessment. Therefore, we had two counts of false positive, 50 counts of true negative, and zero counts of true positive and false negative. Based on the four limited positive cases in EyeQVS and zero positive cases in clinical examination, the sensitivity was calculated as 0%, and the specificity was 96.15% with an accuracy of 96.15% and a balanced accuracy of 48.08%.

Binocular Vision Disorder Screening (Q5-Q10):

The 5-items (Q5-Q10) used in the binocular disorder's investigation of EyeQVS were compared to the vergence and accommodation aspect of the clinical binocular investigation. The formula used to calculate the failure rate is listed in Appendix I. Three cutting points for fail criteria were tested against eight binocular tests – two on ocular alignment, one on simultaneous perception/suppression, three on vergence and two on accommodation. The Chi-square test of independence was performed on the total count of pass-fail in each binocular test (Table 5). Based on statistical analysis using the Chi-Square test of independence, the fail criteria of Option A were better than Option B and C (Table 5). Fail criteria of Option B and Option C showed similar statistical output. Fail criteria of Option A exhibited a significant correlation with the near point of accommodation. Therefore, the referral criteria for EyeQVS binocular disorders component used Option A (total score of ≥ 60%). Respondents were expected to fail at least three out of five items.

Table 5: The comparison of Eye: Questionnaire-based Vision Screening (binocular investigation component) with eight clinical binocular tests

Clinical binocular tests	Eye: Questionnaire-based Vision Screening (binocular disorders investigations)		
	Fail criteria Option A - if ≥ 60%	**Fail criteria Option B - if > 80%**	**Fail criteria Option C - if 100%**
Ocular symmetry using Hirschberg Test	No data because all subjects passed	No data because all subjects passed	No data because all subjects passed
Ocular alignment using Cover Test	No data because all subjects passed	No data because all subjects passed	No data because all subjects passed
Suppression using Worth-4-Dot	$\chi^2 = 1.317$ p = 0.251	$\chi^2 = 0.339$ p = 0.561	$\chi^2 = 0.339$ p = 0.561
Near point of Convergence using RAF rule	No data because all subjects passed	No data because all subjects passed	No data because all subjects passed
Near Phoria using near Howell Card	$\chi^2 = 1.536$ p = 0.215	$\chi^2 = 2.061$ p = 0.151	$\chi^2 = 2.061$ p = 0.151
Stereopsis with Random Dot test	$\chi^2 = 0.018$ p = 0.892	$\chi^2 = 0.441$ p = 0.507	$\chi^2 = 0.441$ p = 0.507
Near point of Accommodation using RAF rule	$\chi^2 = 4.282$ p = 0.039	$\chi^2 = 0.062$ p = 0.803	$\chi^2 = 0.062$ p = 0.803
Accommodation Response at near using Monocular estimated Method	$\chi^2 = 0.029$ p = 0.865	$\chi^2 = 0.415$ p = 0.519	$\chi^2 = 0.415$ p = 0.519

The information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS binocular disorders screening component in a combined comparison of the eight clinical tests is summarised in Appendix IV. The proportion of correctly classified observations was about 44.23% {accuracy = [(TP+TN)/(TP+FP+FN+TN)]X100 = (23/52) x 100}. The proportion of positive cases correctly predicted was about 18.75% {sensitivity = [TP/(TP+FN)] x 100] = (6/32) x 100}. The proportion of negative cases correctly predicted was about 85% {specificity = [TN/(FP+TN)] x 100] = (17/20) x 100}. The proportion of true positives in the total of positive predictions was about 66.67 % {Positive Predictive Value, PPV = [TP/(TP+FP)] x 100] = (6/9) x 100}. The proportion of true negative in the total of negative predictions was about 85% {Negative Predictive Value, NPV = [TN/(FP+TN)] x 100] = (17/20) x 100}. Balanced accuracy, the arithmetic means of the two metrics {(sensitivity + specificity)/2}, was about 51.875%. In conclusion, EyeQVS binocular investigation had low sensitivity (18.75%) but high specificity (85%) with a balanced accuracy of 51.875% compared to a combination of six clinical binocular tests. The pass-fail grading from the binocular disorders data would be included as part of the computer vision syndrome screening output generation calculation.

Due to the near point of accommodation being the only clinical test that displayed a significant correlation with the EyeQVS binocular component (χ^2=4.282P<0.05), we reanalysed the sensitivity, specificity and accuracy using the near point of accommodation single parameter (Appendix

V). The proportion of correctly classified observation became 86.54% {Accuracy = [(TP+TN)/(TP+FP+FN+TN)] X100 = (45/52) x 100}. The proportion of positive cases correctly predicted became 100% {sensitivity = [TP/(TP+FN)] x 100] = (1/1) x 100}. The proportion of negative cases correctly predicted became 86.27% {specificity = [TN/(FP+TN)] x 100] = (44/51) x 100}. The proportion of true positives in the total of positive predictions was about 12.5 % {Positive Predictive Value, PPV = [TP/(TP+FP)] x 100] = (1/8) x 100}. The proportion of true negative in the total of negative predictions was about 86.27% {Negative Predictive Value, NPV = [TN/(FP+TN)] x 100] = (44/51) x 100}. Balanced accuracy became 93.135%. EyeQVS binocular disorders investigation had high sensitivity (100%) and specificity (86.27%) with balanced accuracy of 93.13% compared to the near point of accommodation alone. In conclusion, EyeQVS was more suitable for screening for accommodation problems.

Dry Eye Screening (Q11-Q15):

The 5 items (Q11-Q15) used in the dry eye investigation of EyeQVS were compared to two clinical tests that examine tear stability (non-invasive tear breakup time) and tear volume (Schirmer test), respectively (Table 6). The formula used to calculate the failure rate is listed in Appendix I. Three cutting points for fail criteria were tested against Non-Invasive Tear Breakup Time and Schirmer test. The Chi-square test of independence was performed on the total count of pass-fail in each dry eye test (Table 6). The five items of dry eye investigation in EyeQVS correlate better with the tear stability test (Non-Invasive Tear Breakup Time) than the tear volume test (Schirmer test). Based on statistical analysis using the Chi-Square test of independence, the fail criteria of Option A were better than Option B and C. Therefore, the referral criteria for the EyeQVS dry eye component used Option A (total score of ≥ 60%). Respondents are expected to fail at least three out of five items.

Table 6: The comparison of Eye: Questionnaire-based Vision Screening (dry eye investigation component) with Non-Invasive Tear Breakup Time and Schirmer test

Eye: Questionnaire-based Vision Screening (EyeQVS)	Non-Invasive Tear Breakup Time (NIBUT)	Schirmer test
Fail criteria Option A - if ≥ 60%	$\chi^2 = 4.840$ p = 0.028	$\chi^2 = 4.410$ p = 0.110
Fail criteria Option B - if > 80%	$\chi^2 = 2.920$ p = 0.087	$\chi^2 = 1.984$ p = 0.371
Fail criteria Option C - if 100%	$\chi^2 = 0.435$ p = 0.509	$\chi^2 = 0.097$ p = 0.953

The information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS dry eye screening component is summarised in Appendix VI. The proportion of correctly classified observations was about 65.38% {accuracy = [(TP+TN)/(TP+FP+FN+TN)]X100 = (34/52) x 100}. The proportion of positive cases correctly predicted was about 93.10% {sensitivity = [TP/(TP+FN)] x 100] = (27/29) x 100}. The proportion of negative cases correctly predicted was about 30.43% {specificity = [TN/(FP+TN)] x 100] = (7/23) x 100}. The proportion of true positives in the total of positive predictions was about 62.79 % {Positive Predictive Value, PPV = [TP/(TP+FP)] x 100] = (27/43) x 100}. The proportion of true negative in the total of negative predictions was about 30.43% {Negative Predictive Value, NPV = [TN/(FP+TN)] x 100] = (7/23) x 100}. Balanced accuracy {(sensitivity + specificity)/2} was about 61.76%. In conclusion, EyeQVS dry eye investigation had high sensitivity (93.10%) but low specificity (30.43%) with balanced accuracy of 61.76% when compared to NIBUT.

Postural Ergonomic Screening (Q16-Q20):

Five items (Q16-Q20) were developed to screen for postural ergonomic problems. No routine procedures in full eye examination could be directly compared. Therefore, we only reported the descriptive findings. The formula used to calculate the failure rate is listed in Appendix I. The referral criteria for EyeQVS postural ergonomic screening used a total score of ≥ 60%. Respondents were expected to fail at least three out of five items. About 36.54% (19 out of 52) subjects failed the postural ergonomic screening.

Computer Vision Syndrome Screening (Q5-Q21):

The pre-requisite for computer vision syndrome was more than four hours of daily usage (data from Q21). The generation of pass-fail for computer vision syndrome screening of EyeQVS was generated by combining binocular disorders, dry eye and postural ergonomic status. A subject would be graded as failed computer vision syndrome screening if data from binocular disorders, dry eye or postural ergonomic status was graded as fail. The relationship between Segui Computer Vision Syndrome Questionnaires with Eye: Questionnaire-based Vision Screening was individually compared with binocular disorders, dry eye and postural ergonomic, computer vision syndrome screening components of EyeQVS using the Chi-Square test of independence. Segui Computer Vision Syndrome Questionnaires were significantly correlated with dry eye, binocular disorder and postural ergonomic components of EyeQVS (Table 7).

Table 7: The comparison of Segui Computer Vision Syndrome Questionnaires with Eye: Questionnaire-based Vision Screening (binocular disorders, dry eye and postural ergonomic, computer vision syndrome individual screening components)

Eye: Questionnaire-based Vision Screening (EyeQVS)	Segui Computer Vision Screening Questionnaire
Binocular disorders screening (Q5-Q10)	$\chi^2 = 6.802$, $p = 0.009$
Dry eye screening (Q11-Q15)	$\chi^2 = 21.899$, $p < 0.001$
Postural ergonomic screening (Q16-Q20)	$\chi^2 = 13.941$, $p < 0.001$
Computer vision syndrome screening (Q5-Q21)	$\chi^2 = 5.056$, $p = 0.025$

The information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS computer vision screening component is summarised in Appendix VII. The accuracy was about 51.92% {Accuracy = [(TP+TN)/(TP+FP+FN+TN)]X100 = (27/52) x 100}. The proportion of positive cases correctly predicted was about 21.875% {sensitivity = [TP/(TP+FN)] x 100] = (7/32) x 100}. The proportion of negative cases correctly predicted was about 100% {specificity = [TN/(FP+TN)] x 100] = (20/20) x 100}. The proportion of true positives in the total of positive predictions was about 100% {Positive Predictive Value, PPV = [TP/(TP+FP)] x 100] = (7/7) x 100}. The proportion of true negative in the total of negative predictions was about 100% {Negative Predictive Value, NPV = [TN/(FP+TN)] x 100] = (20/20) x 100}. Balanced accuracy was about 60.94%. In conclusion, the EyeQVS computer syndrome investigation had low sensitivity (21.875%) but high specificity (100%) with a balanced accuracy of 60.94% compared to the Segui Computer Vision Syndrome Questionnaire.

Discussion

EyeQVS as an online vision screening alternative

EyeQVS is specially designed to screen for potential vision problems among vulnerable communities. Visual impairments are more common in vulnerable communities (11). Vision disorders have been reported to be high among the poverty group, elderly and indigenous people (11). Undiagnosed vision impairment can substantially affect social development and health, potentially negatively impacting social, physical, educational, and professional activities (12). Refractive error is a major cause of preventable vision impairment, and uncorrected refractive error can significantly affect educational performance (13). Children from the most deprived backgrounds and those from unstable homes were reported to be more likely to fail preschool vision screening (14). The disparities in vision care utilisation are apparent among vulnerable communities in need of special care, support, or protection because of age, disabilities, poverty or accessibility issues and impact public health care, especially the eyes (11). Vision screening allows the identification but not diagnosis of eye diseases. Screenings cannot diagnose the cause of vision problems, but they can be used to expand entry to the healthcare system and appropriate follow-up care. There is a dearth of economic evidence on the efficacy of vision screening programmes whether vision screening was better than no screening (15, 16). Evidence reports and systematic reviews did not establish (17). Indirect evidence supported the utility of multiple screening tests for identifying individuals at higher risk for vision problems (16). EyeQVS embraces identifying potential problems with visual function or symptoms suggestive of eye disease or condition. It is not designed to be at par with the comprehensive vision screening program like the Modified Clinical Technique (15).

There are two main types of questions in questionnaire construction – structured and unstructured (18). Structured questionnaires are planned and designed to gather precise information with closed-ended questions. The dichotomous question is a closed-ended question with only two possible answers. Multiple-choice questions give respondents a list of answer options, either in a single-select or multiple-choice question responses from a given list of options. Unstructured questionnaires comprise a basic structure and use open-ended to collect specific data from respondents, allowing respondents to answer more freely. Item constructs in EyeQVS employ a structured questionnaire approach. EyeQVS consist of a single-select multiple-choice closed-ended question approach. EyeQVS adheres to the basic rules for questionnaire item construction, including grammatically correct statements with clear and comprehensible wording, easily understood by individuals with various educational levels (18, 19). Questions are not biased or misleading. This closed-ended question approach is simple to administer and easy to collect pre-determined information. One limitation of using a closed-ended questionnaire approach is guessing problems. Another limitation is the recall error and commitment issue linked to the questionnaire data's reliability and validity.

Public awareness about eye and vision health drives a long-term effort to change attitudes, knowledge, behaviours, and practices toward eye healthcare. Ensuring that the eye care system supports at-risk populations is important to public health. EyeQVS concept can be complementary to the preventive eye care system by conjoining with the existing equipment-based vision screening regimen. Technology is used in many healthcare aspects, from prevention to treatment and rehabilitation (20, 21). The concept of EyeQVS may inspire the digitalisation of preventive eye healthcare.

Usability of EyeQVS

High usability is an essential characteristic of a good screening test. Our findings exhibited good usability. All target population was able to be screened with EyeQVS. Eye: Questionnaire-based Vision Screening (EyeQVS) is

user-friendly. All respondents indicated high confidence towards EyeQVS, with an average of more than 8 points on the Likert scale score. The majority found it easy to use and navigate. Respondents also adored the short duration required to complete the vision screening. The completion rate of questionnaires has been reported to decrease when the length of the questionnaire increases. A one-question questionnaire exhibited a 75% completion rate, while the completion rate dropped to 30% for 2-5 questions and 12.5% for a questionnaire containing more than five questions. With the assumption of 5 minutes to answer 10 questions on average, EyeQVS requires approximately 10 minutes to complete. The length of EyeQVS is within the recommended length for questionnaire design (19). EyeQVS provides alternative online easy access to preventive eye care. Online access allows broader coverage. The simplified testing algorithm used for the EyeQVS also enables the test to be completed quickly.

Validity of EyeQVS

In this study, we evaluated the effectiveness of the newly developed EyeQVS. High sensitivity and specificity are desirable in a vision screening design to enable appropriate identification of those with the target ocular condition (sensitivity) and accurate identification of those who do not have the target condition (specificity). The higher the negative predictive value denotes that the more sensitive a test, the less likely a person with a negative result will suffer the ocular disorder. Meanwhile, the higher the positive predictive value signifies that the more specific a test, the less likely a person with a positive test will be free from the ocular disorder.

Previous research on visual acuity screening mostly reported higher specificity than sensitivity (Appendix VIII). Interesting, our visual acuity screening result was somewhat counterintuitive. EyeQVS displayed higher sensitivity (100%) than specificity (68.08% for distance and 80.77% for near) for the detection of reduced visual acuity. EyeQVS exhibited an excellent relationship with visual acuity but not a refractive error. One possible explanation was the vision variation in diverse types of refractive errors.

EyeQVS had high specificity (96.15%) and balanced accuracy of 48.08% for the detection of visual field defects. The sensitivity and specificity of using ocular pressure and optic disc changes in previous survey to detect glaucomatous visual field defect was 67.3% and 96.5% respectively (22). Our specificity results are similar to those reported in the survey by Khandekar & Al Raisi (22).

EyeQVS exhibited a poor relationship with the eight binocular clinical tests with a sensitivity of 18.75% and specificity of 85%. Convergence Insufficiency Symptom Survey (CISS) is one of the commonly used questionnaire to evaluate binocular disorders (23). The reported sensitivity of CISS (52%) was higher than ours but the reported specificity of CISS (72%) was lower than our findings. However, EyeQVS had high sensitivity (100%) and specificity (86.26%) when singled out the near point of accommodation alone.

The sensitivity and specificity of McMonnies Dry Eye Questionnaire (MDEQ) was reported as 57% and 60% respectively (24). EyeQVS exhibited higher sensitivity (93.10%) than MDEQ but lower specificity than MDEQ (30.43%) in the dry eye screening. EyeQVS was found to show a good relationship with NIBUT but not with Schirmer Test in dry eye comparison. It may indicate that the symptomatology used in EyeQVS is more about tear stability than tear volume.

The data on postural ergonomic problems was a part of the computer vision syndrome investigation. About 36.54% of our population suffers postural ergonomic problems. EyeQVS had high specificity (100%) but low sensitivity (21.88%) for detecting computer vision syndrome. Previous study reported good sensitivity (81.1%) and acceptable specificity (69.2%) of computer vision syndrome questionnaire (CVS-Q FA©) (25). It is difficult to compare our findings with previous studies directly due to differences in populations, ages, and pass/fail criteria used.

Conclusion

The EyeQVS provides a simple, rapid, validated vision screening as an alternative option when finances or location hinder healthcare access. EyeQVS is not intended to substitute comprehensive eye examinations or to replace tool-based vision screening programs. EyeQVS reduces the liability of expensive equipment-based vision screening by leveraging the unique properties of questionnaires (convenient and cost-effective). EyeQVS is feasible to enable outreach and to benefit more underprivileged communities who might not have the financial means to go for a comprehensive eye examination. EyeQVS is also pragmatic for implementing vision screening in remote locations where equipment-based screening is unavailable. It is also suitable for vulnerable communities needing special care, support or protection because of age, disability, poverty, or accessibility issues. Both self-administration and proxy-administration in the usability analysis narrated very positive feedback regarding the EyeQVS. The validity data in this study provide essential information if anyone is interested in using EyeQVS in future research investigations.

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Competing interests

The authors declare that they have no competing interests.

Ethical clearance

We obtained ethical approval from the UiTM Research Ethics Committee, registered under REC/09/2021 (MR/803).

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Appendix I

The types of vision disorders and the formulas used to calculate the failure rates are listed as below:

Types of vision disorders	Formulas to calculate failure rate
For reduced vision / refractive error screening at far (VARX at far)	Percentage of failure based on 1 item (Q1) = (total of 'FAIL' or 'NOT SURE' answers / 1) x 100%
For reduced vision / refractive error screening at near (VARX at near)	Percentage of failure based on 1 item (Q2) = (total of 'FAIL' or 'NOT SURE' answers / 1) x 100%
For central visual field defect screening (VFD-central)	Percentage of failure based on 1 item (Q3) = (total of 'FAIL' or 'NOT SURE' answers / 1) x 100%
For peripheral visual field defect screening (VFD-peripheral)	Percentage of failure based on 1 item (Q4) = (total of 'FAIL' or 'NOT SURE' answers / 1) x 100%
For binocular Vision Disorder Screening	Percentage of failure based on 5 items (Q5-Q10) = (total of 'FAIL' or 'NOT SURE' answers / 5) x 100%
For Dry Eye Screening	Percentage of failure based on 5 items (Q11-Q15) = (total of 'FAIL' or 'NOT SURE' answers / 5) x 100%
For Postural Ergonomic Screening	Percentage of failure based on 5 items (Q16-Q20) = (total of 'FAIL' or 'NOT SURE' answers / 5) x 100%

Appendix II

Information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS reduced vision and refractive error screening component.

		Clinical findings using LogMAR letter chart	
		Has reduced vision	No reduced vision
EyeQVS Item Q1 (far)	Positive	True positive, TP (5)	False positive, FP (15)
	Negative	False negative, FN (0)	True negative, TN (32)

		Clinical findings using the BCMRC reading chart	
		Has refractive error	No refractive error
EyeQVS Item Q2 (near)	Positive	True positive, TP (0)	False positive, FP (10)
	Negative	False negative, FN (0)	True negative, TN (42)

		Clinical findings using subjective refraction	
		Has reduced vision	No reduced vision
EyeQVS Item Q1 (far)	Positive	True positive, TP (15)	False positive, FP (5)
	Negative	False negative, FN (18)	True negative, TN (14)

		Clinical findings using subjective refraction	
		Has refractive error	No refractive error
EyeQVS Item Q2 (near)	Positive	True positive, TP (7)	False positive, FP (3)
	Negative	False negative, FN (26)	True negative, TN (16)

Appendix III

Summary of Accuracy, Sensitivity, Specificity, Positive Predictive Value, Negative Predictive Value and Balanced accuracy in reduced vision and refractive error screening by EyeQVS

	EyeQVS components	**EyeQVS Item Q1 (far)**		**EyeQVS Item Q2 (near)**	
Comparison	**Target conditions**	**Reduced vision**	**Refractive error**	**Reduced vision**	**Refractive error**
Accuracy	= [(TP+TN)/ (TP+FP+FN+ TN)]X100	71.15 %	55.77%	80.77%	44.23%
Sensitivity	= [TP/ (TP+FN] x 100	100%	45.45%	No data	21.21%
Specificity	= [TN/ (FP+TN)] x100	68.08%	73.68%	80.77%	84.21%
Positive Predictive Value	= [TP/ (TP+FP)] x 100]	25%	75%	No data	70%
Negative Predictive Value	= [TN/ (FP+TN)] x 100]	68.08%	73.68%	80.77%	84.21%
Balanced Accuracy	= (sensitivity + specificity)/2	84.04%	56.56%	40.385%	52.71%

TP – true positive; TN – true negative; FP – false positive; FN – false negative

Appendix IV

Information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS binocular disorders screening component in a combined comparison of the eight clinical tests.

		Clinical binocular tests	
		Has binocular disorders	No binocular disorders
EyeQVS	Positive	True positive, TP (6)	False positive, FP (3)
	Negative	False negative, FN (26)	True negative, TN (17)

Appendix V

Information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS binocular disorders screening component in comparison to the near point of accommodation (NPA) analysis only

		NPA alone	
		Has binocular disorders	No binocular disorders
EyeQVS	Positive	True positive, TP (1)	False positive, FP (7)
	Negative	False negative, FN (0)	True negative, TN (44)

Appendix VI

Information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of EyeQVS dry eye screening component.

		NIBUT	
		Has dry eye	No dry eye
EyeQVS	Positive	True positive, TP (27)	False positive, FP (16)
	Negative	False negative, FN (2)	True negative, TN (7)

Appendix VII

Information about True Positive (TP), False Positive (FP), False negative (FN) & True Negative (TN) of the EyeQVS computer vision screening component.

		Segui CVSQ	
		Has dry eye	No dry eye
EyeQVS	Positive	True positive, TP (7)	False positive, FP (0)
	Negative	False negative, FN (25)	True negative, TN (20)

Appendix VIII

The Sensitivity and Specificity of Visual Acuity Screening Performed by Non-eyecare Personnel.

Country (Study)	Visual acuity test	Sensitivity	Specificity
Canada (Sabri et al., 2016)	Snellen Chart	96%	71%
China (Sharma et al., 2008)	Tumbling E Chart	93%	91%
India (Muralidhar & Vijayalakhmi, 2019)	Tumbling E Chart	24.8%	98.65%
Iran (Ostadi Moghaddam et al., 2012)	E Chart	38%	92%
Malaysia (Abu-Bakar & Chen 2017)	HOTV chart	78%	96%
Nepal (Adhikari & Shrestha, 2011)	HOTV Chart	80%	98%
Oman (R Khandekar et al., 2004)	Snellen E	63.5%	99%
Singapore (Tong et al., 2004)	Simplified visual acuity screening	86%	92%
Thailand (Teerawattananon et al., 2014)	Lea Symbol	35%	98%
	E chart (7 years old) & Snellen Chart (8-12 years old)	65%	97%
USA (The Vision in Preschoolers Study Group, 2005)	Linear Lea Symbol (10ft)	37%	90%
	Single Lea Symbol (5ft)	61%	91%
	Linear Lea Symbol (10ft)	49%	90%

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