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Real World Application of a Smartphone-Based Visual Acuity Test (WHOeyes) with Automatic Distance Calibration

Running title: Development and validation of WHOeyes

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Ethics statements

Patient consent for publication

All participants provided written informed consent, while for participants under the age of 18 years, written informed consent was obtained from their legal guardians.

Ethics approval

This study involves human participants and received approval from the Institutional Review Board of Zhongshan Ophthalmic Center, Guangzhou, China (No. 2021KYPJ104), and adhered to the tenets of the Helsinki Declaration. The participants gave informed consent to participate in the study before taking part. The tenets of the Declaration of Helsinki were followed throughout this study.

Disclosure

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Conflict of interest

The authors have no financial or other conflicts of interest concerning this study.

Contributors

Concept and design: YW, XH, MH; Software engineering: CL; Experiment execution and data collection: YW, SZ, WW, XT; Statistical analysis: YW, SK, VLAC; Manuscript writing and revision: YW, SK, VLAC, XH; Management of this project:

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Abstract

Background: To develop and assess usability of a smartphone-based visual acuity (VA) test with an automatic distance calibration (ADC) function, the iOS version of WHOeyes.

Methods: The WHOeyes was an upgraded version with a distinct feature of ADC of an existing validated VA testing APP called V@home. Three groups of Chinese participants with different ages (≤20, 20-40, >40 years) were recruited for distance and near VA testing using both an Early Treatment Diabetic Retinopathy Study (ETDRS) chart and the WHOeyes. The ADC function would determine the testing distance. Infrared rangefinder was used to determine the testing distance for the ETDRS, and actual testing distance for the WHOeyes. A questionnaire-based interview was administered to assess satisfaction.

Results: The actual testing distance determined by the WHOeyes ADC showed an overall good agreement with the desired testing distance in all three age groups ($p > 0.50$). Regarding the distance and near VA testing, the accuracy of WHOeyes was equivalent to ETDRS. The mean difference between the WHOeyes and ETDRS ranged from -0.084 to 0.012 logMAR, and the quadratic weighted kappa (QWK) values were greater than 0.75 across all groups. The test-retest reliability of WHOeyes was high for both near and distance VA, with a mean difference ranging from -0.040 to 0.004 logMAR and QWK all greater than 0.85. The questionnaire revealed an excellent user experience and acceptance of WHOeyes.

Conclusions: WHOeyes could provide accurate measurement of the testing distance as well as the distance and near VA when compared to the gold standard ETDRS chart.

Keywords: smartphone-based; visual acuity test; WHOeyes, V@home; ETDRS;

Precis: Based on real world application, WHOeyes with the ADC function could provide accurate measurement of the testing distance as well as the distance and near VA when compared to the gold standard ETDRS chart.

Key Messages

What is already known on this topic

The Automatic Distance Calibration (ADC) feature enhances convenience for visual acuity (VA) testing. We have expanded this functionality in our previously developed V@Home software, now officially recognized as the World Health Organization's VA testing application, named WHOeyes.

What this study adds

WHOeyes enables automatic and precise identification of testing distances, matching the accuracy of the gold standard ETDRS chart method, with excellent reliability for repeated testing.

How this study might affect research, practice or policy

WHOeyes could provide accurate distance and near VA testing, with the potential to positively impact remote healthcare, vision impairment detection, and public health by enhancing accessibility, enabling early intervention, and fostering a proactive approach to eye health.

Introduction

Vision impairment (VI) and blindness are significant public health concerns that can lead to reduced quality of life and substantial economic burden for individuals and society.[1 2] The latest Global Burden of Disease Study estimates that globally in 2020, there were approximately 258 million people with mild VI, 295 million with moderate to severe VI, 43 million with blindness, and the number of people with near VI from uncorrected presbyopia was as high as 510 million.[3] Despite the fact that more than 80% of VI could be prevented with early detection and timely treatment, missed or delayed diagnoses of VI are still common due to a range of factors, including inadequate infrastructures and human resource shortages for eye care services, as well as the lack of cost-effective screening strategies.[4 5]

Visual acuity (VA) is a fundamental ophthalmic measurement that evaluates an individual's ability to discriminate between two stimuli separated in space at high contrast relative to the background.[6] It is the most frequently performed clinical examination in eye care and plays a crucial role in the diagnosis, treatment assessment, and follow-up of eye diseases.[7 8] A multitude of methodologies are employed for the conventional evaluation of VA, with the Early Treatment Diabetic Retinopathy Study (ETDRS) serving as the gold standard.[9] However, these methods have limitations that prevent them from benefiting a larger population, especially in low-resource settings, including a lengthy testing time, costs of VA testing charts, availability of testing room and personnel, as well as the costs for the examination and traveling to the examination center.[10] Thus, an automated, accurate, and user-friendly approach is needed for vision screening or self-monitoring.

The advent of mobile-based VA testing has revolutionized the landscape of ophthalmic diagnostics, offering a novel and pragmatic solution to the challenges of traditional testing methods.[11-14] In a recent review of VA testing applications found in the United States App Store, many VA applications still lack validation and reliability testing and may not be suitable for telemedicine use.[10 15] Bastawrous et al. innovatively proposed the Peek Acuity mobile app which was validated against Snellen charts and ETDRS.[16] We have previously developed a mobile-based VA testing method and system, V@Home, which has been validated for its accuracy and stability in detecting distance and near VA in reference to the ETDRS chart.[17] An accurate testing distance is crucial for accurate VA testing results, to our knowledge, existing VA testing APPs mostly require manual calibration of the testing distance.[15 17-19] The ability to automatically and currectly detect and calibrate the testing distance will give more convenience to VA testing, especially in low resource areas.[20] Hence, we have extended the capabilities of V@Home by incorporating the Automatic Distance Calibration (ADC) function, enabling effortless visual acuity testing at any place and time. This new feature facilitates accurate use of the application in real-world settings, i.e., as a self-assessment screening tool or within clinical environments. This app has been endorsed as the novel WHO VA testing application called WHOeyes.[21]

The aim of this study was to evaluate the usability and acceptability of the iOS version of WHOeyes VA testing system, by assessing its accuracy in determining the testing distance, and comparing its accuracy and repeatability with the gold standard ETDRS VA testing among subjects of different ages and vision statues.

Methods

Study Participants

Between August 1, 2021, and August 30, 2022, subjects were recruited from the Zhongshan Ophthalmic Center (ZOC), Guangzhou, China. Those who failed to provide informed consent, or with a history of mental diseases were not included. The included subjects were divided into three age groups: (1) children and adolescents (age ≤ 20 years) ; (2) young adults (age >20 and ≤40 years); (3) middle-aged and elderly individuals (age >40 years). Group 1 and 3 were tested within the context of our hospital's outpatient department. These participants were attending routine eye examinations which represents a direct application of the test in a healthcare setting. For the group 2, hospital staff and students were predominantly recruited, and the WHOeyes VA testing was conducted within their work and study spaces.

The present study received approval from the Institutional Review Board of

ZOC, China (No. 2021KYPJ104), and adhered to the tenets of the Helsinki Declaration. All participants provided written informed consent, while for participants under the age of 18 years, written informed consent was obtained from their legal guardians.

Testing protocol

The testing protocol of this study is presented in **Supplementary Figure 1**. In this study, participants underwent standardized distance and near VA testing using the ETDRS chart and WHOeyes on the same day by two ophthalmologists, one for ETDRS and one for WHOeyes. To reduce biases arising from memory and visual fatigue caused by the testing sequence, the sequence of ETDRS and WHOeyes testing for each participant was determined by a random number table generated by R software before the study. All participants were instructed to wear their habitual spectacles during the examination under the guidance of the ophthalmologist. During the WHOeyes testing, the testing distance was automatically determined by the ADC function, and the actual distance between the user and the mobile device was identified by another study personnel using an infrared rangefinder. A questionnaire interview was administered right after the VA tests by both methods.

ETDRS VA examination

An ETDRS tumbling E VA chart with external lighting (ESV3000TM; Precision Vision, Inc., Woodstock, IL) was used for distance VA testing at 4 meters, and a tumbling E ETDRS near VA card with a 40cm measuring cord (No. 728000; Precision Vision Inc.) was used for near VA testing. Before distance VA testing, the testing distance of 4m was measured by a laser rangefinder. Distance VA is assessed monocularly, with the right eye being tested first, followed by the left eye. An occluder was used to cover the eye not being tested. Near VA testing is performed binocularly. The ophthalmologist recorded the ETDRS VA testing results right after the test and no re-test was performed.

WHOeyes Test

WHOeyes has been globally launched and recommended by the WHO on World Sight Day in 2023.[21] Both the iOS and Android versions are available for free download. Instructions for using WHOeyes can be found in our previous research[17] and on the official WHO website.[22]

WHOeyes utilized the standard ETDRS-style tumbling E optotypes and design. A tutorial is shown on the WHOeyes homepage, providing visual instructions to guide users on the correct execution of the test. Instructions included properly aligning the device with the eyes, maximizing the device's brightness, and wearing habitual spectacles if any. Users are informed that an “E” optotype will be displayed in one of the four orientations (0, 90, 180, and 270) and instructed to swipe the screen in the direction indicated by the letter "E". In both distance and near VA testing, a single letter scoring method is used, and the initial displayed letter "E" represents a logMAR visual acuity of 1.0. A black bounding box is used to simulate the crowding effect of the ETDRS visual acuity chart, and the space between the letter "E" and the box is equal to half the size of the letter. The orientation of the letter "E" is randomly displayed to minimize the effects of memory and learning. The app employs a staircase algorithm to enhance testing efficiency, adjusting the size of the letter "E" based on the examinee's responses.

The ADC function is currently exclusive to the iOS version of WHOeyes and is not available on Android. This function enables automatic determination of whether the examinee has reached the correct testing distance (2m for distance VA and 40cm for near VA). For near VA testing, the examinee will be asked if they want to activate the 40cm calculation and informed that the camera of their iOS device is required to be activated to calculate the 40cm and the whole process will not record any data. If selecting yes by pressing the button on the screen, the examinee is informed that they should hold their mobile device at arm's length and slowly bring it closer until the bell sounds. When reaching 40cm (bell sounds), the app will directly jump to the interface asking the examinee to open both eyes and get ready for subsequent tumbling E optotype-based VA testing. During the use of the WHOeyes app, there are step-by-step instructions in the app indicating that a second person's assistance is required for the distance vision test, along with specific methods provided. In this study, a research assistant assumed this role. Distance VA is assessed monocularly, with the right eye being tested first, followed by the left eye, then the right eye was retested. Near VA is assessed binocularly twice.

In order to avoid the scenario where individuals might perceive normal vision results from an app-based test as an indicator that no further eye care is needed, potentially leading them to avoid necessary routine ophthalmic evaluations, we have included the following content in the installation disclaimer: "This application is for informational purposes, does not provide a medical diagnosis, and should not be used as a substitute for professional medical advice." Moreover, even if users obtain good vision results, such as 20/20, the system will prompt a cautionary message stating: "Although you have good vision, have your eyes checked regularly by an eye care professional. This is required because not all eye conditions immediately cause noticeable vision impairment.

Questionnaire

Upon completion of the VA testing, participants were asked to complete a brief questionnaire regarding their satisfaction with the WHOeyes system (**Supplementary File 1**). For participants under 18 years of age, the questionnaire was completed with the aid of the study personnel and their guardians.

Statistical analysis

Statistical analysis was conducted using GraphPad Prism (version 8; San Diego, California, US) and R (version 4.1.0; Auckland, New Zealand) software. All VA measurements were recorded in logMAR units, and the median (range) of VA measurements was reported, along with the percentage distribution of questionnaire responses for each population group. Performance of the ETDRS and WHOeyes were compared for both monocular distance VA and binocular near VA measurements. The test-retest reliability was calculated for the WHOeyes. Paired comparisons were made, and the mean difference in measured logMAR VA and 95% confidence interval (CI) were calculated, along with the 95% limit of agreement (LOA). A Bland Altman plot was used to demonstrate the consistency between ETDRS and WHOeyes in measuring distance and near VA in the three groups of participants. To account for fluctuations in VA measurements and systematic error bias, Cohen's quadratic weighted kappa (QWK) metric was utilized to assess the level of disagreement between testing methods. Furthermore, we presented the distribution of ADC data using a frequency histogram and performed a t-test to evaluate the difference between the measured distances of WHOeyes ADC and the actual distances measured by the infrared distance meter. The questionnaire results from different groups were analyzed using the Chi-square analysis. Statistical significance was set at p-values less than 0.05.

Results

A total of 220 participants (median age,18 years, range, 7-80 years, 41.8% male) were included in this study. Specifically, group 1 included 120 children and adolescents with a mean age of 10 years (range, 7-20 years), of whom 50.8% were female. Group 2 included 50 young adults with a median age of 26 years (range, 21-39 years), of whom 76.0% were female. Group 3 enrolled 50 middle-aged and elderly participants with a mean age of 63 years (range, 41-80 years), of whom 57.9% were female. Notably, the VA levels of the participants in these three groups spanned the full VA range, from logMAR 0.0 to 1.0. The distance and near logMAR VA of participants in these three groups showed a skewed distribution (**Supplementary figure 2**). Median logMAR distance VA in groups 1-3 was 0.2 (range, 0.1-1.0), 0.1 (range, 0.1-1.0), and 0.2 (range, 0.1-0.9) in the right eye, and 0.2 (range, 0.1-1.0), 0.1 (range, 0.1-1.0), and 0.2 (range, 0.1-0.9) in the left eye, respectively.

Figure 1 illustrates the actual testing distances determined by the WHOeyes ADC as compared to the standard testing distance (distance 2m; near 40cm) in each group. The distances measured by the ADC closely aligned with the standard testing distance. The median distance for near VA testing was 41.0 cm (range: 35.6-46.4 cm), and for distance VA testing, it was 1.96 m (range: 1.73-2.29 m). No significant difference was identified between the actual and standard testing distances ($p > 0.50$)

in all groups. Based on the following formula: L'=L-lgd'/d (L': standard VA value, L: actual VA value, d': actual distance, d: standard distance), we calculated that the VA would exceed one line on the ETDRS chart (i.e., an error greater than 0.1 logMAR) only when the actual testing distance determined by ADC was beyond 2.52m or below 1.58m for distance VA testing, and beyond 50.4cm or below 31.6cm for near VA testing. All the actual measured distances determined by the ADC in this study were within the range of 1.58-2.52m or 31.6-50.4cm.

Table 1 shows the pairwise comparison of ETDRS and WHOeyes in measuring distance and near VA. For distance VA in the right eye, the mean difference was -0.079 (95% CI: -0.103 to -0.055) logMAR for group1, -0.032 (-0.072 to 0.008) logMAR for the group 2 and -0.028 (-0.066 to 0.010) logMAR for the group 3. Similar differences were also observed for the left eye. For near VA testing, there was a mean difference of -0.025 (95% CI: -0.040 to -0.010) logMAR for group 1, 0.010 (-0.014 to 0.034) logMAR for group 2 and 0.012 (-0.022 to 0.046) logMAR for the group 3. In both near and distance VA testing, the 95% LOA ranged from -0.34 to 0.25, and the QWK were all greater than 0.75 across three groups. The agreement and discrepancy between ETDRS and WHOeyes in measuring distance and near VA testing in the three different age groups was shown in the Bland Altman plots (**Figure 2**). In both distance and near VA testing of WHOeyes across the three groups, the mean difference of test-retest was close to zero, indicating WHOeyes had excellent repeatability and consistent results in VA testing (**Table 1**). In addition, the 95% LOA ranged from -0.25 to 0.25, and the QWK were all greater than 0.90.

The questionnaire survey revealed that more than half of the participants preferred WHOeyes to ETDRS for VA testing, and would like to use WHOeyes again (**Figure 3, Q1-2**). Notably, the ADC function was highly rated by users, with over 70% of participants agreeing that it made VA testing more convenient (**Figure 3, Q3**). The majority of participants demonstrating a high level of trust in its results and willingness to recommend its use to others (**Figure 3, Q4-5**). More than half of users are subjectively satisfied with WHOeyes (**Figure 3, Q6**). Overall, the adult and elderly groups exhibited slightly higher acceptance rates and trust in WHOeyes compared to the adolescent and child groups, although these differences did not reach statistical significance.

Discussion

Traditionally, interventions aimed at improving awareness and education in the field of eye care have received little attention. A key WHO recommendation in the World report on vision (2019) is to strengthen general awareness and demand for eye care services. There is a strong rationale for this given the majority of cases of vision impairment and blindness can be prevented through early detection and timely management. The widespread adoption and improved portability of mobile devices have presented promising prospects for the development of mobile device-based VA assessments,[10 23 24] which hold the potential to greatly improve the accessibility and affordability of VA testing.[16 25] Nevertheless, the accuracy of VA testing applications may be affected by various factors, including mobile device resolution, quality, and environmental conditions,[26] and it was crucial to further validate and optimize the accuracy and convenience of these mobile device-based VA tests before widespread adoption. In this study, we developed and validated a mobile device-based app with ADC function (WHOeyes) which showed comparable testing accuracy in reference to the gold standard ETDRS chart method and also an excellent test-retest reliability.

Traditionally, the testing distance of VA measurement needs to be set using a ruler, measuring tape or laser device, which may not be available in many households, reducing individuals' willingness to have their vision tested using a mobile device at home. A key benefit of the WHOeyes is the ADC function in its iOS version, making it more convenient and accessible for diverse settings, especially in resource-limited areas. In this study, we found that the ADC-identified testing distance by WHOeyes showed good agreement compared to the standard distance measurement. It should also be noted that the ADC distance calibration performance of the WHOeyes was similar in participants of all age groups, suggesting wide applicability. In comparison to our previously reported V@home, the addition of the ADC function in the

WHOeyes has only resulted in a slight change in the mean difference with ETDRS.[17] For example, in the distance VA testing of the right eye in the young adult group, the mean difference with ETDRS was -0.010 (-0.045 to 0.025) compared to V@home, and -0.032 (-0.072 to 0.008) compared to WHOeyes. The questionnaire survey also indicated that over 70% of the participants favored the convenience of the automatic testing distance calibration function of WHOeyes. Hence, the addition of the ADC function in WHOeyes made it more convenient and user-friendly, without compromising the reliability of VA testing.

As a self-assessment tool that provides immediate feedback on their VA, the app can empower patients to take an active role in managing their eye health, enhancing general awareness and demand for eye care. Moreover, WHOeyes can serve as a valuable tool for teleophthalmology consultations. The app's ability to provide accurate VA measurements enables ophthalmologists to make informed clinical decisions from a distance. This can be particularly beneficial for monitoring chronic ophthalmic conditions, such as diabetic retinopathy or age-related macular degeneration, where regular follow-ups are necessary to assess disease progression or treatment efficacy. The scalability of WHOeyes offers the potential to reach a wider demographic, including underserved populations who may have previously been excluded from traditional eye care services. This aligns with the WHO's vision of universal eye health coverage and can contribute to reducing the global burden of preventable blindness.

WHOeyes employed a patented method that uses the front-facing camera to assess the testing distance. The observed variations of testing distance in our study may be explained by several factors, including position and angle of the head, user-initiated movements, and speed of movement during the test, among others. Additionally, since the near vision test is self-administered, examiner variability during the measurement process can also be a source of variance. These factors underline the importance of ongoing refinement in the development of the ADC function, addressing these variables for improved accuracy in real-world scenarios.

To be readily applicable to a broader population, a mobile device-based VA testing app needs to have a range of characteristics in addition to good accuracy and reliability, including a minimum requirement on resources (human, space, materials etc.), and it should ensure readability and accessibility for individuals of diverse backgrounds and statuses (different age, education, health status, vision status etc.).[27] We believe that mobile device-based VA tests could still benefit from further improvement in this regard. Jiang at al. developed an automated calibration system for length measurement of lateral cephalometry based on deep learning and showed high potential for clinical application.[28] It is believed that with the advancement of artificial intelligence and further research, mobile intelligent VA testing devices can be deployed for widespread medical purposes in the future. In addition, similar to other VA testing softwares,[29] WHOeyes requires the assistance of a second person to determine the measurement distance and slide the E-letter on the screen during distance VA testing. Further development of an intelligent voice system holds the potential to enable people to perform VA examinations independently.

Key strengths of this study include the inclusion of participants of different ages, the randomized testing sequence, and VA assessments performed on the same day by different ophthalmologists who were masked to the testing result of the other method to minimize bias. Some limitations need to be noted. Firstly, WHOeyes had the inherent limitations of the inability to measure VA poorer than 1.0 logMAR, and was only designed to measure VA and no other visual functions. Secondly, the ADC function of WHOeyes is currently only available in the iOS version. The Android version of WHOeyes is essentially identical to V@home, with performance and user experience detailed in our previous study.[17] Due to significant variations in camera software and hardware among numerous Android devices, further exploration is needed to develop a compatible ADC function for Android devices. Thirdly, we only tested the performance of WHOeyes using an iPhone 8 at one hospital under the aid of a trained ophthalmologist, the feasibility of using this APP for VA tests by patients themselves at home and based on other devices still requires further investigation.

Conclusion

In conclusion, with the wide and growing availability of mobile devices and internet access, individuals and health care practitioners could benefit significantly from smartphone-based eye care services, especially in lower resource areas with limited eye care personnel and services. The WHOeyes intends to improve population and awareness and demand for eye care, by offering a simple tool for individuals in the population to check their near and distance vision and to learn how they can protect their eyes. Regardless of whether vision impairment is identified, WHOeyes encourages all users to have regular eye examinations, which could serve as a potentially useful tool to improve access to eye care and uptake of necessary ophthalmic services globally.

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Figure legends

Figure 1. The frequency distribution histogram of actual distance identified by ADC in three ZOC groups. The three lines from top to bottom represent adolescent, adult and elderly cohort. First and second column shows the frequency distribution of actual distance for distance and near VA measurements, respectively. The p-values indicate the level of significance between actual distance and standard distance.
ADC: automatic distance calibration; ZOC: Zhongshan Ophthalmic Center;
VA: visual acuity.

Figure 2. Bland Altman plot of VA measurements by the ETDRS and WHOeyes method in three ZOC groups. The three lines from top to bottom represent adolescent, adult and elderly cohort. The leftmost column displays distance VA measurements in the right eye, followed by distance VA measurements in the left eye in the middle column, and binocular near VA in the rightmost column. The black dashed line represents the mean difference between the two methods, while the gray dashed line represents the 95% CI of the bias. The red dashed line represents the 95% CI of the difference in VA measurements.
VA: visual acuity; ETDRS: Early Treatment Diabetic Retinopathy Study; ZOC: Zhongshan Ophthalmic Center; CI: confidence interval.

Figure 3. The stack percentage charts show participants' feedback on WHOeyes based on questionnaire interview. There are five questions: question 1 (which method do you prefer for vision testing?), question 2 (how likely would you be to use WHOeyes again?), question 3 (do you agree that the WHOeyes system with automatic distance calibration is more convenient than the traditional method of ETDRS?), question 4 (do you trust the test results of WHOeyes system?), question 5 (would you recommend the WHOeyes system to a friend?), question 6 (how satisfied are you with the WHOeyes testing system?). The options for each question are displayed in the legend to the right of each stack percentage chart.
ETDRS: Early Treatment Diabetic Retinopathy Study

Supplementary figure 1. Flow diagram of VA testing in this study.

VA: visual acuity; ETDRS: Early Treatment Diabetic Retinopathy Study; ADC: automatic distance calibration.

Supplementary figure 2. The frequency distribution histogram of VA measurements by the ETDRS method in three ZOC groups. The three lines from top to bottom represent adolescent, adult and elderly cohort. The leftmost column displays distance VA measurements in the right eye, followed by distance VA measurements in the left eye in the middle column, and binocular near VA in the rightmost column.

VA: visual acuity; ETDRS: Early Treatment Diabetic Retinopathy Study; ZOC: Zhongshan Ophthalmic Center.

Supplementary file 1. Questionnaire for Participants.

ETDRS: Early Treatment Diabetic Retinopathy Stud

551 **Table 1. Pairwise Comparisons of ETDRS and WHOeyes in Distance and Near VA testing.**

Population	Comparison	Mean Difference (95% CI)	95% LOA	QWK (95% CI)
Group 1* (n=120)	Distance VA: ETDRS vs. WHOeyes right eye	-0.079 (-0.103 to -0.055)	-0.337 to 0.179	0.852 (0.792-0.912)
	Distance VA: ETDRS vs. WHOeyes left eye	-0.084 (-0.109 to -0.060)	-0.351 to 0.182	0.828 (0.764-0.892)
	Distance WHOeyes test-retest	0.000 (-0.022 to 0.022)	-0.241 to 0.241	0.914 (0.871-0.957)
	Near ETDRS vs. WHOeyes	-0.025 (-0.040 to -0.010)	-0.186 to 0.136	0.751 (0.611-0.890)
	Near WHOeyes test-retest	-0.015 (-0.027 to -0.003)	-0.141 to 0.111	0.858 (0.752-0.965)
Group 2** (n=50)	Distance ETDRS vs. WHOeyes right eye	-0.032 (-0.072 to 0.008)	-0.305 to 0.241	0.906 (0.829-0.983)
	Distance ETDRS vs. WHOeyes left eye	-0.044 (-0.082 to -0.006)	-0.307 to 0.219	0.917 (0.866-0.968)
	Distance WHOeyes test-retest	0.004 (-0.032 to 0.040)	-0.243 to 0.251	0.929 (0.860-0.998)
	Near ETDRS vs. WHOeyes	0.010 (-0.014 to 0.034)	-0.154 to 0.174	0.842 (0.737-0.948)
	Near WHOeyes test-retest	0.000 (-0.008 to 0.008)	-0.056 to 0.056	0.973 (0.956-0.990)
Group 3*** (n=50)	Distance ETDRS vs. WHOeyes right eye	-0.028 (-0.066 to 0.010)	-0.291 to 0.235	0.843 (0.769-0.917)
	Distance ETDRS vs. WHOeyes left eye	-0.022 (-0.054 to 0.010)	-0.244 to 0.200	0.908 (0.871-0.944)
	Distance WHOeyes test-retest	-0.040 (-0.069 to -0.011)	-0.238 to 0.158	0.901 (0.832-0.971)
	Near ETDRS vs. WHOeyes	0.012 (-0.022 to 0.046)	-0.221 to 0.245	0.834 (0.750-0.918)
	Near WHOeyes test-retest	0.004 (-0.019 to 0.027)	-0.154 to 0.162	0.923 (0.869-0.978)

552 *Group 1: children and adolescents below 20 years old; **Group 2: young adults aged 20-40 years old; ***Group3: middle-aged and elderly individuals over 40 years old.
553 ETDRS: Early Treatment Diabetic Retinopathy Study; WHO: World Heath Organization; VA:visual acuity; CI: confidence interval; LOA:limit of agreement;
554 QWK: quadratic weighted kappa