PEEK ACUITY AS AN ALTERNATIVE METHOD FOR VISUAL ACUITY MEASUREMENT FOR VISION SCREENING IN CHILDREN

AMIRUL ASRAF MOHD NOORDIN, *B.Optom (Hons.)*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
amirulash29@gmail.com

MOHD ZULFAEZAL CHE AZEMIN, *PhD.*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
zulfaezal@iium.edu.my

ARNI MUSA, *B.Optom (Hons.)*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
arni@iium.edu.my

MUHAMMAD AFZAM SHAH ABDUL RAHIM, *PhD.*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
afzamshah@iium.edu.my

NOOR WAFIRAH SHAFEE, *PhD.*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
wafirah@iium.edu.my

NORSHAM AHMAD, *PhD.*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
ansham@iium.edu.my

MD MUSTAFA MD-MUZIMAN-SYAH, *DPhil (Optom).*
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
syah@iium.edu.my

FIRDAUS YUSOF, *PhD.* (CORRESPONDING AUTHOR)
DEPARTMENT OF OPTOMETRY AND VISUAL SCIENCE, KULLIYYAH OF ALLIED HEALTH SCIENCES, INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA, JLN SULTAN AHMAD SHAH BANDAR INDERA MAHKOTA 25200 KUANTAN, PAHANG, MALAYSIA
yfirdaus@iium.edu.my

ABSTRACT

Introduction: Accurate and reliable clinical measurement of visual acuity (VA) is necessary to establish the needs for further clinical investigations. A simpler option for VA measurement is the use of smartphones, in which the measurement method is programmed in an application that enables automated and self-administered VA testing. **Aims:** This study aimed to investigate the validity of PEEK Acuity (PA), a smartphone's application for VA measurement, in testing children's vision, especially for vision screening programs. **Methodology:** Data were obtained from a vision screening program involving children aged 3–13 years. One hundred thirteen participants were included in the study (mean age 7.47±2.33 years old, 59 boys). The participants' VA was measured using the PA and Snellen chart in random order. Both eyes were tested, with 226 data points used in the statistical analysis. The Kolmogorov-Smirnov test revealed non-normal data. The VA between the PA and Snellen tests was compared using the Wilcoxon signed rank test. Test-retest variability was calculated for both tests using intraclass correlation (ICC) analysis. Spearman's rank correlation and the Bland-Altmann test were plotted to evaluate the agreement between tests. **Results:** The mean VA recorded using PA was 0.066±0.007 logMAR, while that recorded using Snellen was 0.103±0.009 logMAR ($z=-4.119$, $p<0.0005$, Wilcoxon signed rank test; ≈ two-letter differences). The ICC between the PA and Snellen was 0.641. Spearman's rank correlation revealed a significant correlation between PA and Snellen ($r=0.508$, $p<0.001$). **Conclusion:** There was a moderate correlation between the PA and Snellen scores. The PA application showed good agreement with conventional Snellen. Thus, smartphone applications such as PA may serve as an alternative to measure VA in children, especially in vision screening programs.

KEYWORDS: Visual Acuity, PEEK Acuity, Children's Vision, Vision Screening

INTRODUCTION

Visual impairment drastically affects a person's life, resulting in functional and psychological problems. Visual impairment lowers productivity, raises healthcare costs, and slows a country's economic growth (Wang et. al., 2014; Armstrong et al., 2012). More than two billion people have distance or near vision problems, with more than one billion being preventable with early detection (Flaxman et al., 2017). Clinically, the most important step in identifying visual problems may be the measurement of visual acuity (VA).

VA is the most common, yet the most important, visual function test performed on patients. VA measurements should be reliable and accurate, as VA is usually used to establish the need for further clinical investigations. The Snellen acuity chart was developed in the early 1860s and remains the most commonly used chart in clinical practice (Bailey et al., 2013). Nevertheless, the Snellen chart suffers from problems such as variable contour interaction, which affects the accuracy of threshold determination (Lovie-Kitchin, 2015). Although the Snellen chart may be lacking in optical inconsistency, it is arguably the most widely used because of its accessibility in hospitals and primary care settings and the degree of familiarity among clinicians (Perera et al., 2015). The Early Treatment Diabetic Retinopathy Study (ETDRS) acuity chart may provide a better VA measurement by overcoming Snellen's limitations. Despite the accuracy of the ETDRS chart, its cost, larger chart size, longer testing time, and longer testing distance may reduce its use in clinical settings (Lovie-Kitchin, 2015; Han et al., 2019). Both Snellen and EDTRS acuity testing require trained personnel to administer the tests. The need for a better acuity test that improves convenience, cost, and accuracy is important for tackling visual problems and preventing visual impairment and irreversible blindness (Bastawrous et. al., 2015; Siktberg et al., 2021).

Conventional VA testing may require patients to be in a clinic with highly trained personnel to perform the test. These become barriers for testing VA in screening programs and testing vulnerable patients such as children, the elderly, indigenous people, and those with impaired mobility. A promising approach to address this issue is to use mobile smartphones. Advancements in smartphone technology have enabled its application in medical practice (Perera et al., 2015). Being a staple technology in modern life, smartphones are accessible to many. VA testing applications in smartphones allow self-

administered testing, which improves accessibility and provides a solution to the aforementioned barriers.

There are a few vision-testing applications available, but PEEK Acuity (PA; Peek Vision Ltd, United Kingdom) has gained credible coverage in the literature (Han et al., 2019; Bastawrous et al., 2015; de Venecia et al., 2018). Nevertheless, the accuracy of this application, especially in its clinical use in children, has yet to be reported. In this study, we sought to identify the reliability of PA and establish its agreement with the conventional Snellen acuity chart, on testing children especially for vision screening programs.

METHODOLOGY

This cross-sectional retrospective study used data obtained from a mass health screening program on children in the Kuantan Pahang vicinity. The study was approved by the IIUM Research Ethics Committee (IREC No. KAHS 77/22). All guardians provided consent for the use of the data in this study.

Participants

A total of 113 participants (59 boys, 54 girls) were included in this study. The participants' age varies between three and 13 years, with a mean age of 7.47±2.33 years old. Both eyes were measured and used as data points. None of the participants had profound visual impairment and none were categorized as having low vision. The inclusion criterion was the ability of participants to comprehend instructions involving VA testing, whereas the exclusion criterion was any vision screening participants with missing data.

Visual Acuity Testing

The PA application is installed on various smartphones owned by multiple visual screeners. The screen brightness was set to 100% during testing. The PA follows the standard EDTRS chart design with a 5×5 grid optotype letter E displayed in one of four orientations (90°, 180°, 270°, and 360°) of varied sizes. The participants were given an "E" shaped cardboard to aid them in showing the direction of the E limb displayed on the phone screen. The visual screener held the smartphone two meters from the participant. The visual screener slid the smartphone's screen in the direction of the participant's response without looking at the screen to eliminate bias. This was done to reduce any verbal and nonverbal clues from the screeners, which may have biased the results. PA results were standardized to logMAR units. The test completion was indicated by sound and vibration alerts. All the instructions given to the participants were based on the directions provided by the application developer.

Snellen VA measurements were performed at a six-meter distance. The results were recorded as imperial Snellen units and converted to logMAR values. The conversion was conducted using the Snellen to logMAR calculator and by the Visual Impairment Network for Children & Young People (VINCYP) under the National Health Services (NHS) Scotland (NHS Scotland, 2022).

For all visual acuity tests, the presenting acuity was measured as habitual VA, with correction if worn. Participants were tested one eye at a time. The order of the tests (PA and Snellen) was not standardized. The tests were strictly performed or supervised by optometrists to ensure their precision and accuracy.

Statistical Analysis

Statistical analysis was conducted using IBM Statistical Package for Social Science Software (SPSS) (version 20.0; IBM Corp., Armonk, NY, USA). The normality of the data was investigated using the Kolmogorov-Smirnov test. Data were deemed non-normal; thus, non-parametric tests were used to evaluate the data. The mean and standard error of the VA for each method are reported. Acuity results

from PA and Snellen were compared using the Wilcoxon signed rank test. The validity of acuity between PA and Snellen was analyzed using the intraclass correlation coefficient (ICC) test. The test-retest variability of both methods was also calculated. Spearman's rank correlation coefficient was calculated to determine the agreement between PA and Snellen acuity. The Bland-Altman plot was used to demonstrate the consistency between PA and Snellen acuity. The significance level was set at $\alpha \leq 0.05$ (95%).

RESULT

The mean VA using PA was recorded as 0.066±0.007 log, while that using Snellen was 0.103±0.009 log (z=-4.119, p<0.0005, Wilcoxon signed rank test) (Table 1). Although the analysis showed a significant difference, the mean PA and Snellen VAs differed by approximately two logMAR letters only.

Table 1. Mean and standard deviation values of the PA and Snellen tests. The p value was indicated as significantly different and was calculated using the Wilcoxon signed rank test.

	PA (n = 266)	Snellen (n = 266)	z, p
VA (logMAR)	0.066±0.007	0.103±0.009	z=-4.119, p<0.0005

ICC analysis between PA and Snellen acuity yielded a coefficient value of 0.641 (95%CI:0.518–0.731, p < 0.001), indicating moderate reliability between the two tests. The Bland-Altman analysis indicated good agreement between the tests, with most data points concentrated within the 95% limit of agreement (LoA) (Figure 1). The logMAR acuity differences between PA and the Snellen chart are clinically acceptable for screening purposes as they lie within +0.037 logMAR (denoting a difference of about two acuity letters only).

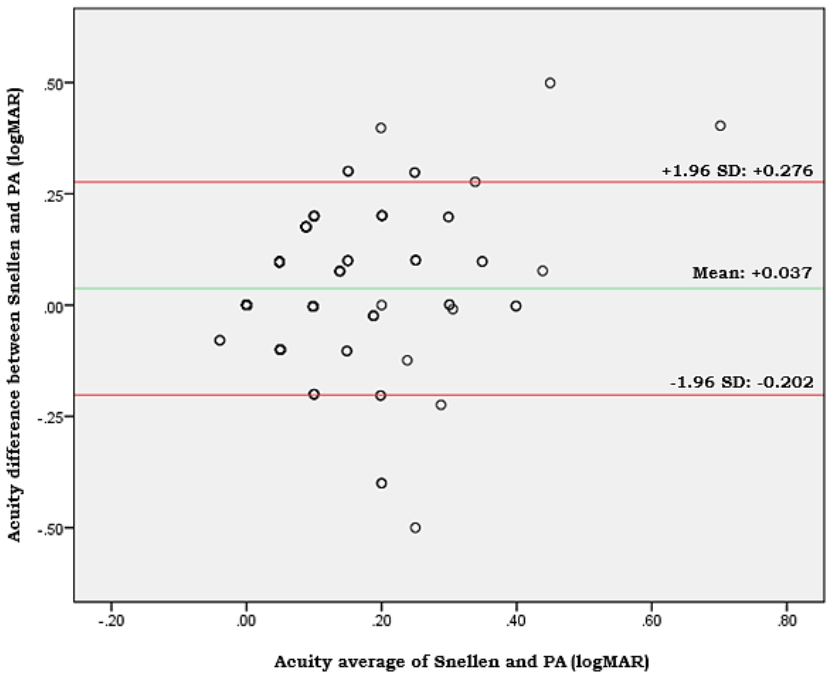

Figure 1 - Bland–Altman plot analysis of the agreement between PEEK Acuity (PA) and Snellen acuity. The y-axis marks the visual acuity differences between PA and Snellen acuity and the x-axis marks the acuity means of both tests.

The relationship between acuities yielded by PA and Snellen is shown in Figure 2. Spearman's rank correlation coefficient analysis revealed an r_s value of 0.508 ($p<0.001$), indicating a moderate positive correlation between Snellen and PA.

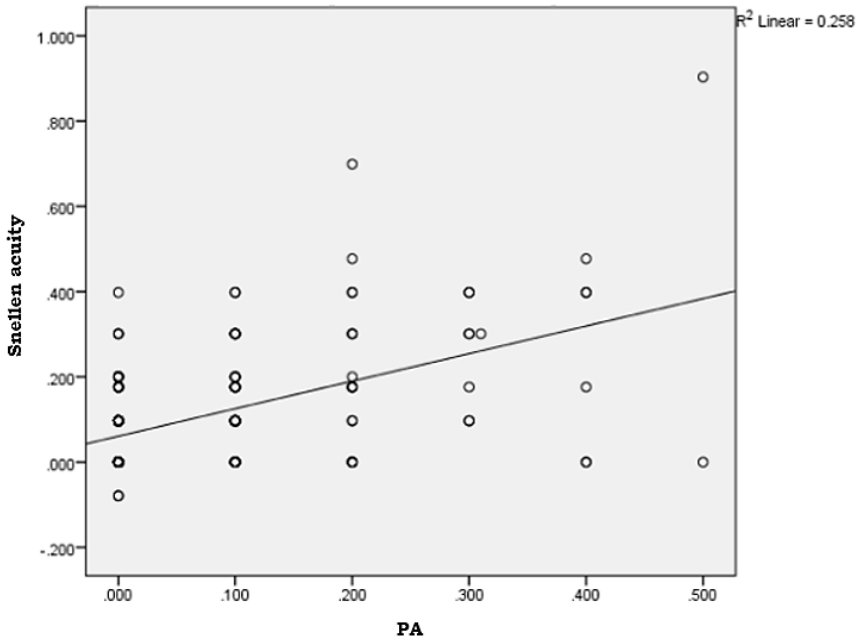

Figure 2 Spearman's rank correlation plot analyzing the agreement between the PA and Snellen acuity tests. An r-value of 0.508 indicated a moderate positive correlation between the tests.

DISCUSSION

The ubiquity of smartphones in modern life and their widespread use offers healthcare professionals an opportunity to improve the measurement of health-related outcomes. VA measurement using smartphone technology has proven its many benefits, particularly in low clinical settings, for communities that require testing and monitoring of their VA (Bert et al., 2014; Bastawrous et al., 2013). Many vision-testing applications are currently available, but only a few have been validated. Determining the accuracy, for instance, the self-testing VA application, is crucial because unreliable and inaccurate measurements may result in improper management and treatment of ocular disorders (Brady et al., 2015; Han et al., 2015).

This study aimed to test the reliability of the smartphone application PA to conventional Snellen acuity in testing children's VA. The VA obtained from the PA application was significantly better than that obtained using the Snellen acuity test (Table 1). VA obtained using PA seemed to yield better results than those obtained using the conventional Snellen test, albeit only by 0.038 logMAR. Even though the analysis indicated a significant difference, the 0.038 logMAR value only amounted to approximately two logMAR letters, which is arguably not clinically significant. External factors include illumination, contrast, glare, nature of the test object, distance, size of the retinal image, and visual efficiency (Lebensohn et al., 1993). Any ill-fitting factor could result in inaccurate VA measurements. For example, the acuity testing using the Snellen chart conducted in this study was using a printed version of the test. Such a setup is simple and probably ideal for vision screening purposes but may be lacking in illumination, resulting in a lower acuity response.

It is important to note that the findings of this study are in line with other studies in literature. It has been reported that PA tends to overestimate VA compared with other VA tests (Rono et al., 2018; de Venecia et al., 2018; Zhao et al., 2019). Overestimation of VA may result in higher acuity that may mask visual concern. Rono et al. (2018) reported a lower specificity using PA compared to the conventional Snellen tests, which resonated with the overestimation of patients' VA. de Venecia et al. (2018) in their

studies only reported a 48% sensitivity and 83% specificity, while Zhao et al. (2019) reported an average sensitivity and specificity of 80% and 96%, respectively. These two studies also indicated an overestimation of VA when using PA. Care must be taken when deciphering the results of PA to ensure the best management of a patient.

The ICC value with a 95% confidence interval has a value range of 0 to 1 and is divided into 4 value categories; (i) values below 0.5 indicate low reliability, (ii) between 0.5 to 0.75 suggest moderate reliability, (iii) between 0.75 to 0.9 indicates good reliability, and (iv) above 0.9 indicates exceptional reliability (Koo & Li, 2016). The ICC results of the current study indicate that PA and Snellen acuity tests have an inter-reliability of 0.641 (95% CI:0.518 – 0.731), which falls under the category of moderate reliability. Bastawrous et al. (2015) and Brady et al. (2015), who tested PA application against the ETDRS chart, concluded that there was a high degree of correlation between the two methods (95% CI, 0.05-0.10; p =0.08). In addition, Irawati et al. (2020) tested PA against the Snellen chart in participants who had leprosy. They concluded that PA is a reliable and repeatable screening tool that is as useful as the Snellen chart.

The agreement between the PA and Snellen tests was also investigated using the Bland–Altman plot. The VA measurement by these tests was consistent with one another, considering that the data points were mostly concentrated within the 95% of LoA (between +0.276 and -0.202 logMAR) and most were clustered near the mean difference value of 0.037. Spearman's rank correlation analysis indicated a significant positive correlation between the acuity results obtained using the tests (r_s =0.58, p<0.001). The results of the current study are consistent with those of Bastawrous et al. (2015), who demonstrated a much stronger correlation between tests. Although they separated their analysis according to the location of the test being conducted, both tests showed an r (at clinic) of 0.950 (p=0.08) and r (at home) of 0.902 (p=0.08). Their mean difference recorded were -0.078 log MAR (95% CI; -0.100 to -0.056) and 0.029 logMAR (95% CI; -0.007 to 0.065) for tests conducted at clinic and home, respectively.

Limitations of the Study

The current study had several limitations which warrant considerations in future studies. Firstly, the smartphones were not standardized in measuring the VA using PA. The screen projection by different smartphones may not be similar where it may affect image resolutions, and acuity responses (Han et al., 2019). Secondly, the participants of young children age ranged from three to 13 years old may yield different responses during the testing. Factors including cognitive level and test surrounding may have an impact on the VA results (Salthouse et al., 1996). Thirdly, the current study used the Snellen chart as opposed to a more standardized logMAR EDTRS chart. As the data were collected during a vision screening, employing EDTRS chart was not feasible as the test consumes more time for a vision screening. The Snellen test may be lacking in accuracy (Lovie-Kitchin, 2015), yet its usage in clinics is universal. Considering Snellen's popularity in a clinical setting, it is imperative to benchmark the PA application to Snellen.

Implications of the Study

The result of this study shows the feasibility of smartphone-based VA testing, specifically the PA, for use in vision screening programs. Care should be given in interpreting the VA obtained in children where overestimations may occur. The performance of PA in older patients is likely better based on the literature (Brady et al., 2015; Irawati et al., 2020) yet needs to be elucidated given the population and surroundings.

The ability to assess VA using smartphones is a game changer, especially given the alarming prevalence of myopia among younger generations and the rapidly growing elderly populations (Holden et al., 2016; Chew et al., 2018). With the availability of smartphones globally, such important vision tests can be self-administered at a meager cost, which in turn helps to reduce visual impairment (Free et al., 2013). Especially in settings where ophthalmic instrumentation or ophthalmic training is limited, the ability to reliably measure vision may improve the vision testing assessment in routine clinical practice.

Vision screening programs can be conducted easily with the availability of smartphones, and may also be conducted by untrained screeners (Siktberg et al., 2021).

CONCLUSION

The PA application in smartphones shows a promising potential to be used for visual screening on children, albeit the moderate agreement with the Snellen acuity test. The PA may yield a slightly better VA result relative to the Snellen acuity test. Yet, the simplicity, low cost, and quick testing may favor its usage in screening children's vision.

REFERENCE

Armstrong, K. L., Jovic, M., Vo-Phuoc, J. L., Thorpe, J. G., & Doolan, B. L. (2012). The global cost of eliminating avoidable blindness. Indian Journal of Ophthalmology, 60(5), 475.

Bailey, I. L., & Lovie-Kitchin, J. E. (2013). Visual acuity testing. From the laboratory to the clinic. Vision research, 90, 2-9.

Bastawrous, A., & Armstrong, M. J. (2013). Mobile health use in low-and high-income countries: an overview of the peer-reviewed literature. Journal of the Royal Society of Medicine, 106(4), 130-142.

Bastawrous, A., Rono, H. K., Livingstone, I. A., Weiss, H. A., Jordan, S., Kuper, H., & Burton, M. J. (2015). Development and validation of a smartphone-based visual acuity test (peek acuity) for clinical practice and community-based fieldwork. JAMA Ophthalmology, 133(8), 930-937.

Bert, F., Giacometti, M., Gualano, M. R., & Siliquini, R. (2014). Smartphones and health promotion: a review of the evidence. Journal of Medical Systems, 38, 1-11.

de Venecia, B., Bradfield, Y., Trane, R. M., Bareiro, A., & Scalamogna, M. (2018). Validation of Peek Acuity application in pediatric screening programs in Paraguay. International Journal of Ophthalmology, 11(8), 1384.

Brady, C. J., Eghrari, A. O., & Labrique, A. B. (2015). Smartphone-based visual acuity measurement for screening and clinical assessment. Jama, 314(24), 2682-2683.

Chew, F. L., Salowi, M. A., Mustari, Z., Husni, M. A., Hussein, E., Adnan, T. H., ... & Goh, P. P. (2018). Estimates of visual impairment and its causes from the National Eye Survey in Malaysia (NESII). PloS one, 13(6), e0198799.

Flaxman, S. R., Bourne, R. R., Resnikoff, S., Ackland, P., Braithwaite, T., Cicinelli, M. V., ... & Zheng, Y. (2017). Global causes of blindness and distance vision impairment 1990–2020: a systematic review and meta-analysis. The Lancet Global Health, 5(12), e1221-e1234.

Free, C., Phillips, G., Watson, L., Galli, L., Felix, L., Edwards, P., ... & Haines, A. (2013). The effectiveness of mobile-health technologies to improve health care service delivery processes: a systematic review and meta-analysis. PLoS medicine, 10(1), e1001363.

Han, X., Scheetz, J., Keel, S., Liao, C., Liu, C., Jiang, Y., ... & He, M. (2019). Development and validation of a smartphone-based visual acuity test (vision at home). Translational Vision Science & Technology, 8(4), 27-27.

Holden, B. A., Fricke, T. R., Wilson, D. A., Jong, M., Naidoo, K. S., Sankaridurg, P., ... & Resnikoff, S. (2016). Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. Ophthalmology, 123(5), 1036-1042.

Irawati, Y., Bani, A. P., Gabriella, K., Fitriana, A., Paramita, C., Susiyanti, M., ... & Lestari, Y. D. (2020). Peek Acuity vs Snellen Chart for visual impairment screening in leprosy: A cross-sectional study. Leprosy Review, 91(3), 262-273.

Koo, T. K., & Li, M. Y. (2000). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med. 2016; 15 (2): 155–63.

Lebensohn, J. E. (1933). Factors in the determination and interpretation of visual acuity. Archives of Ophthalmology, 10(1), 103-109.

Lovie-Kitchin, J. E. (2015). Is it time to confine Snellen charts to the annals of history? Ophthalmic and Physiological Optics, 35(6), 631-636.

NHS Scotland. (2022). JT LogMAR Calculator. Retrieved from https://www.vincyp.scot.nhs.uk/wp-content/uploads/2022/11/20150513-JT-logmar-calculator-VINCYP.xls on 16 September 2023.

Perera, C., Chakrabarti, R., Islam, F. M. A., & Crowston, J. (2015). The Eye Phone Study: reliability and accuracy of assessing Snellen visual acuity using smartphone technology. Eye, 29(7), 888-894.

Rono, H. K., Bastawrous, A., Macleod, D., Wanjala, E., Di Tanna, G. L., Weiss, H. A., & Burton, M. J. (2018). Smartphone-based screening for visual impairment in Kenyan school children: a cluster randomised controlled trial. The Lancet Global Health, 6(8), e924-e932.

Salthouse, T. A., Hancock, H. E., Meinz, E. J., & Hambrick, D. Z. (1996). Interrelations of age, visual acuity, and cognitive functioning. The Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 51(6), P317-330.

Siktberg, J., Hamdan, S., Liu, Y., Chen, Q., Donahue, S. P., Patel, S. N., ... & Gangaputra, S. S. (2021). Validation of a standardized home visual acuity test for teleophthalmology. Ophthalmology Science, 1(1), 100007.

Wang, X., Lamoureux, E., Zheng, Y., Ang, M., Wong, T. Y., & Luo, N. (2014). Health burden associated with visual impairment in Singapore: the Singapore epidemiology of eye disease study. Ophthalmology, 121(9), 1837-1842.

Zhao, L., Stinnett, S. S., & Prakalapakorn, S. G. (2019). Visual acuity assessment and vision screening using a novel smartphone application. The Journal of Pediatrics, 213, 203-210.