Parents' performance using the AAPOS Vision Screening App to test visual acuity in Malaysian preschoolers

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PURPOSE To evaluate parents' performance in using the American Association for Pediatric Ophthalmology and Strabismus (AAPOS) Vision Screening App (application) as a vision screening tool among preschool children and to evaluate the reliability of this app.

METHODS A total of 195 5- and 6-year-old preschoolers were recruited from children attending Hospital Selayang, Selangor, Malaysia, to test the app. Uncooperative children and those with visual acuity of >logMAR 0.6 were excluded. Results from parents and the screening doctor using the app (Lea symbols) to test visual acuity were compared to each other and to gold standard vision testing by an optometrist using the Lea symbols chart.

RESULTS Children 5 years of age represented 46.7% of the study population. The mean age of parents was 37.27 ± 7.68 years. Bland-Altman scatterplot agreement between assessors mainly was within the 95% confidence interval for bilateral eyes screening. Parents obtained a sensitivity of 86.6% (right vision) and 79.5% (left vision) and specificity of 78.9% (right vision) and 71.8% (left vision). Parents took a mean of 191.2 ± 70.82 seconds for bilateral screening. The intraclass correlation coefficient between optometrist and parents in bilateral eyes screening was good ($P < 0.001$). Cronbach's α for all three assessors was >0.7, indicating high internal reliability of the app. Most parents (178/195 [91.3%]) strongly agreed on the app's acceptability and ease of use.

CONCLUSIONS The AAPOS Vision Screening App used by parents is a promising tool for visual acuity screening among Malaysian preschool children and a reliable app for vision screening. (J AAPOS 2019;23:268.e1-6)

Visual acuity testing plays a key role in vision screening among young children worldwide in detecting visual impairment and amblyopia.[1,2] The Vision 2020 strategy of the World Health Organization estimates the prevalence of amblyopia at 3%, whereas in Malaysia, it is estimated to be as high as 7%.[3-5] In 2017 the Malaysian Ministry of Health started the Amblyopia and Visual Impairment Screening program based on local data, which emphasized an urgent need for early and inclusive preschool vision screening.[3,5-8] This was consistent with other developed countries, which screened children as early as 3-5 years of age.[2,3,6,9]

The Lea symbols chart has been shown to offer a better amblyopia detection rate compared to the Sheridan Gardiner chart among Malaysian preschool children; however, accessibility is limited to ophthalmology services where trained personnel perform the testing.[10] The Lea symbols chart is available, however, in the American Association for Pediatric Ophthalmology and Strabismus (AAPOS) Vision Screening App (application), which serves as one of many electronic apps developed to bridge the gap between office- and home-based screening. This app also offers an option to test visual acuity using Sloan letters optotype. The current study aimed to evaluate parents' performance using this app for vision screening in Malaysian preschoolers. The reliability of the Lea symbols in the app's form was also studied.

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Subjects and Methods

This study was approved by the Medical Research Ethics Committee of the Malaysian Ministry of Health. Written permission was also obtained from the app developer (Good-Lite, Elgin, IL). All study protocols were in accordance with the Declaration of Helsinki. This cross-sectional study used the convenience sampling method for recruitment. A sample size of 200 participants was selected based on Bland-Altman sample size with the study power of 100%.[11] Inclusion criteria were children age 5-6 years and attendance at the Hospital Selayang, Selangor, Malaysia, from December 2017 to March 2018, and visual acuity of at least logMAR 0.6. Subjects were both patients (non-naïve to acuity assessment) and nonpatients (naïve to visual acuity testing, accompanying other patients to the hospital). Children were excluded if they were deemed uncooperative during acuity assessment, became irritable or had attention disorders, or if they failed the binocular pretest of logMAR 0.6 by the doctor.

Eligible parents or guardians were counseled on study objectives and procedures. They were also provided with information sheets in either Malay or English. Written parental consent was obtained before the children were screened. Visual acuity testing was then conducted following a similar study protocol for all assessors.

Materials used included an iPad mini (Apple Inc, Cupertino, CA) set to the brightest screen settings (163 pixels per inch, 160 mm × 120 mm screen size) throughout all the testing procedures, a 3 m measuring tape, a self-purchased AAPOS Vision Screening app (Good-Lite, Elgin IL), smartphone stopwatch timer, spectacle-shaped occluders, and Lea symbols chart on a retro-illuminated standard Early Treatment Diabetic Retinopathy Study (ETDRS) lightbox (illumination from two Daylight 20-watt fluorescent tubes), as well as quiet and well-lit consultation rooms for the assessment. The app displayed on iPad mini was set at a distance of 3 m using Lea symbols and threshold screening for children at least 5 years of age. The logMAR scale was displayed on the right side of the iPad screen. Additional numbering was placed next to the logMAR scale on each line to enable quicker recording of vision while referencing a table to record exact vision.

Three sets of visual acuity measurements for the right eye, left eye and time taken to complete testing were recorded. The first set was recorded by the parents or guardians and the second set was recorded by a particular assigned ophthalmology registrar. Both doctor and parents were present in the same consultation room during the first and second sets of visual acuity recording. The app using Lea symbols was used for the first and second sets of visual acuity measurements. The third set of visual acuity recording was made by a single optometrist using a retroilluminated standard ETDRS lightbox with the Lea symbols chart set as the gold standard, during which children were accompanied by parents.

The iPad mini was positioned at the child's eye level resting flat against the wall. Screening began with a binocular pretest by the doctor while parents observed. The child was asked to identify verbally or by matching 4 picture optotypes (apple, square, house, and circle) fixed at logMAR 0.6, as by using the app, only visual acuity of at least logMAR 0.5 could be recorded. Any child unable to complete the pretest was excluded from the study. Visual acuity was taken starting with the right eye while occluding the left eye. The same refractive correction was maintained for the measurements during all visual acuity tests (either unaided or habitual correction with glasses). If the child was using glasses, an occlusive patch was used to cover the untested eye. Parents then proceeded to take the child's visual acuity using the app starting from logMAR 0.5 onward. Parents received no coaching or practice time during testing; however, the doctor was available in the same examination room for any queries. The doctor, parents, and optometrist were not masked to test results. Visual acuity testing was halted when the child showed hesitation, was no longer able to resolve the optotype, or when the child repeatedly read the same optotype for all optotypes tested in a similar line.

Each eye was tested separately. The child was asked to read all optotypes on each line until errors were made. The number of errors and the line on which the errors occurred were noted, and final visual acuity and time to completion were recorded (separately for each eye).

Children had a 5-minute interval between tests. Parents completed a demographic information sheet, including age, ethnicity, sex, and level of education (for both parents and child). Parents were also asked to rate the ease of the testing app using a 5-point Likert scale questionnaire where 5 indicated strong agreement.

The doctor then retested the child's visual acuity using the app, with the optotypes shuffled prior to retesting. Lastly, a single licensed optometrist tested visual acuity using a retro-illuminated standard ETDRS lightbox with the Lea symbols chart at a distance of 3 m in a similarly well-lit examination room. The optometrist also recorded visual acuity and duration of test completion.

Children with visual acuity worse than logMAR 0.26 were referred for a full optometric and ophthalmological assessment. The cut-off visual acuity was based on the AAPOS screening guidelines.[5] Refractive errors and other ocular conditions were treated accordingly.

Data entry and analyses were performed using SPSS IBM version 23.0 (SPSS Inc, Chicago, IL). Descriptive tests were used to determine the mean and standard deviation of visual acuity reading and duration of visual acuity testing. In fulfilling the primary objective in determining the performance of parents, specificity and sensitivity using cross-tables via SPSS, Bland-Altman scatter plot for agreement assessment, Likert scoring by parents for ease of usage, and analysis on the mean time taken by assessors to complete testing were compared using an ANOVA test, with $P < 0.05$ being statistically significant. For the secondary study objective of determining the reliability of the Lea symbols in the app form, intraclass correlation coefficient (ICC) based on a 95% confidence interval was used[12] to check for inter-rater consistency as well as Cronbach's α. The ability of the app to detect visual impairment in testing-naïve children was also analyzed.

Table 1. Children's demographic data

Characteristic (n = 195)	Overall, no. (%)	*P* value[a]	5-year-olds, no. (%) (n = 91)	6-year-olds, no. (%) (n = 104)	*P* value[a]
Sex					
Female	99 (50.8)	0.83	49 (53.8)	50 (48.1)	0.42
Male	96 (49.2)		42 (46.2)	54 (51.9)	
Ethnicity					
Malay	153 (78.5)	0.00	71 (78.0)	82 (78.8)	0.30
Chinese	26 (13.3)		11 (12.1)	15 (14.4)	
Indian	13 (6.7)		6 (6.6)	7 (6.7)	
Other	3 (1.5)		3 (3.3)	0	
Naïve to vision testing					
Yes	93 (47.7)	0.52	47 (51.6)	46 (44.2)	0.30
No	102 (52.3)		44 (48.4)	58 (55.8)	
Attending schooling					
Yes	191 (97.9)	0.00	87 (95.6)	104 (100)	0.03
No	4 (2.1)		4 (4.4)	0	

[a]*P* value of <0.05 reflects unequal distribution between categories compared.

Results

Of the 200 children enrolled, 5 were excluded because of poor visual acuity. Of the 195 included children, 91 (46.7%) were 5 years of age, and 99 were girls (50.8%). See Table 1. Of the 102 children nonnaïve to the visual acuity testing procedure had preexisting ocular comorbidities, including 40.2% (41) with refractive errors, 7 with strabismus (6.9%), and 14 (13.7%) with underlying ocular conditions, such as treated cataracts. Of the 93 children (including 47 5-year-olds) who were naïve to testing, 10 (10.8%; 3 5-year-olds) were diagnosed with refractive errors and prescribed glasses. Another 10.8% on request were referred to other hospitals for comprehensive eye assessments.

Visual acuity testing by parents was mainly performed by mothers or female guardians (153/195 [78.5%]). Mean age of parents was 37.27 ± 7.68 (standard deviation) years. Parental age distribution was 12.8% from 21 to 30 years; 63.1%, 31-40 years; 15.4%, 41-50 years; 7.2%, 51-60 years; and 1.5%, 61-70 years. Parents with tertiary education were 49.7% (97) of the study population; with secondary school education, 47.2% (92); and with primary school education, 3.1% (6). Most parents (178 [91.3%]) strongly agreed on the app's acceptability and ease use.

Bland-Altman scatterplot between parents and optometrist as well as doctor and optometrist were both mainly within 95% limits of agreement for bilateral visual acuity screening (Figure 1), with difference (logMAR) plotted against mean (logMAR). ICC was excellent for parents versus doctor and doctor versus optometrist. Good ICC was obtained for parents versus optometrist. All three comparisons were highly significant ($P < 0.001$). The Cronbach's α overall was >0.7, indicating high internal reliability of the app (Table 2). The app as a visual acuity testing tool by parents yielded 86.6% sensitivity and 78.9% specificity for the right visual acuity screening and a sensitivity of 79.5% and a specificity of 71.8% for the left visual acuity screening when compared to the gold standard visual acuity recorded by the optometrist (Table 3).

The differences in time taken for visual acuity testing was statistically significant between the doctor and parents using the app (mean difference = 20.9 sec; $P = 0.006$) but not statistically significant between doctor and optometrist (mean difference = 15.7 sec; $P = 0.051$) and between optometrist and parents (mean difference = 5.2 sec; $P = 0.72$). Testing-naïve children took longer in assessment time for all assessors (Table 4).

Discussion

Having parents test children's visual acuity increases the chances of early detection of visual impairment. Parent-administered electronic visual acuity testing was found in Florida to be reliable tool for screening children 3-9 years of age[13]; although this result reflects a different testing mechanism than that used in this study, it nevertheless emphasizes the benefits of empowering parents as first-line screeners.

Professional background training in vision screening was only one of the factors affecting the reliability of visual acuity testing in children. Others included the children's cognitive aptitude and psychological factors.[1,14] This further supported the potential role of parents as screeners, because they might better understand their children's responses, mood, and behavior. It was documented that lay visual acuity screeners had comparable sensitivity to nurses for visual acuity screening.[15] Lay screeners were defined as individuals with at least a high school degree, which in our study translated to those who completed secondary school in Malaysia. From our study, 50% of parents had primary and secondary school education, and our study showed these parents to have performed the visual acuity testing reliably.

Parents showed good (>70%) sensitivity and specificity in both eyes vision screening. Right vision screening had a higher sensitivity and specificity compared to the left vision

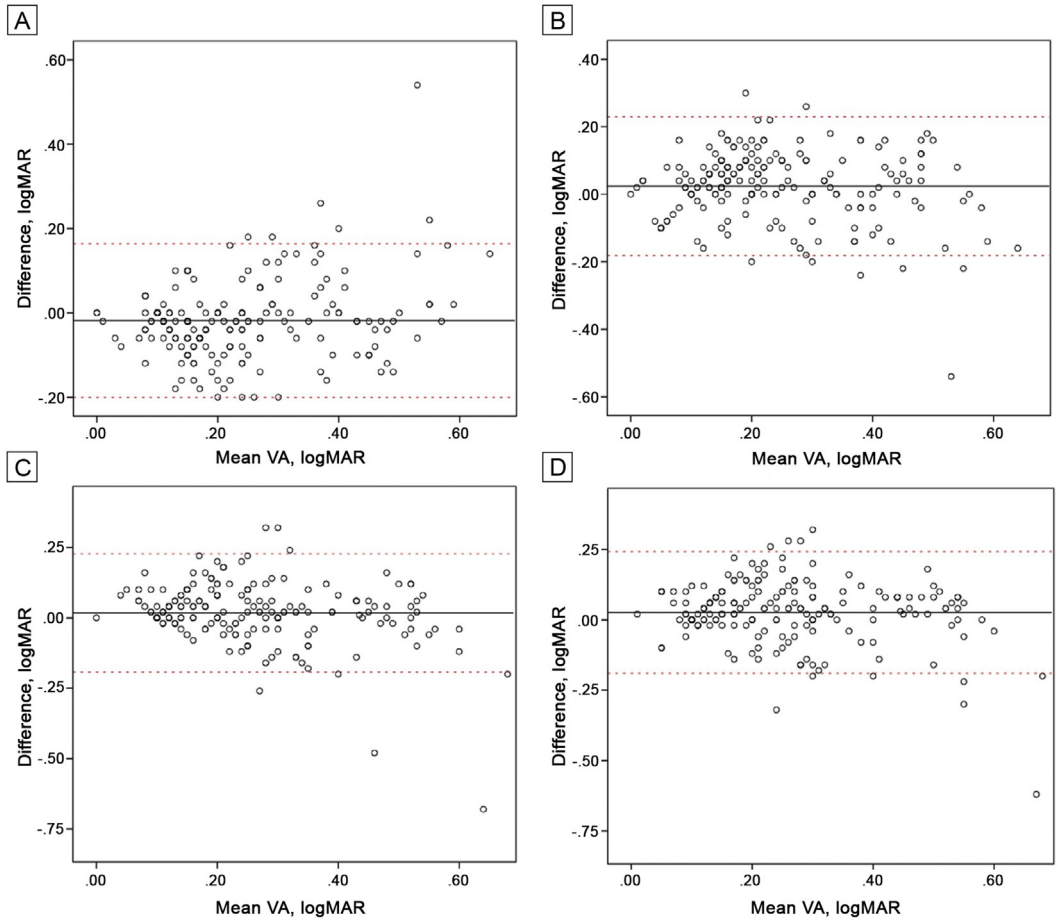

FIG 1. Bland-Altman scatterplot comparing mean difference in right visual acuity (VA) taken by optometrist using the gold standard Lea chart to the Lea app taken by doctor (A) and by parent (B), with mean difference indicated by the solid line and 95% limits of agreement (LoA) by dotted lines (A, −0.018 [0.164 to −0.200]; B, 0.024 [0.230 to −0.182]). Bland-Altman scatterplot comparing mean difference in left VA by optometrist using the gold standard Lea chart to Lea app by doctor (C) and by parents (D), with mean difference indicated by solid line and 95% LoA by dotted lines (C, 0.017 [0.227 to −0.193]; D, 0.026 [0.242 to −0.190]).

Table 2. Comparing reliability of Lea symbols between AAPOS Visual Screening App in parents and doctor, and between standard Lea chart[a]

	Right eye	Cronbach's α	Left eye	Cronbach's α	*P* value
Between AAPOS Vision Screening App					
Parent vs doctor	0.924	0.961	0.933	0.966	<0.001
Between AAPOS Vision Screening App and standard chart					
Doctor vs optometrist	0.790	0.886	0.747	0.857	<0.001
Parent vs optometrist	0.739	0.856	0.737	0.855	<0.001

[a]Intraclass correlation: good reliability, 0.60-0.74; excellent reliability, 0.75-1.00.[12] Cronbach's $\alpha > 0.7$: high reliability.

screening which could be due to the children being more alert and attentive at the beginning of assessment. The negative predictive value was 91.8% for the right and 84.0% for the left vision which reflects the app as a good screening tool to detect visual impairment. The lower positive predictive value between 65.0% and 68.0% reflected that in children with good acuity, discerning their exact vision may not be accurate via the app.

Completion time was not a true reflector of performance of parents, as it was subjected to the child's cooperation and attention span, hence was not the main studied factor.[13] Parents took the longest (mean 191/2 ± 70.82 sec) as expected, especially in such testing-naïve children as they were the first assessors and familiarization took time for both children and parents. There was no significant correlation between time taken to complete testing and the lower satisfaction ratings on Likert scoring by parents. Time taken was similar ($P = 0.72$) between parents and optometrists, as perhaps children were tired by the third repeated acuity assessment although different tools and

Table 3. Sensitivity and specificity of AAPOS Vision Screening App between users and Lea symbols chart

	Right vision screening				Left vision screening			
Lea symbol	Sens %	Spec %	PPV %	NPV %	Sens %	Spec %	PPV %	NPV %
Gold standard chart by optometrist vs AAPOS App by parents	86.6 (76.0-93.7)	78.9 (70.8-85.6)	68.2 (60.3- 75.3)	91.8 (85.9-95.4)	79.5 (68.8-87.8)	71.8 (62.7-79.7)	65.3 (57.9-71.9)	84.0 (68.2-80.8)
Gold standard chart by optometrist vs AAPOS App by doctor	82.1 (70.8-90.4)	81.3 (73.4-87.6)	69.6 (61.1-76.9)	89.7 (83.7-93.6)	82.1 (71.7-89.8)	76.9 (68.2-84.2)	70.3 (62.6-77.0)	86.5 (79.8-91.3)

All parameters (95% confidence interval range); *NPV*, negative predictive value; *PPV*, positive predictive value; *Sens*, sensitivity; *Spec*, specificity.

Table 4. Comparison of mean time for bilateral screening by different assessors

	Time, seconds		
Patient group	Parent	Doctor	Optometrist
Familiar to VA testing (n = 102)	180.75 ± 70.64	160.85 ± 64.80	182.67 ± 65.73
Testing naïve (n = 93)	202.59 ± 69.61	180.58 ± 58.88	189.61 ± 64.72
P value[a]	0.03	0.03	0.46

VA, visual acuity.
[a]A *P* value of <0.05 indicates statistical significance.

different assessors were used. Optometrists had no time difference when recording the acuity between vision naïve and non-naïve children ($P = 0.43$) likely due to their experience. Overall, assessors took about 3 minutes for bilateral acuity testing.

The AAPOS Vision Screening App was able to detect up to 10% of visual impairment in the 195 children, which concurs with data on prevalence of visual impairment in the Malaysian population of between 6.7%-10%.[3,10,16]

Many studies have studied the reliability of visual acuity measurements using tablets and smartphones in adults, including apps such as EyeSnellen, Eye Chart Pro iOS, Peek Acuity, and REST.[17-20] However, most app-related studies in children were based on photoscreening tests like GoCheck Kids Vision Screening app, Spot Vision Screener, and Plusoptix, which are recommended for children younger than 5 years.[9,21-23] Furthermore, photoscreening and photorefractors typically do not test direct visual acuity as compared to a optotype visual acuity testing app, which is preferred in cooperative children.[5]

This study is limited by the fact that the study population was from a single center and may not reflect the general population accurately. Although comparison was made between the app set at maximum brightness on an iPad mini and the gold standard ETDRS retroilluminated lightbox chart, the brightness or illuminance for both tools was not measured prior to the study. There was also no masking of assessors during visual acuity testing. Randomization of assessor sequence was not performed, because the main objective was to evaluate the performance of parents in testing visual acuity. Cooperation and attentiveness of the children varied with consecutive assessments of visual acuity. Only educated parents participated in this study.

We believe that, with the availability of the AAPOS visual acuity screening app, parents and guardians can be competent first-line screeners for their children's vision. Children with underlying visual acuity problems can also be home monitored. Further research is necessary to standardize referral guidelines to avoid overestimation of visual impairment by parental screeners.

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