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A Novel Bluetooth-Based Automated Flipper for Measuring Accommodative Facility: a Comparison with Conventional Manual Flipper

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Purpose: To evaluate the diagnostic accuracy of a Bluetooth-based automated flipper for measuring accommodative facility (AF) in children.

Design: A cross sectional study with crossover design.

Participants: Children aged 8 to 12 years were enrolled and randomly divided into 2 groups (A and B).

Methods: Initially, group A participants used the manual flipper to measure monocular (MAF) and binocular (BAF) AF, whereas participants in group B used the automated flipper. Subsequently, the groups underwent a crossover, exchanging the methods to measure AF. The diagnostic accuracy of the automated flipper was evaluated against gold standard, which defined inadequate AF as <7 cycles per minute (cpm) for MAF and <5 cpm for BAF, as measured with the manual flipper.

Main Outcome Measures: Accommodative facility measured using automated and manual flipper. Area under the receiver operating characteristic curve for automated flipper; sensitivity and specificity at the optimal cutoff (maximal Youden index).

Results: The average age of the 129 participants was 10.50 ± 1.42 years. The MAF and BAF values obtained using automated flipper were significantly correlated with those from the manual flipper (correlation coefficients of 0.819 and 0.813, respectively, both $P < 0.001$). The mean MAF and BAF measured with the automated flipper were 9.30 ± 2.30 cpm and 9.13 ± 2.34 cpm, respectively, significantly higher than the manual flipper's measurements (8.53 ± 2.16 cpm and 8.33 ± 2.22 cpm, respectively), even after adjusting for the learning effect associated with multiple measurements using analysis of variance for crossover design. The area under the curve for the automated flipper in diagnosing inadequate MAF and BAF was 0.911 (cutoff value = 9 cpm, sensitivity = 71.11%, specificity = 97.44%) and 0.920 (cutoff value = 7 cpm, sensitivity = 85.34%, specificity = 84.62%), respectively.

Conclusions: The automated flipper showed a strong correlation with the manual flipper, and demonstrated satisfactory sensitivity and specificity in diagnosing inadequate AF. It is recommended that the Bluetooth-based automated flipper be adopted as a novel tool to enhance the accuracy of AF testing in children.

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Accommodative facility (AF) refers to the ability of the eye to change focus from 1 object to another and to maintain a clear focus on the object of regard. Evidence has shown that inadequate AF is prevalent among children.[1,2] Inadequate AF not only contributes to asthenopia,[3−7] but also has a close association with the onset and progression of myopia.[8−13] Besides, AF is also an indicator used to assess children's reading ability.[14−16] Therefore, AF is a vital clinical measure that provides insights into the efficiency of the ocular accommodation, and guides clinical decision-making and intervention strategies for myopia prevention and control. Traditionally, in clinical practice, the AF test was conducted at a near distance (0.4 meters) with a handheld flipper containing −2.00-diopter (D) and +2.00-D spherical lenses. During the cyclic test, the flipper would be overturned from one pair of lenses to the other as soon as the examinee correctly identify the optotype. However, this method required the lens pairs manually held to align with the eyes and overturned time and again by either the examiner or the examinee, which potentially leads to inconvenience and inaccuracy. It has been acknowledged that the examinee's reaction time and speed of movement can significantly influence number of cycles.[17] Therefore, this testing approach should be more controlled and standardized.

With the progress in automation and electronic information technology, wireless control technology, like smart Bluetooth communication, has been deeply implanted into wearable medical devices, which enhanced the portability and immediacy of the device and offered the benefits including real-time data monitoring, device management, and patient engagement. Recently, a Bluetooth-based automated flipper has been developed, which consists of 2 pairs

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of lenses mounted in a headset processor. The automated flipper can be connected with the software on the users' smartphones, and the examinee can synchronously control the flip of the lens pairs by tapping the correct button on the smartphone. Due to the advantage of smooth flip in constant speed and minimized individual variability, the automated flipper has been thought of as a substitute device of the manual flipper. Recently, Wang et al[18] have found that the data for AF measured by automated flipper and manual flipper were comparable. However, their study might be more convincing if taking the learning effect of AF test into consideration because the experience of the first measurement using 1 flipper potentially affected the result of the following measurement using the other. Besides, their study enrolled subjects aged 18 to 22 years, which limited the extrapolation of their conclusions. To our knowledge, there is still a dearth of studies on the utilization of such an automated device for measuring AF in children, the target population of myopia control.

The aim of this study was to assess the diagnostic accuracy of the Bluetooth-based automated flipper in AF test, as compared with the conventional manual flipper, mainly focusing on children. We believed that this study would provide more document on the application of automated flipper.

Methods

Setting and Participants

This cross sectional study was carried out from December 2021 to April 2022 at the Joint Shantou International Eye Center (JSIEC) of Shantou University and the Chinese University of Hong Kong and adhered to the tenets of the Declaration of Helsinki. This study has obtained ethics approval from the Institutional Review Board of JSIEC, and written consent from the parents was obtained in addition to the children's verbal consent.

Schoolchildren aged 8 to ~12 years were included in the study. The criteria for exclusion were as follows: (1) previous history of ocular diseases or surgeries; (2) experience of AF test; (3) corrected visual acuity worse than 20/25 in both eyes; (4) astigmatism ≥1.50 D in either eye; (5) interocular difference in spherical equivalent refraction (sphere plus half the cylinder, by cycloplegic subjective refraction) ≥1.00 D; (6) heterotropia; (7) accommodative amplitude (AA) in either eye below the minimum accommodation calculated using Hofstetter's formula (15−0.25 × age); and (8) inability in using automated or manual flipper.

The sample size of 120 was determined according to the primary measurement, considering 80% sensitivity, 80% specificity, 0.95 confidence level, 0.20 confidence interval (CI) width (2-sided) and 10% precision.

Devices and Testing Procedure

Devices for AF test in this study included the manual flipper (Tianjin OPT Technology Development Co., Ltd) and Bluetooth-based automated flipper (Eyecure Visual Function trainer ED-VFTI-01, Guangxi Anxintong Medical Equipment Co., LTD). The test using both devices should be conducted with refractive correction, whether for binocular test with both eyes uncovered or monocular test with the other eye covered by patches. The testing duration is 1 minute.

The manual flipper consisted of a handle with +2.00-D and −2.00-D prescriptions and a near vision chart with Snellen 20/30 tumbling E optotypes. The test began with the participants holding the handle and placing the +2.00 D prescription in front of the eyes. The visual chart was placed at a distance of 40 cm with an illuminance of 300 lux. The participants were directed by 1 researcher (L.Z.) to focus on 1 optotype. Once the optotype was correctly identified, the participants promptly switched the lens pair into the −2.00 D prescription and then focused on the next optotype. The researcher monitored the participants in case any improper operation such as flipping after incorrect identification.

The automated flipper was a wearable device that consisted of a headset processor mounted with 2 pairs of lenses: 1 with a +4.00 D prescription on the outer layer and the other with a −2.00 D prescription on the inner layer (Fig 1A). The headset processor was connected with a smartphone via Bluetooth and controlled by a software application specifically developed for this study (Fig 1B). The testing procedure commenced with the automated flipper being wore on the participants' heads, with both lenses pairs aligned in front of the eyes, effectively acting as a combined +2.00 D prescriptions. The participants were instructed by another researcher (P.G.) to identify the 20/30 tumbling E optotype on the smartphone touchscreen with a luminance of 200 cd/m^2 at a distance of 40 cm as quickly as possible, and then to tap the button corresponding to the optotype. Once the participants correctly tapped the button, the +4.00 D prescription could be flipped over synchronously, leaving the −2.00 D prescription in front of the eyes. The next correct tap would trigger the +4.00 D prescription to flip back. The automated flipper could be sourced online through an e-commerce platform (https://www.taobao.com/).

Study Design and Data Collection

The study followed a randomized crossover design. The research protocol was conducted on 2 separate days (Fig 2).

On the first day, a skilled ophthalmologist (R.Z.) conducted the slit-lamp examinations, direct ophthalmoscopy, and cover test after obtaining the informed consent and medical history. Then, an experienced optometrist (D.Z.) performed the visual acuity test and cycloplegic subjective refraction (using 1% tropicamide, given the shorter onset, time to maximum cycloplegia, and duration of action, as well as fewer side effects compared with cyclopentolate[19]). On the second day, the optometrist (D.Z.) conducted a thorough noncycloplegic subjective refraction with the principle of maximum plus to maximum visual acuity and used the push-up method to measure the AA by moving a target from far to near gradually (with a speed of 2 cm per second) until the participant reported that the target first becomes blurry. Then, all participants were taught to complete the AF test using manual and automated flippers under wearing spectacles with full refractive correction. Each participant was given a 20-second trial to ensure their competence in the tests.

After enrolling the eligible participants, the investigator (H.W.) generated the random sequence and equally allocated the participants into 2 groups (A and B). At the beginning, participants in group A used the manual flipper to measure the monocular accommodative facility (MAF) and binocular accommodative facility (BAF), whereas participants in group B used the automated flipper. Then, the measurements were crossed over 5 minutes later. Each measurement was conducted twice with 1-minute interval given in between for test-retest repeatability test. The researchers remained unaware of the previous AF measurements.

Accommodative facility is recorded as the number of accommodation cycles, which involves positive to negative lenses changes and back, within 1 minute, and was expressed in cycles per minute (cpm). If the final cycle was proceeded with the positive prescription flipped but not completed by the end of the minute, a half cycle was added. The cutoff values for diagnosing inadequate

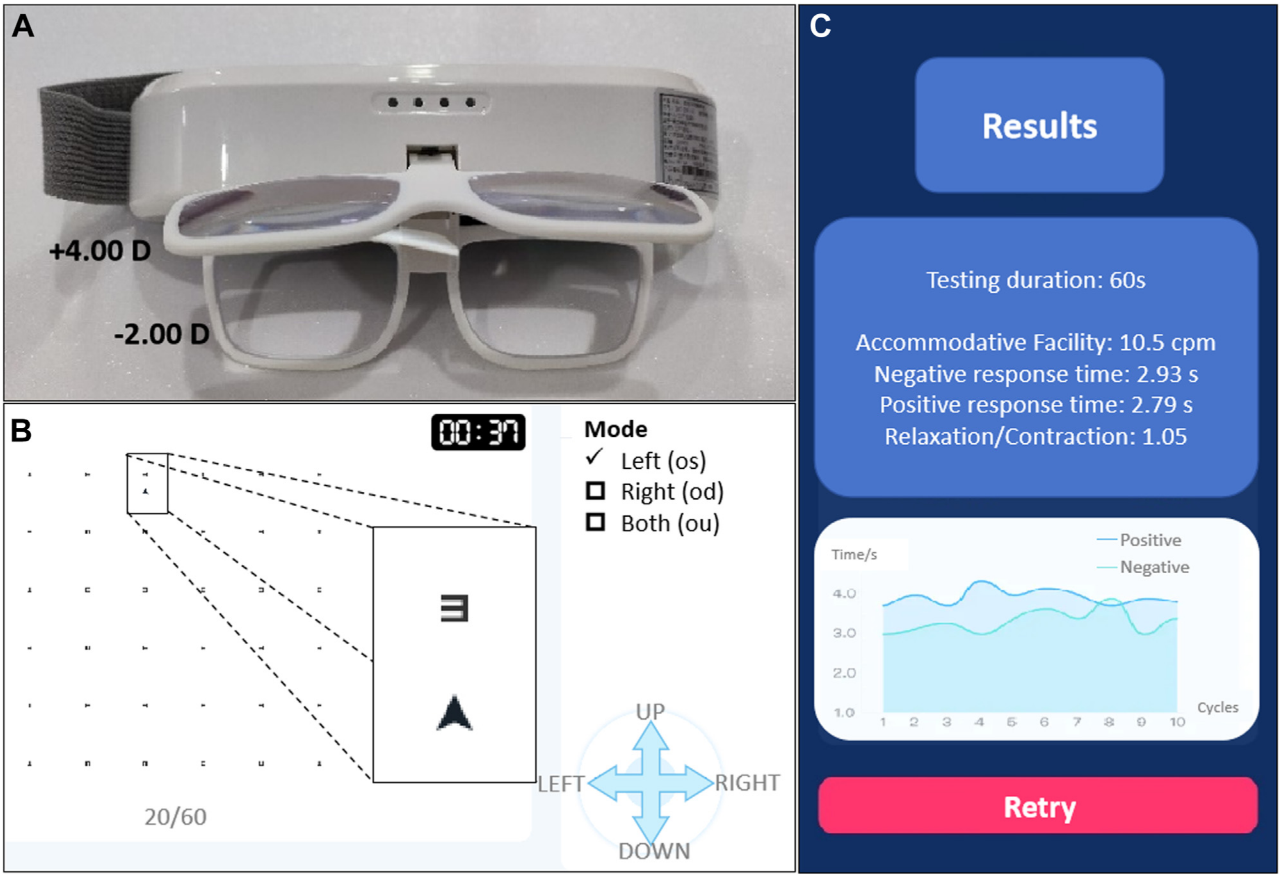

Figure 1. Bluetooth-based automated flipper. The automated flipper was a wearable device that consisted of the headset processor mounted with 2 pairs of lenses (**A**). The smartphone software presented target letters and touch screen buttons (**B**). The test results included the accommodation cycles, as well as the negative and positive response time (**C**).

AF, measured by the gold standard method (manual flipper), is <7 cpm for MAF and <5 cpm for BAF.[20] Additionally, the smartphone software also recorded the time taken for each period of negative and positive accommodation response (time to compensate the +2.00 D and −2.00 D, respectively) (Fig 1C).

Statistical Analyses

The data were presented in terms of mean with standard deviation or 95% CI, as well as number with percentage. The normal distribution of all descriptive data was assessed using the Shapiro−Wilk test. The repeatability of the measuring tools was evaluated using the intraclass correlation coefficient (ICC). Pearson's product-moment correlation coefficient (r) was calculated to determine the level of association between the number of cycles with the automated flipper and the manual flipper. The strength of the correlation was interpreted as weak, moderate, or strong when r was <0.3, 0.3−0.8, and ≥0.8, respectively. Analysis of variance for crossover design was performed between groups A and B to account for variables such as period, sequence, and flipper type. To evaluate the diagnostic accuracy of the automated flipper in identifying inadequate AF, receiver operating characteristic (ROC) curves were generated, and then the area under the curve (AUC), sensitivity, and specificity were computed to predict performance. The optimal cutoff value to define inadequate AF was determined according to the Youden's indexes. All data analyses were conducted using SPSS software (version 23.0). A P value of <0.05 was considered statistically significant.

Results

Baseline Characteristics

Out of the 169 children initially invited to participate in the study, 26 were subsequently excluded due to inability in using any flipper, and 4 were excluded due to significant astigmatism or anisometropia. Therefore, a total of 129 patients were included in the study, 63 in group A and 66 in group B. The mean age was 10.50 ± 1.42 years, and men accounted for 42.6% (Table 1). There were no significant differences between both groups regarding sex, age, spherical equivalent refractive error, or AA. No significant between-group difference was found in the measuring results of MAF or BAF, regardless the measuring flippers.

Repeatability and Correlation of Manual Flipper and Automated Flipper

The manual flipper method for measuring both MAF and BAF had a high level of repeatability, with ICCs of 0.768 (95% CI: 0.668−0.838) and 0.736 (95% CI: 0.549−0.837), respectively

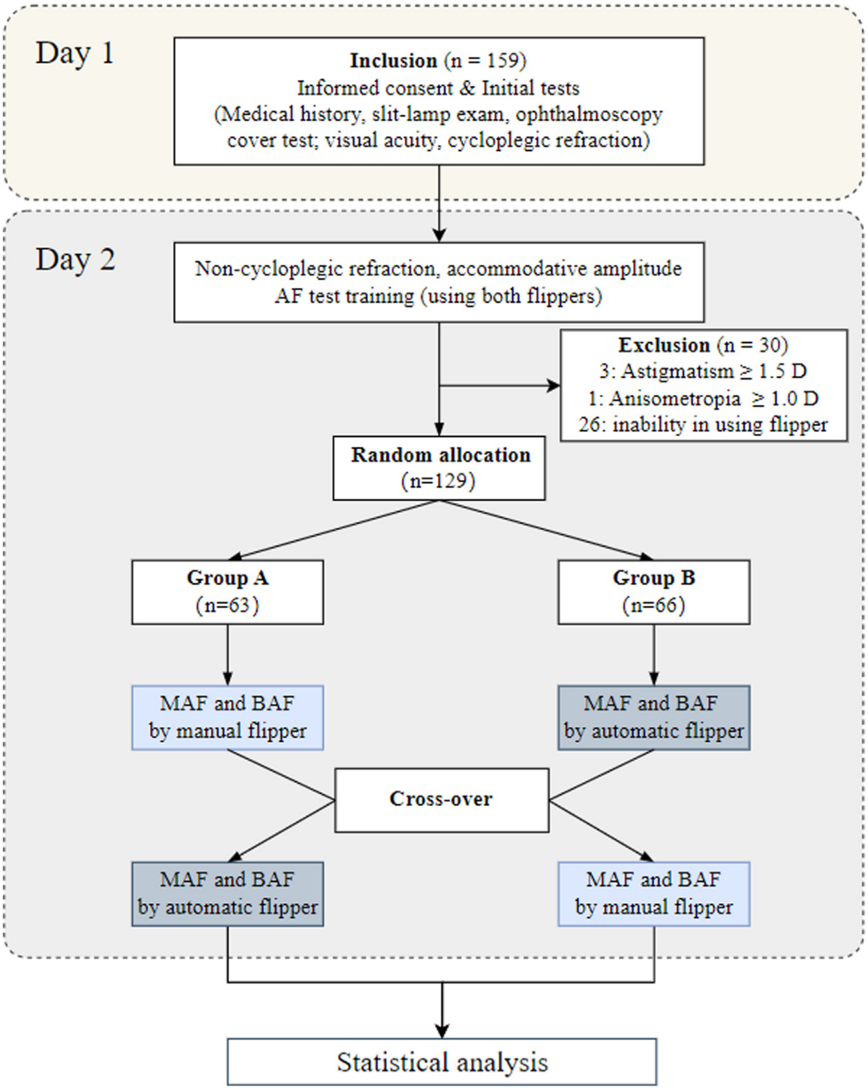

Figure 2. Study design and flowchart. BAF = binocular accommodative facility; D = diopters; MAF = monocular accommodative facility.

(both $P < 0.001$). The automated flipper method also demonstrated strong repeatability in measuring both MAF and BAF, with ICCs of 0.824 (95% CI: 0.715–0.877) and 0.812 (95% CI: 0.692–0.874), respectively (both $P < 0.001$).

The MAF and BAF values obtained by the automated flipper was significantly correlated with those from the manual flipper ($r = 0.819$ and $r = 0.813$, respectively, both $P < 0.001$) (Fig 3).

Table 1. Baseline Characteristics of the Study Population

Characteristics	Total	Group A (n = 63)	Group B (n = 66)	P
Male, n (%)	55 (42.6%)	28 (44.4%)	27 (40.9%)	0.685
Age, yrs	10.50 ± 1.42	10.51 ± 1.52	10.50 ± 1.32	0.975
SER of right eye, D	−2.34 ± 1.46	−2.40 ± 1.53	−2.27 ± 1.32	0.642
AA of right eye, D	14.74 ± 2.61	14.53 ± 2.43	14.95 ± 2.78	0.369
Manual flipper MAF, cpm	8.53 ± 2.16	8.34 ± 2.10	8.71 ± 2.23	0.344
Manual flipper BAF, cpm	8.33 ± 2.22	8.11 ± 2.24	8.55 ± 2.20	0.262
Automated flipper MAF, cpm	9.30 ± 2.30	9.57 ± 2.42	9.04 ± 2.17	0.190
Automated flipper BAF, cpm	9.13 ± 2.34	9.19 ± 2.35	9.07 ± 2.35	0.768
Inadequate MAF, n (%)	39 (30.2%)	18 (28.5%)	21 (31.8%)	0.986
Inadequate BAF, n (%)	13 (10.0%)	8 (12.6%)	5 (7.57%)	0.334

AA = accommodative amplitude; BAF = binocular accommodative facility; cpm = cycles per minute; D = diopters; MAF = monocular accommodative facility; SER = spherical equivalent refraction.

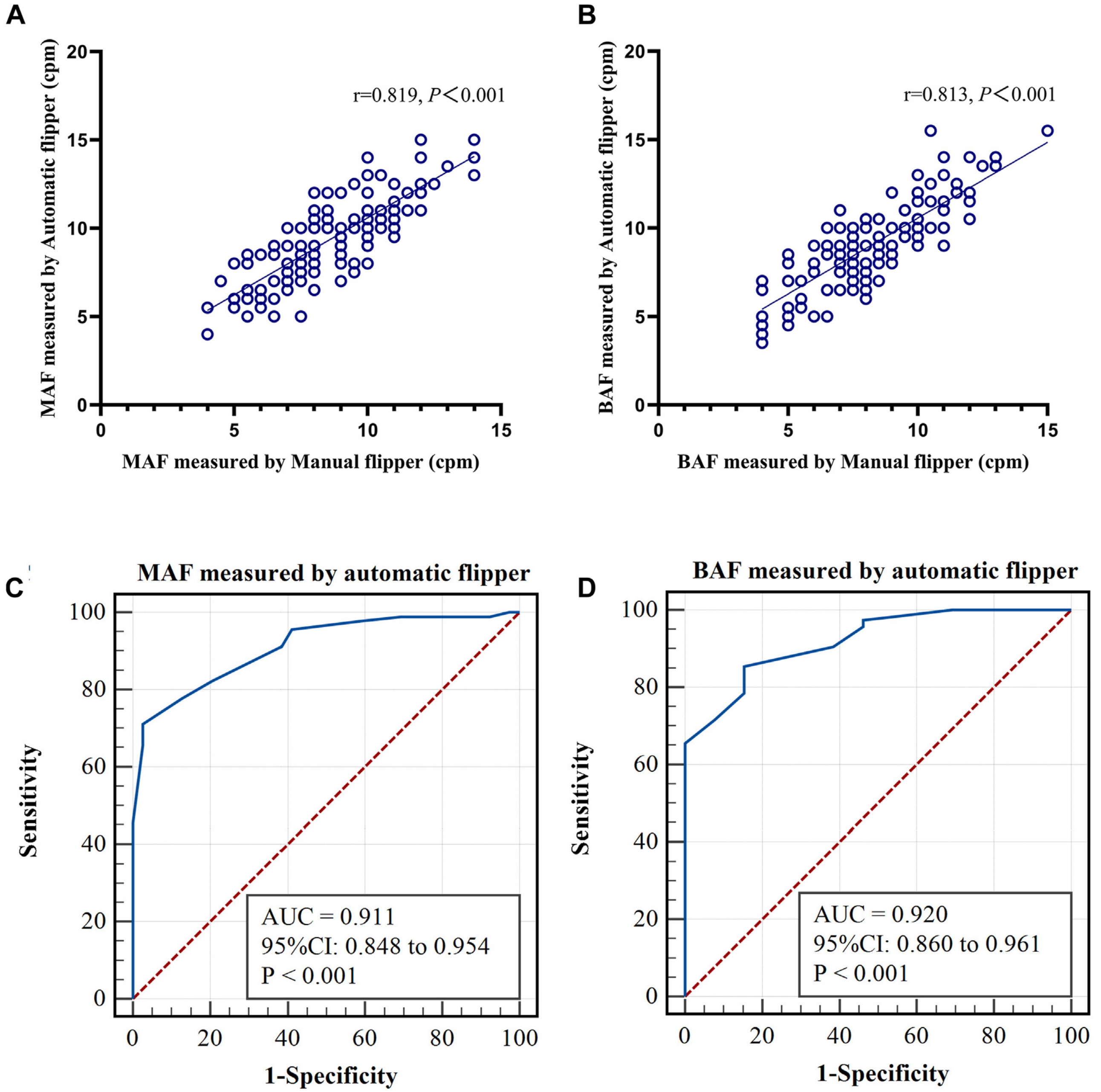

Figure 3. Accuracy of the automated flipper. Scatter plots showed strong correlations of automatic flipper and manual flipper in measuring monocular accommodative facility (MAF) (**A**) and binocular accommodative facility (BAF) (**B**). Receiver operating characteristic curve showed high diagnostic performance of the automated flipper in detecting inadequate MAF (**C**) and inadequate BAF (**D**). AUC = area under the curve; CI = confidence interval.

Effect of Flipper Type, Period, and Sequence

The analysis of variance showed that automated flipper has significantly higher MAF and BAF measuring results (both $P < 0.001$). Besides, analysis on period effect indicated that the AF measured in the second measuring period was higher than that in the first period ($P < 0.001$ for MAF), even though for BAF the difference was not statistically significant ($P = 0.054$). However, the analysis on sequence effect revealed no significant difference when comparing the results between both groups ($P = 0.596$ for MAF and $P = 0.496$ for BAF).

Test Accuracy

The ROC curves were constructed to assess the diagnostic performance of the automated flipper in detecting inadequate AF, using the threshold values established by manual flipper, which serves as the gold standard: <7 cpm for MAF and <5 cpm for BAF (Fig 3). The AUC for the automated flipper in diagnosing inadequate MAF and BAF was 0.911 and 0.920, respectively. The optimal cutoff value was 9 cpm for inadequate MAF, and the sensitivity and specificity were 71.11% and 97.44%, respectively. The optimal cutoff value was 7 cpm for inadequate BAF, and the sensitivity and specificity were 85.34% and 84.62%, respectively.

Negative and Positive Response in Accommodation

In automated monocular AF test, the average negative response time and average positive response time was comparable (3.34 ± 1.26 vs. 3.30 ± 1.24, $P = 0.77$), whereas in binocular AF test, the average negative response time is significantly shorter than the average positive response time (3.11 ± 1.14 vs. 3.48 ± 1.63, $P = 0.02$).

Discussion

We have introduced a novel Bluetooth-based automated flipper and carried out a randomized crossover diagnostic study to assess its validity in measuring the monocular and binocular AF in children aged 8 to 12 years, as compared with the conventional manual flipper. The automated flipper showed high measurement repeatability, as well as strong correlation with the manual flipper. Additionally, the automated flipper demonstrated satisfactory sensitivity and specificity in detecting inadequate AF. The insights from this study propose the automated flipper as a potential successor to the manual flipper.

Although AF testing is not a routine ophthalmological examination in practice, it offers significant value when assessing children with unexplained visual discomfort, such as blurred vision, headaches, or difficulty on near tasks. Therefore, ophthalmologists could integrate AF testing into their practice and further give suggestions for children with inadequate AF to improve the visual function and alleviate the symptoms. For example, the flipper lenses could be also used as a training tool to enhance accommodative speed and accuracy.[21−23] Additionally, some environmental and behavior suggestions, such as proper lighting and regular breaks during near work, can also help mitigate symptoms associated with AF insufficiency.[24]

In traditional clinical settings, the interindividual subjective variability is an important factor that cannot be ignored during the conventional manual flipper test. This variability, including hand-eye coordination, the time taken to switch the lenses, and the subjective criteria for judging when the target is clear or blurry, could significantly cause inconsistencies in the interpretation of test results and impact the reliability.[25] Over the past 2 decades, many researchers have dedicated their efforts to the development and validation of novel methods, aiming at addressing the inherent variability of manual AF test. These studies invariably used some computer-supported, automated instruments, which offered a more standardized and objective method compared with traditional manual flippers.

The technological advancement could be traced back to the semiautomated flipper developed by Ashok Pandian's team.[11] This innovative device featured a mercury tilt switch for cycle detection and was interfaced with a computer via cable. When the examinee correctly identified the target letter, the examiner would manually flip the lenses. This action would activate the mercury switch, thereby initiating the software-assisted recording procedure. Subsequently, Radhakrishnan et al[17] further improved this semiautomated method by employing a photorefractor to objectively capture the dynamic refractive error, synchronized with the subjective measurements.[26] The objective AF, derived from an analysis of the dynamic records through fast Fourier analysis and peak-fitting module, demonstrated high consistency with the subjective AF. Despite the semiautomated flipper ensuring the accuracy in measuring the duration and frequency of each accommodative phase, the procedure relied on examiner-supervised identification and manual operation, which constrained the level of automation and potentially introduced interoperator variability. Besides, the usage of the traditional photorefractor restricted the application of this method to monocular conditions, as it required presenting the stimulus of flippers to the other eye.

Afterward, the binocular open-field autorefractor was used to objectively record the dynamic refractive change in AF test. Otero et al[27] first proposed an automated extension of AF test using a focus-tunable electro-optical lens (EOL) to stimulate the accommodation. During the test, the examinee was asked to press a key to indicate the clarity, which automatically triggered the computer-controlled current driver to induce a change in EOL power. However, their study revealed a low level of agreement between the automated and manual AF test, which could be attributed to the different duration required for the change in accommodative demand in each cycle (40 microseconds for EOL settling vs. 0.6 seconds for manual flipping). Even worse, the complexity of the electro-optical system, comprising 3 coaxial lenses, could present challenges in target visualization and introduce confounding factors, thereby amplifying the intersubject variability in automated test.

Different from Otero et al,[27] Vera et al[25,28] used the targets (0.19 logarithm of the minimum angle of resolution) positioned at 5 m and 40 cm to stimulate the periodic change in accommodation. The open-field autorefractor objectively recorded not only the number of cycles per minute (quantitative data) but also the percentage of incorrect cycles, defined as the cycles containing over- or underaccommodative response exceeding 1 standard deviation from the mean refractive state at each distance (qualitative data). Their study found a moderate correlation between the quantitative data and the results using the traditional ±2.00 D flipper ($r = 0.46-0.58$). Only when the qualitative data were subtracted did a strong positive association become evident ($r = 0.78-0.83$). Nevertheless, overestimation of the AF in patients with stable underaccommodative response could not be ignored because they might regularly bypass the near target without achieving peak sharpness. Besides, the specific accommodation demand, as well as the vergence/accommodation response, would make it less comparable with the manual ±2.00-D flipper test.

Although the implementation of the open-field autorefractor facilitated a binocular AF test because it enabled the simultaneous target viewing and dynamic accommodation responses measurement, the above automatized AF tests had markedly different design with the traditional manual flipper, resulting in limited interchangeability of the AF tests. Consequently, it was suggested that automation might be only suited for routine accommodative training rather than for examination or diagnostic purposes.

More recently, the headset-mounted automated flipper has been introduced, integrating Bluetooth communication technology while preserving the fundamental design of manual flipper. The correct identification of target, indicated by pressing the control button, would trigger the lenses flipping. Previously, Wang et al[18] found the manual and automated AF was positively correlated in adults (r = 0.738), suggesting that the automated flipper could be a potential alternative for AF testing. However, to ensure an accurate comparison and uncover any inherent difference between the 2 flippers, it is essential to adjust the potential confounding factors.

Previous studies have identified multiple technological and individual factors that can affect AF, such as age,[29,30] lens powers,[31] target size,[32] testing distance,[33−35] learning effects,[36−38] and the participant's comprehension of the testing procedure.[25,39] Therefore, in this study, we controlled the lens power, target size, and testing distance throughout the testing procedure. Also, to control the age-related changes in accommodative function, we targeted the enrolled children between 8 and 12 years of age, who possessed comparable level of AF and a similar understanding of the test protocol.[20]

On one hand, the learning effect of repeated testing is an important consideration. Previously, Rouse conducted 3 consecutive AF assessments over a span of 3 minutes and found that >40% of the patients initially classified as borderline in the first minute have improved and passed the test when monitored over the full 3-minute period,[37] indicating a low test-retest reliability. Similarly, Wang et al[18] took only a few cycles, not exceeding 6, to assess the number of cycles per minute in their automated flipper study, and found that the result was significantly worse than that using the traditional 1-minute manual test (10.01 ± 2.77 vs. 12.00 ± 3.70). In their perspective, the observed improvement with testing duration might be partly ascribed to the learning and acceleration effect. In contrast, our study showed a high level of test-retest repeatability and intertest comparability. This divergence might be attributed to our study design, which ensured the participants' cooperation and competence by a 20-second prior trial. Besides, we incorporated a 1-minute rest period between each test, standardizing the starting conditions for each 1-minute test session. This methodology also implied that the diminished test-retest reliability, often associated with consecutive repeated testing, could be counteracted by extending the interval between tests. Echoing with the results of our study, Siderov, in his longitudinal investigation involving repeated AF test spread over a month, reported no significant variance in the outcomes.[40]

On the other hand, as the participants should use 2 types of flippers during the study, it is important to investigate the extent to which the measurement using the second flipper is affected by that using the first. To address the potential bias, the current study used a randomized blinded crossover study design and adjusted the difference between the second and the first measurement.

The current study had several limitations. First, the study only enrolled participants within a specific age range, limiting the extrapolation of conclusions because children at different ages might have various time consumption in manual flipping and benefit in different degree when using the automated flipper. Therefore, further studies should enroll diverse populations. Second, the negative and positive response time recorded by the smartphone software revealed that some participants might be occasionally absent-minded during the test, presenting as a few outliers of unusual delay of relaxation or accommodation. In the future study, we would update the software and eliminate the outliers to calculate the frequency of accommodation. Besides, further classification and clinical character of inadequate AF based on the negative and positive response time should also be explored. Last but not least, the cyclopentolate was typically considered as the standard of care for pediatric cycloplegic examination, whereas the tropicamide has been considered as the least effective cycloplegia, which might potentially affect the accuracy of AF measurement. Fortunately, a recent multicenter, randomized controlled study has proven that the difference between refraction of cyclopentolate and tropicamide for all refractive error groups was clinically insignificant.[19]

In conclusion, this study introduced a novel Bluetooth-based automated flipper, aiming to minimize the interoperator variation and enhance the precision of AF measurement. It showed a strong correlation with the manual flipper in measuring monocluar and binocular AF. The automated flipper has proven capable of accurately identifying inadequate AF, establishing diagnostic thresholds with satisfactory sensitivity and specificity. These findings suggest that the automated flipper holds promise as a reliable tool for screening and diagnosing accommodative disorders.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used Kimi AI (https://kimi.moonshot.cn/) to enhance the readability and coherence of the manuscript, optimize vocabulary, and ensure clear presentation of complex ideas. After using this tool, the authors reviewed and edited the content thoroughly. The authors take full responsibility for the content of the publication.

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Footnotes and Disclosures

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Disclosures:

All authors have completed and submitted the ICMJE disclosures form.

The author(s) have made the following disclosure(s):

M.Z.Z.: Patents − Guangxi Anxintong Medical Equipment Co., LTD, authorized patent (CN 212913793 U).

The other authors have no proprietary or commercial interest in any materials discussed in this article.

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HUMAN SUBJECTS: Human subjects were included in this study. This cross sectional study was carried out from December 2021 to April 2022 at the Joint Shantou International Eye Center (JSIEC) of Shantou University and the Chinese University of Hong Kong and adhered to the tenets of the Declaration of Helsinki. This study has obtained ethics approval from the Institutional Review Board of JSIEC, and written consent from the parents was obtained in addition to the children's verbal consent.

No animal subjects were used in this study.

Author Contributions:

Conception and design: Wang, Guo, M Zhang

Data collection: Guo, Zhao, Zhu

Analysis and interpretation: Wang, R Zhang, Qiu, M Zhang

Obtained funding: N/A

Overall responsibility: Wang, M Zhang

Abbreviations and Acronyms:
AA = accommodative amplitude; **AF** = accommodative facility; **AUC** = area under the curve; **BAF** = binocular accommodative facility; **CI** = confidence interval; **D** = diopters; **EOL** = electro-optical lens; **ICC** = intraclass correlation coefficient; **JSIEC** = Joint Shantou International Eye Center; **MAF** = monocular accommodative facility; **ROC** = receiver operating characteristic.

Keywords:
Accommodative facility, Automated flipper, Bluetooth-based, Accommodation assessment, Manual flipper.

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