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# Agreement of the Eyerobo VS portable refractometer with ARK-1 in community refractive screening

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# Abstract

This study assessed the agreement between the Eyerobo VS portable refractometer and the ARK-1 in 952 eyes (476 participants, mean age 10.22 ± 2.13 years) under non-cycloplegic conditions. Spherical diopter, spherical equivalent (SE), J0, and J45 were measured. The mean SE was − 1.80 ± 1.09 D for Eyerobo VS and − 1.73 ± 1.05 D for ARK-1. The 95% limits of agreement for SE ranged from − 1.28 to 0.46 D, with a mean difference of -0.07 D. Bland-Altman analysis revealed 82% agreement within the 95% confidence interval, and 83.2% of differences fell within ± 0.50 D. A strong correlation between devices was observed (r = 0.92). Eyerobo VS demonstrated good agreement with ARK-1 measurements, showing high accuracy in detecting refractive errors (RE) in children and adolescents. These findings suggest that Eyerobo VS is a reliable alternative to traditional autorefractors and holds potential for effective use as a refractive examination device in large-scale community screening programs.


# 1. Introduction

Visual impairment constitutes a significant global public health burden, with uncorrected refractive error being the leading cause of visual impairment and the second leading cause of blindness worldwide.[1–3] Evidence indicates that large-scale vision screening programs enable early identification of refractive and other ocular conditions, thereby allowing prompt treatment and protecting the visual health of the participants. [4]

Refractive screening is mainly conducted for multiple age groups and regions through schools and communities.[4] Effective refractive screening facilitates early diagnosis and treatment, thereby reducing adverse effects in children and adolescents. Cycloplegic refraction is widely recognized as the gold standard for diagnosing myopia, particularly for the initial vision examination in children and adolescents to rule out pseudomyopia, its application in large-scale screening settings is challenging.[5] Therefore, non-cycloplegic autorefraction is typically employed under these circumstances. Autorefractors, like the Nidek ARK-1 (Nidek, Japan), are widely adopted by eye care professionals globally for rapid, convenient refractive measurements in clinical practice.[6] However, the high cost, regular maintenance, calibration requirements, limited portability, and reliance on trained personnel associated with most autorefractors may limit their feasibility for large-scale refractive screening programs.[4, 7] Therefore, a cost-effective and time-efficient vision screening approach is desirable for large-scale applications in children and adolescents.

The Eyerobo VS (Eyerobo, China) is a compact, handheld autorefractor designed to actively measure the eye's refractive status through the emission specific light or signals.[8] Previous studies compared non-cycloplegic Eyerobo VS with cycloplegic retinoscopy; cycloplegic ARK-1 with cycloplegic Eyerobo VS and subjective refraction (including repeatability); and non-cycloplegic ARK-1 with non-cycloplegic Eyerobo VS.[9–11] While excellent agreement and accuracy between the other modalities (retinoscopy, subjective refraction, and ARK-1) and Eyerobo VS has been established in both pediatric and adult populations, the

device's performance in children undergoing community or large-scale vision screening remains unknown.

The purpose of this study was to assess the agreement between the Eyerobo VS and ARK-1, as well as its applicability in community-based refractive screening, to provide a basis for future large-scale screening implementation.

# 2. Result

A total of 476 participants (952 eyes) aged from 6 to 18 years (mean age 10.22 ± 2.13 years) were included in this study, including 212 males and 264 females. Descriptive data for spherical diopter, SE, and astigmatism-related parameters ($J_0$ and $J_{45}$) were presented in Table 1.

Table 1
Mean values of the measured indices of Eyerobo VS and ARK-1.

| | **Eyerobo VS** | | | **ARK-1** | | |
|---|---|---|---|---|---|---|
| | **Mean ± SD** | **Min** | **Max** | **Mean ± SD** | **Min** | **Max** |
| Sphere (D) | -1.50 ± 1.07 | -6.00 | 2.00 | -1.45 ± 1.04 | -6.75 | 2.50 |
| SE (D) | -1.80 ± 1.09 | -6.25 | 1.88 | -1.73 ± 1.04 | -7.25 | 2.62 |
| $J_0$ (D) | 0.25 ± 0.32 | -0.53 | 2.85 | 0.24 ± 0.31 | -0.62 | 2.04 |
| $J_{45}$ (D) | -0.01 ± 0.13 | -0.87 | 0.86 | -0.03 ± 0.13 | -0.80 | 0.47 |
| SE: spherical equivalent; D: diopter; $J_0$ = −(cylinder/2) cos (2 × axis); $J_{45}$ = −(cylinder/2) sin (2 × axis) | | | | | | |

# 2.1Eyerobo VS and ARK-1

The mean difference for spherical diopter, SE, $J_0$, and $J_{45}$ was − 0.04D, -0.05D, 0.02D, and − 0.00D, respectively, (with 86.3%, 93.2%, 98.6%, and 99.1% of the differences within ± 0.50 D). The 95% LOA for spherical diopter, SE, $J_0$, and $J_{45}$ was − 0.86D to 0.75D, -0.89D to 0.75D, -0.33D to 0.33D, and − 0.24D to 0.28D respectively. The spherical diopter, SE, and $J_0$ show statistically significant differences between the measurements of the ARK-1 and Eyerobo VS of the same individuals ($P < 0.001$). There was a strong correlation between the two apparatuses for spherical diopter (r = 0.92), SE (r = 0.92), and $J_0$ (r = 0.85). (Table 2)

Table 2
Comparison of Eyerobo VS with ARK-1: Paired Differences and Correlation Coefficients.

| Sphere (D) | Paired Mean Difference | p-value | 95% Limits of Agreement | R | Agreement Within ≤ 0.5 D |
|---|---|---|---|---|---|
| | **-0.05** | ***P* < 0.001** | **-0.86–0.75** | **0.92** | **86.3%** |
| SE (D) | -0.07 | *P* < 0.001 | -0.89–0.75 | 0.92 | 83.2% |
| $J_0$ (D) | 0.00 | 0.944 | -0.33–0.33 | 0.85 | 98.6% |
| $J_{45}$(D) | 0.02 | *P* < 0.001 | -0.24–0.28 | 0.49 | 99.1% |

SE: spherical equivalent; D: diopter; $J_0$ = −(cylinder/2) cos (2 × axis); $J_{45}$ = −(cylinder/2) sin (2 × axis)

## 2.2Bland-Altman plots

Bland-Altman plots illustrate the agreement between ARK-1 and Eyerobo VS for spherical diopter, SE, $J_0$, and $J_{45}$. The mean difference for spherical diopter was − 0.05 D, with 94.9% (903/952) of eyes within the 95% confidence interval (Fig. 1(a)). For SE, the mean difference was − 0.07 D, with 95.1% (905/952) within the interval (Fig. 1(b)). The mean difference for $J_0$ was 0.00 D, with 98.6% (939/952) within the interval (Fig. 1(c)).For $J_{45}$, the mean difference was 0.02 D, with 95.3% (907/952) within the interval (Fig. 1(d)).

## 3. Discussion

Refractive measurement plays a significant role in RE screening[12], enabling timely detection of vision problems in children and intervention to prevent further visual deterioration.[13] This study measured spherical equivalent (SE) and spherical diopter using the Eyerobo VS device, calculated $J_0$ and $J_{45}$ from astigmatism vectors, and compared these measurements with those obtained from the ARK-1 autorefractor. The Eyerobo VS demonstrated strong agreement with the ARK-1, showing strong correlations for spherical diopter and SE ($r > 0.9$), and acceptable correlations for $J_0$ and $J_{45}$ suitable for screening purposes. Although statistically significant differences were observed between the two devices, evaluation based solely on p-values is insufficient; therefore, Bland-Altman analysis and clinically acceptable limits of agreement (within ± 0.50 D) were also considered.

Agreement studies play a crucial role in clinical decision-making when choosing a device or method for refractive screening.[14] If the 95% limits of agreement (LoA) fall within the predefined criterion of ≤ 0.50 D, this indicates acceptable concordance between the two measurement techniques.[15] Liu et al.[9] resulted a mean difference of 0.46 D in spherical equivalent (95% LoA: −1.32 to 2.24 D) between Eyerobo VS and cycloplegic retinoscopy, with 95% eyes within these limits. Piotr et al.[10](n = 82; age 18–62 years) reported a mean difference of 0.06 D (95% LoA: −0.76 to 0.88 D) in spherical equivalent between

the ARK-1 and Eyerobo VS the under non-cycloplegic conditions. Cui et al.[11] (n = 158; age 6–18 years) reported good agreement with subjective refraction, with acceptable concordance rates ranging from 79.4% to 100.0%. In this study, the agreement within ≤ 0.5 D between Eyerobo VS and ARK-1 measurements were 86.3%, 83.2%, 98.6%, and 99.1% for Spherical diopter, $J_0$, $J_{45}$, and SE, respectively. Compared earlier investigations, which were conducted in ophthalmic hospital settings, the present study was performed in a community-based large-scale population. Moreover, it represents the largest agreement evaluation between the Eyerobo VS and a reference device to date, involving 952 eyes, thus providing more stable and reliable estimates of the limits of agreement. In addition, measurements were obtained under non-cycloplegic conditions, which better reflect real-world vision screening scenarios in schools and communities. Although statistically significant differences were observed between the Eyerobo VS and the mean values of the ARK-1, the high proportion of measurements falling within ± 0.50 D indicates good clinical agreement. Therefore, the Eyerobo VS can be a valuable complementary tool for community-based RE screening.

Remote areas of China are characterized by scarce healthcare resources and limited access to professional optometrists and ophthalmologists.[16] Furthermore, most ophthalmic devices are prohibitively expensive and technically complex, rendering them unsuitable for large-scale refractive screening in underserved regions.[17] In contrast, the Eyerobo VS offers a practical alternative for large-scale screening. It is small, lightweight, easy to carry and operate,[9] and can complete vision screening in a short time, thereby improving the efficiency of large-scale screening. Previous studies have demonstrated the agreement of Eyerobo VS with ARK-1, retinoscopy, and subjective refractive, as well as its repeatability.[9–11] In this large-scale study, Eyerobo VS also showed good agreement with ARK-1, suggesting it could serve as a refractive examination device for large-scale screening, especially in remote areas with a shortage of optometrists.

The limitations of this study are as follows: first, we only measured the refraction of children and adolescents under 18 years of age; second, no comparison was made with other automated refractors. Further studies should focus on comparing measurement consistency between professionals and non-professionals and conducting cost-effectiveness analyses to lay the foundation for large-scale screening in remote areas with a shortage of eye care professionals.

# 4. Materials and methods

This prospective study recruited participants aged 6–18 years who were willing to undergo community refractive screenings between December 2023 and March 2024. The study was approved by the Ethics Committee at He Eye Specialist Hospital and carried out in compliance with the Declaration of Helsinki (IRB (2023) K026.01). All participants and parents provided written informed consent.

4.1Experimental procedure

This study was carried out by He Eye Specialist Hospital. Participants were randomly divided into two groups: the first group initially underwent measurements with the Eyerobo VS, while the second group

started with the ARK-1. After completing the initial measurements, both groups rested for 15 minutes before switching devices for the second round of measurements. The autorefractors were standardized and calibrated to ensure measurement accuracy before each examination.

4.2Inclusion and exclusion criteria

Inclusion criteria;

a. Ages 6 - 18 years;

b. Ability to cooperate with the refractive examination procedures.

Exclusion criteria

a. People with strabismus and a history of previous ophthalmic surgeries.

b. Other health conditions are not suitable for participation in the study.

c. Having had prior ocular surgeries and eye conditions like strabismus;

4.3Measurement parameters

a. Spherical diopter

b. Spherical equivalent (SE): spherical diopter +1/2 cylindrical diopter

c. $J_0$ and $J_{45}$: $J_0$ and $J_{45}$ are vector analysis methods that account for both the direction and magnitude of astigmatism when calculating RE. This is an established technique for accurately evaluating RE. The vector analysis was conducted using the formula proposed by Thibos et al., which involves Jackson crossed cylinders oriented at 0º/90º for J0 and 45º/135º for J45. [18]

$J_0 = -(\text{cylinder}/2) \cos(2 \times \text{axis})$

$J_{45} = -(\text{cylinder}/2) \sin(2 \times \text{axis})$

4.4Equipment information

4.4.1Eyerobo VS

The Eyerobo VS (Eyerobo, China) is a compact, handheld autorefractor derived from the 2WIN-S (Adaptica, Italy). It uses infrared light to measure the refractive state of the eye. The reflected light will form a specific brightness change in the pupil.[8] The device measures the intensity of the brightness changes to ascertain the eye's refractive state, fixation abnormalities, and anterior segment abnormalities. The AI algorithm can identify potential abnormalities in the anterior segment with high accuracy and reliability.[9]

4.4.2ARK-1

The ARK-1 (Nidek, Japan) is processed through a series of optical lenses and elements to determine the refractive status of the eye based on changes in the characteristics of the reflected light, such as intensity, direction, and focus position.[19] The ARK-1 has large-pupil imaging technology that can measure refraction over a wide area up to 6mm in diameter and show the difference between the wide-area and central-area refractions, with a 3.5mm diameter.[20]

4.5Statistical method and sample size calculation

Stata statistical software (version 18.0; StataCorp, United States) was used for data analysis. The Kolmogorov–Smirnov test was used to assess data normality. Data following a normal distribution were presented as mean ± standard deviation. The consistency between ARK-1 and Eyerobo VS was evaluated using Bland-Altman plots and 95% Limits of Agreement (LOA). P <0.05 was considered statistically significant. The clinically acceptable range of agreement was a difference of ±0.50 D between measured values.

# 5. Conclusion

In this study, Eyerobo VS demonstrated good concordance with ARK-1 in measurements of sphere, SE, $J_0$, and $J_{45}$. Given its accuracy and efficiency in assessing pediatric refractive status, the Eyerobo VS is well-suited for use as a refractive examination device in large-scale screening.

# Declarations

**Authors' Contributions**

The study was conceived by Guanghao Qin. Supervision, analysis guidance, and critical manuscript review were provided by Sile Yu. Man Cui and Chunxiu Lin designed the analysis plan, performed the data analysis, and wrote the initial draft. Data collection was supervised by Jiayan Chen. All authors have reviewed and approved the final manuscript and consented to its publication.

**Data availability statement**

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

**ETHICAL APPROVAL**

This study was approved by the Ethics Committee of He Eye Specialist Hospital (IRB (2023) K026.01) and conducted by the Department of Clinical Research.

**CONSENT FOR PUBLICATION**

Not Applicable.

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**Additional Information**

We have no conflicts of interest to disclose.

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# Figures

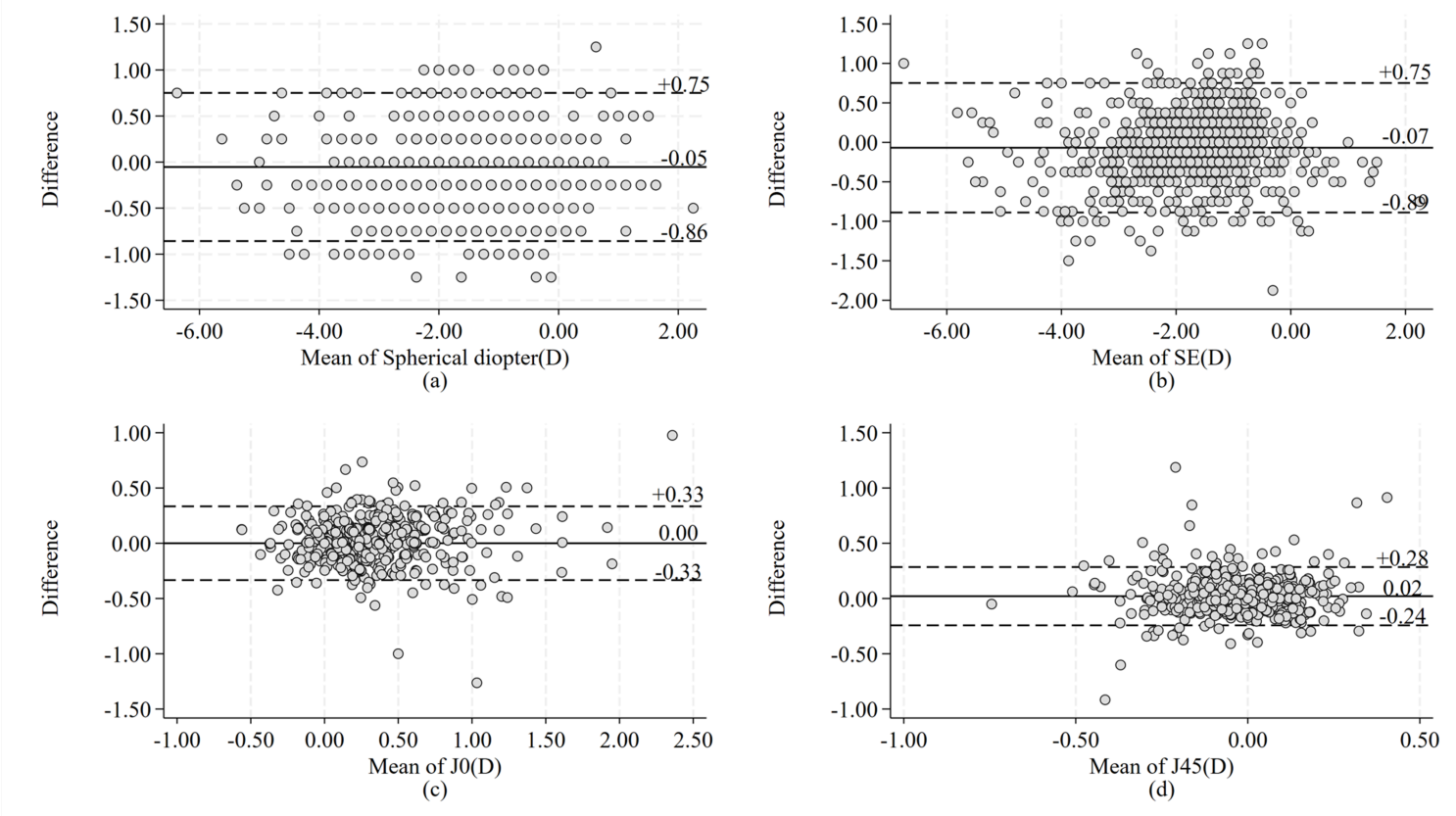


**Figure 1**

Bland-Altman plots showing the spherical diopter(a), SE (b), J0(c), and J45(d) of Eyerobo VS and ARK-1, showing means and 95% confidence intervals.