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ORIGINAL ARTICLE

Reliability and Reproducibility of a Handheld Videorefractor

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ABSTRACT

Purpose. To assess the performance of the 2Win eccentric videorefractor in relation to subjective refraction and table-mounted autorefraction.

Methods. Eighty-six eyes of 86 adults (46 male and 40 female subjects) aged between 20 and 25 years were examined. Subjective refraction and autorefraction using the table-mounted Topcon KR8800 and the handheld 2Win videorefractor were carried out in a randomized fashion by three different masked examiners. Measurements were repeated about 1 week after to assess instrument reproducibility, and the intertest variability was compared between techniques. Agreement of the 2Win videorefractor with subjective refraction and autorefraction was assessed for sphere and for cylindrical vectors at 0 degrees (J_0) and 45 degrees (J_{45}).

Results. Reproducibility coefficients for sphere values measured by subjective refraction, Topcon KR8800, and 2Win (±0.42, ±0.70, and ±1.18, respectively) were better than their corresponding J_0 (±1.0, ±0.85, and ±1.66) and J_{45} (±1.01, ±0.87, and ±1.31) vector components. The Topcon KR8800 showed the most reproducible values for mean spherical equivalent refraction and the J_0 and J_{45} vector components, whereas reproducibility of spherical component was best for subjective refraction. The 2Win videorefractor measurements were the least reproducible for all measures. All refractive components measured by the 2Win videorefractor did not differ significantly from those of subjective refraction, in both sessions ($p > 0.05$). The Topcon KR8800 autorefractometer and the 2Win videorefractor measured significantly more positive spheres and mean spherical equivalent refraction ($p < 0.0001$), but the J_0 and J_{45} vector components were similar ($p > 0.05$), in both sessions.

Conclusions. The 2Win videorefractor compares well, on average, with subjective refraction. The reproducibility values for the 2Win videorefractor were considerably worse than either subjective refraction or autorefraction. The wide limits of reproducibility of the 2Win videorefractor probably limit its usefulness as a primary screening device.

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Key Words: autorefraction, subjective refraction, videorefractor, vision screening, refractive error, astigmatism

The most common amblyogenic factors in childhood disorders in developed countries are strabismus, refractive errors, and media opacities.[1–3] Only a few screening programs identifying amblyogenic factors have been conducted on infants.[3–9] Early screening leads to earlier detection and can reduce the prevalence of amblyopia in childhood.[10,11] Photoscreeners/video screeners have been used to detect these disorders because they require very little cooperation from the infant. Also, the eye images allow fundus reflection that can reveal media opacities, refractive errors, and strabismus.[12]

The 2Win videorefractor (Adaptica, Padova, Italy) is a new handheld video intended for use with young children. We chose to first study only young adults assuming that comparison to established alternatives was a first logical step.

The 2Win videorefractor has no internal fixation target that risks proximal accommodation; instead, it enables use of real-world targets. It is small, is easy to use, and has several important technologies for a faster and more accurate screening process and efficient record-keeping. As with two popular photoscreeners—the MTI photoscreener (Medical Technology, Iowa City, IA)[13] and the VRB-100 photoscreener (Fortune Optical, Padova, Italy)[14]—the 2Win videorefractor operates on the principle of eccentric photorefraction using infrared light. This differs from isotropic refraction, which essentially measures accommodative lag and

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relates this lag to the refraction of the subject. An earlier study[15] showed that the 2Win videorefractor had lower sensitivity and specificity than the Plusoptix S12 photoscreener but similar sensitivity and higher specificity than another photoscreener (the Spot). In that study,[15] the 2Win enabled some measurements where the other two photoscreeners could not.

Compared with autorefractometry and retinoscopy, subjective refraction most closely approximates the results of cycloplegic refraction,[21–28] with autorefractometers overestimating myopia and underestimating hyperopia.[21,22,29] The difference in mean spherical equivalent refraction (MSER), with and without cycloplegia, was reported to be 0.21 to 0.71 diopters (D)[21,22,29] in children and to be smaller with adults (about 0.14 D).[29] Most previous studies[15–17,20,25,26] validated photoscreeners/video screeners against cycloplegic refraction, although some studies[18,22,27,29,30] have also used noncycloplegic refraction. Our study compared the 2Win videorefractor with objective (Topcon KR8800 autorefractometer) and subjective refraction. The authors are unaware of any prior studies comparing the Topcon KR8800 autorefractor with subjective refraction without cycloplegia.

We tested the 2Win on adult eyes assuming good agreement with subjective refraction and with the autorefractometer, a condition we felt needed to be demonstrated before carrying out measures with young children.

METHODS

Subject Population

The study was approved by the Research Ethics Committee of the College of Applied Medical Sciences, King Saud University. Consent was obtained from adult participants after understanding the nature of the study. The study adhered to the tenets of the 1967 Declaration of Helsinki as revised in Edinburgh in 2000. Eighty-six eyes of 86 healthy participants, all of whom were students from the College of Applied Medical Sciences, were included in this study. Inclusion criteria were age 18 years or older and a corrected visual acuity of 0.1 logMAR (logarithm of the minimum angle of resolution) (6/7.5) or better. Exclusion criteria were ocular pathology (including any condition known to interfere with autorefractor performance, e.g., asteroid hyalosis[31] or abnormality including strabismus and any previous ocular surgery). Only measurements from the right eye of each subject were included in the study. The left eye was used only if the right eye did not meet inclusion criteria.

Between January and April 2014, subjective refraction was performed by an experienced optometrist (KO), autorefraction using the 2Win videorefractor was carried out by another optometrist (UO), and Topcon KR8800 autorefractor was performed by WA. To assess reproducibility, measures were repeated about 1 week later. All measurements were made between about 10 AM and about 3 PM. In all measurement sessions, the order of measurement with the three techniques was randomized. Examiners were masked to the results of other refractive measurements, each conducted in separate rooms.

Subjective Refraction

Static retinoscopy was the starting point for monocular subjective refraction at 6 M. Cross-cylinder axis refining (in 2.5-degree increments) and power refining (in 0.25-D increments) were used for the astigmatic refraction, and then binocular balancing and duochrome testing and sphere were used for best-corrected visual acuity. The average of two successive refractions was used for statistical analysis.

2Win Videorefractor

The 2Win (Adaptica), a handheld infrared videorefractor, measures binocular infrared photorefraction and evaluates the gaze direction, ocular alignment, pupil diameter, pupil distance, and the accommodative balance/imbalance between the two eyes. The infrared target provides the reflected image that depends on refractive error. Refraction, at 1 m distance constantly monitored, is based on measures in four different meridians whereas binocular alignment is maintained using corneal reflexes. Dim light assures needed pupils between 4 and 7 mm diameter.

The examiner held the instrument horizontally with both hands, at the height of the patient's eyes. Subjects were instructed to fixate on the small central target at the center of the camera wide-open eyes. The examiner adjusted the measurement distance by focus while noting the corneal reflexes. Two green circles and a horizontal line appear around the patient pupils. The 2Win displays measurements on the screen. As advised by the manufacturer, measurements were only recorded if they had a reliability index higher than 5 (maximum is 9); measures were repeated when the reliability index was 5 or less. The manufacturer's instructions ask that measurement sensitivity be set to ±0.25 D for power and 1 degree for axis. Manual averaging of two accurate measurements was the basis of statistical analysis.

Topcon KR8800 Autokeratorefractometer

The KR8800 (Topcon Inc, Tokyo, Japan) autorefractor is a multifunctional device that determines corneal refractive status using a rotary prism measurement.[32] It measures objective spherical refractive power, cylindrical refractive power, astigmatic axis, corneal curvature, the direction of the principal meridian, and corneal refractive power. It must have at least a 2-mm pupil and uses a 3D auto alignment function.

The Topcon KR8800 uses the Scheiner double-pinhole principle for data capture. Two light sources are imaged in the plane of the pupil to simulate the Scheiner pinhole apertures. First, the Badal system is focused in one meridian, and then continuous measurements are taken through 180 degrees using a rotating prism system. A "fogging" target is used to relax accommodation.[33] Automatic capture of four measures was repeated twice and the average was used for statistical analysis. Measurement accuracy was set to 0.12 D for power and 1 degree for axis as advised by the manufacturer.

Statistical Analysis

The averages (in negative cylinder form) gave MSER and cylinder. The cylinder and axis were expressed as vectors.[34] The resulting vector components were Jackson cross-cylinders at 0 degrees [$J_0 = -(\text{cylinder}/2) \times \cos(2 \times \text{axis})$] and at 45 degrees [$J_{45} = -(\text{cylinder}/2) \times \sin(2 \times \text{axis})$]. The calculated values are tabulated descriptively as mean ± SD and range of values for all tests, in each session. The Pearson correlation coefficient provided association between

TABLE 1.

Comparison of mean values of sphere, MSER, cylindrical power, and vector components by the 2Win videorefractor with both subjective refraction and Topcon KR8800 autokeratorefractometer objective refraction in both sessions

Refraction	Subjective	Topcon 8800	2Win	p*	p†	p‡
Session 1						
Sphere, mean ± SD (range), D	−0.26 ± 1.97 (−6.50 to 5.50)	−0.61 ± 2.12 (−6.62 to 6.62)	−0.16 ± 1.95 (−5.50 to 5.75)	<0.0001	>0.05	<0.0001
SER, mean ± SD (range), D	−0.58 ± 2.03 (−7.25 to 5.13)	−0.96 ± 2.21 (−7.81 to 6.37)	−0.67 ± 1.96 (−6.00 to 4.91)	<0.0001	>0.05	<0.0001
Cyl, mean ± SD (range), D	−0.64 ± 0.83 (−4.50 to 0.00)	−0.71 ± 0.92 (−5.00 to 0.00)	−1.01 ± 1.07 (−5.63 to 0.00)	>0.05	<0.0001	<0.0001
J_0, mean ± SD (range), D	0.07 ± 0.41 (−0.94 to 2.23)	0.11 ± 0.47 (−0.90 to 2.48)	0.03 ± 0.53 (−1.03 to 2.66)	>0.05	>0.05	>0.05
J_{45}, mean ± SD (range), D	0.01 ± 0.32 (−0.84 to 1.36)	0.01 ± 0.33 (−0.77 to 1.19)	0.02 ± 0.51 (−2.78 to 0.96)	>0.05	>0.05	>0.05
Session 2						
Sphere, mean ± SD (range), D	−0.30 ± 2.00 (−6.00 to 6.00)	−0.59 ± 2.12 (−6.13 to 7.45)	−0.27 ± 2.00 (−6.00 to 4.38)	<0.001	>0.05	<0.001
SER, mean ± SD (range), D	−0.63 ± 2.06 (−6.75 to 5.63)	−0.96 ± 2.19 (−7.06 to 7.10)	−0.79 ± 2.05 (−6.50 to 3.75)	<0.0001	<0.0001	<0.0001
Cyl, mean ± SD (range), D	−0.66 ± 0.80 (−4.25 to 0.00)	−0.74 ± 0.95 (−5.50 to 0.00)	−1.06 ± 0.96 (−5.13 to 0.00)	>0.05	<0.0001	<0.0001
J_0, mean ± SD (range), D	0.03 ± 0.38 (−1.61 to 1.74)	0.08 ± 0.48 (−0.62 to 2.73)	−0.06 ± 0.57 (−2.34 to 1.90)	>0.05	>0.05	>0.05
J_{45}, mean ± SD (range), D	0.03 ± 0.35 (−1.38 to 1.09)	0.05 ± 0.36 (−1.37 to 1.26)	0.01 ± 0.43 (−1.21 to 1.21)	>0.05	>0.05	>0.05

p Values are results of comparison: Topcon versus subjective (*), 2Win versus subjective (†), and Topcon versus 2Win (‡) autorefractometers.

SER, spherical equivalent refractive error (sphere + 0.5 * cylinder); Cyl, cylinder.

techniques for all refractive components (both session measurements were pooled). Analyses were made using GraphPad Prism software (version 6.00; GraphPad Software Inc, La Jolla, CA). Statistical significance ($p < 0.05$) was established. A power of 80% was calculated for the 84 eyes using the G* Power software 3.1.10 version.

Analysis of the Limits of Agreement between Refractive Techniques

Agreement between methods in each session was assessed for sphere, MSER, and J_0 and J_{45} vector components using Bland and Altman plots showing agreement between the 2Win videorefractor and subjective refraction, between subjective refraction and KR8800, and between the 2Win videorefractor and the KR8800 autorefractor. The mean of the differences between methods and the 95% limits of agreement (LoAs) between measurements expressed as mean difference ± 1.96 SD of differences[35] were calculated. Differences between the three methods in each session were compared using repeated-measures analysis of variance.

Assessment of Reproducibility and Instrument Variability

The mean and SD of the differences between test and retest (i.e., sessions 1 and 2) were calculated for sphere, MSER, and J_0 and J_{45} vector components in each method. The coefficient of reproducibility (CoR) for each technique was also calculated as 1.96 × SD of differences between sessions. Differences between sessions for each technique were compared using paired t tests. Bland-Altman plots also showed the 95% confidence intervals (mean ± SD of between-session differences) for each technique. The differences in intertest variability compared between-session mean differences for all three methods.

RESULTS

Of the initial subject cohort of 89 subjects, three subjects were excluded. Two were lost to follow-up after completing the first session of measurements, and for the third subject, it was not possible to get a reading with the 2Win videorefractor. In all, 46 men (53.5%) and 40 women (46.5%) were analyzed. Based on MSER of subjective refraction, the percentage of myopes (≥−0.75 D), emmetropes (±0.50 D), and hyperopes (≥+0.75 D) was 32.5, 53.5, and 14%, respectively. Table 1 shows the mean ± SD spherical refractive error, MSER, the cylindrical component, and the J_0 and J_{45} vector components determined by subjective refraction, the 2Win videorefractor, and the Topcon KR8800 autorefractor with the results of comparative analysis between methods in each session. The cylindrical power was measured in all participants from −5.00 to 0.00 D, from −5.63 to 0.00 D, and from −4.50 to 0.00 D for the Topcon KR8800 autorefractor, the 2Win videorefractor, and subjective refraction, respectively. In the second visit, the corresponding cylindrical values ranged from −5.50 to 0.00 D, from −5.13 to 0.00 D, and from −4.25 to 0.00 D, respectively.

Values of refractive error measured by the 2Win videorefractor were significantly correlated ($p < 0.0001$ for all) with subjective

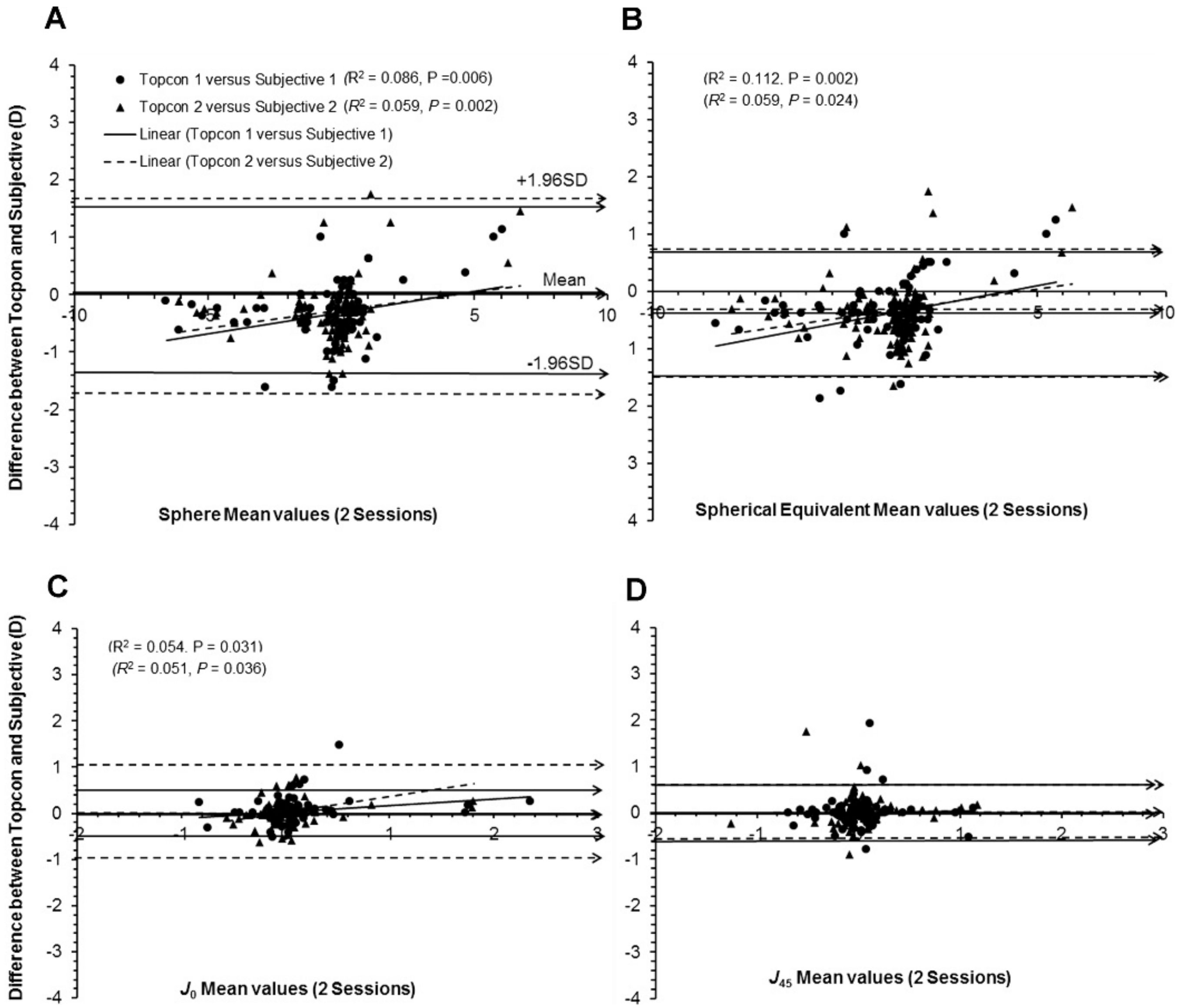

FIGURE 1.

Difference between subjective refraction and Topcon KR8800 autorefractometer objective (A) mean sphere measures, (B) MSER measures, (C) mean Jackson cross-cylinder measures at 0 degrees (J_0), and (D) mean Jackson cross-cylinder measures at 45 degrees (J_{45}). Solid lines, session 1; dotted lines, session 2.

refraction and autorefraction for sphere (r = 0.92 and 0.92), cylinder power (r = 0.89 and 0.90), and MSER (r = 0.93 and 0.93). The autorefraction values were also significantly correlated ($p < 0.0001$ for all) with subjective refraction for sphere (r = 0.97), cylinder power (r = 0.96), and MSER (r = 0.97).

Agreement between Methods of Refraction

The spherical component, MSER, and cylindrical power were significantly different between methods for session 1 ($p < 0.0001$ for all) and session 2 ($p < 0.0001$ for all), but J_0 and J_{45} vector components were not significantly different between methods (repeated-measures analysis of variance, $p > 0.05$ for both). *Post hoc* tests showed that, in each session, the spherical refractive errors and the MSER measured by subjective refraction were significantly different ($p < 0.0001$) from those obtained by the Topcon KR8800 autorefractor but were similar ($p > 0.05$) to those measured with the 2Win videorefractor, for both measurement sessions (Table 1). There were statistically significant differences in the cylindrical component between the 2Win videorefractor and subjective refraction ($p < 0.0001$ in both sessions) but not between the Topcon autorefractor and subjective refraction ($p > 0.05$ for both sessions).

Combined-session Bland-Altman plots showing the LoAs for the spherical component of the refractive error, MSER, and J_0 and J_{45} vector components between subjective refraction and the Topcon KR8800 autorefractor are shown in Fig. 1A to D, respectively. The corresponding LoA plots between subjective refraction and the 2Win videorefractor are shown in Fig. 2A to D, respectively. From the figures, it can be deduced that the 2Win videorefractor performed better than the Topcon KR8800 autorefractor when compared with subjective refraction for spherical refractive error (maximum bias, 0.10 vs. −0.35 D) and MSER (maximum bias, 0.16 vs. −0.38 D). The Topcon KR8800 autorefractor consistently returned more myopic measurements than the subjective refraction (Fig. 1A, B).

In all sessions, about 60% of the MSER estimated using the Topcon KR8800 was within ±0.50 D of subjective refraction, and for the 2Win videorefractor, 59% of the MSER was within ±0.50 D of subjective refraction (Table 2). There were no significant differences in the cylindrical vectors measured by the Topcon KR8800 autorefractor (Fig. 1C) and the 2Win videorefractor (Fig. 2C) when compared with subjective refraction. However, a significant difference was evident in the mean cylinder powers measured by the 2Win videorefractor with respect to subjective refraction (Table 1). In all sessions, the difference in mean refractive components between 2Win videorefractor and the other techniques is also depicted in Table 2.

When the Topcon KR8800 autorefractor was compared with the 2Win videorefractor, the former measured statistically significantly more myopic sphere and SER than the latter (2Win videorefractor) with a maximum bias of 0.45 D ($p < 0.0001$) for sphere (Fig. 3A) and 0.29 D ($p < 0.0001$) for MSER (Fig. 3B). The mean cylinder powers measured by the Topcon autorefractor were also statistically significantly ($p < 0.0001$) more positive than 2Win videorefractor measured values, in both sessions. The LoA between the two techniques for the measured cylinder powers ranged from −0.62 to 1.24 D and from −0.53 to 1.14 D in sessions 1 and 2, respectively. In contrast, the cylindrical vectors determined by the 2Win videorefractor and the Topcon

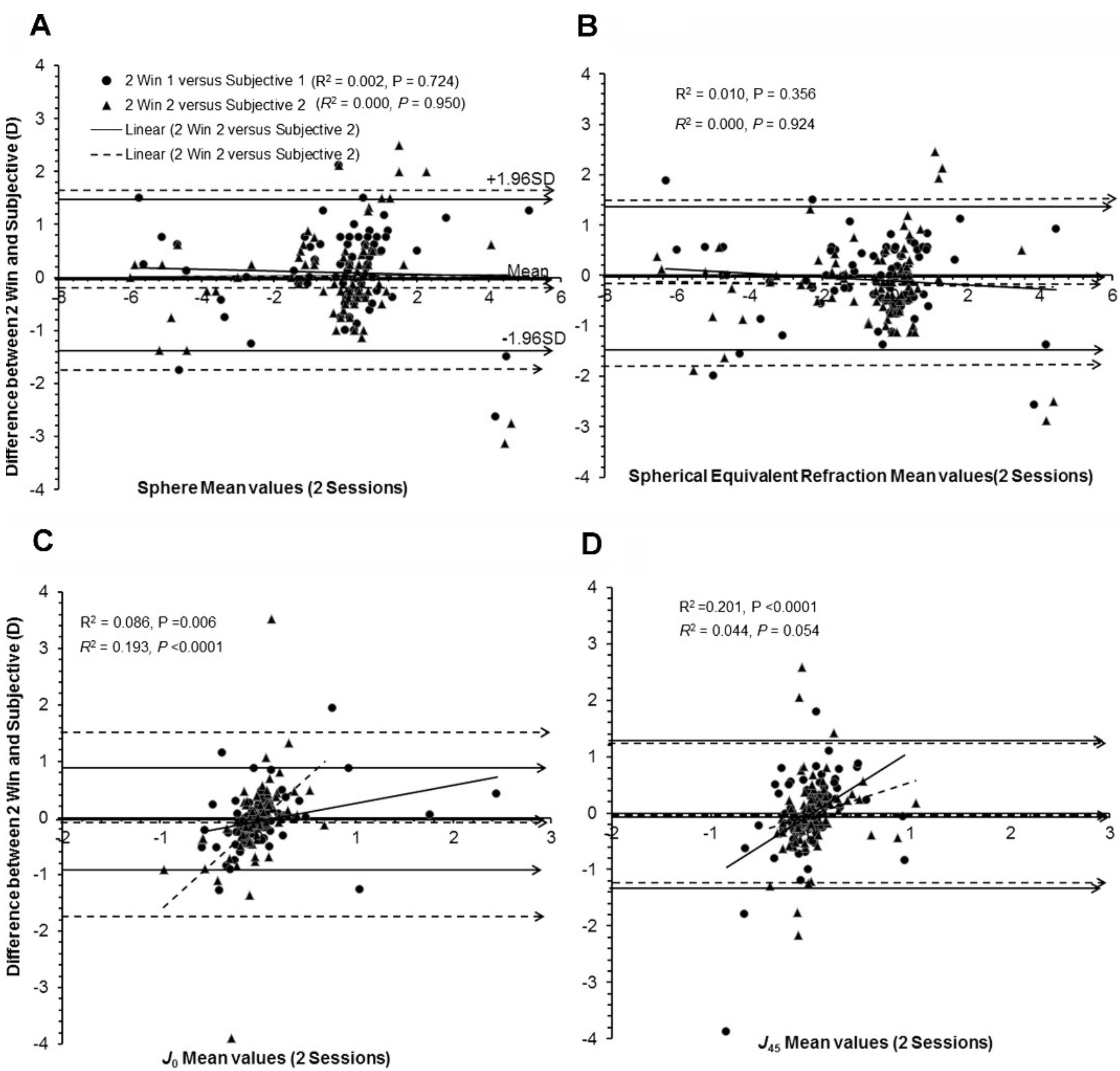

FIGURE 2.

Difference between subjective refraction and 2Win videorefractor objective (A) mean sphere measures, (B) MSER measures, (C) mean Jackson cross-cylinder measures at 0 degrees (J_0), and (D) mean Jackson cross-cylinder measures at 45 degrees (J_{45}). Solid lines, session 1; dotted lines, session 2.

TABLE 2.

Difference in mean refractive components of the final prescription between techniques (2Win videorefractor minus subjective refraction/Topcon KR 8800 autorefractometer minus subjective refraction) in all sessions

	Sphere	MSER	Cylinder	J_0	J_{45}
Mean difference	0.06/−0.32	−0.13/−0.35	−0.38/−0.07	−0.07/0.04	−0.02/0.01
SD of differences	0.81/0.52	0.77/0.55	0.47/0.27	0.67/0.41	0.65/0.30
Within ±0.25 D, %	41/39	30/27	44/83	56/82	51/83
Within ±0.50 D, %	62/65	59/60	72/95	84/94	77/95
Within ±1.00 D, %	87/94	90/94	94/99	95/99	93/99

J_0, Jackson cross-cylinder at 0 degrees; J_{45}, Jackson cross-cylinder at 45 degrees.

KR8800 autorefractor were not significantly different ($p > 0.05$) as shown in Table 1. Corresponding Bland-Altman plots are consequently not shown. Table 4 shows that the sphere, cylinder and SER values were strongly correlated between techniques ($P < 0.0001$, for all comparisons), but the cylinder vector components were better correlated when the autorefractor was compared with subjective refraction.

Reproducibility of Refraction Techniques

The calculated CoRs for the three techniques are shown in Table 3. Although reproducibility indices were acceptable for the spherical component and spherical equivalent refraction measured with subjective refraction and for all indices measured with Topcon KR8800, they were otherwise poor. The plots shown in Fig. 4 are combined reproducibility plots for all measured refractive components by the three techniques. For the Topcon KR8800 autorefractor and subjective refraction, the bias was very small for all refractive components (<0.04 D) and smallest for J_{45} vector components. For the 2Win videorefractor, the maximum bias was observed for MSER (0.13 D), and the intertest variability was greatest for the measured J_0 vector component (±1.5 D) in comparison with those of the Topcon KR8800 autorefractor and subjective refraction. Between techniques, intertest variability (comparing the between-session mean differences) did not differ significantly for sphere ($p = 0.2029$), MSER ($p = 0.1642$), J_0 ($p = 0.6816$), and J_{45} ($p = 0.9254$) measured values.

DISCUSSION

The results from this study show that the 2Win videorefractor is comparable to subjective refraction in its ability to measure spherical refractive error and MSER in young adults. There was no significant difference in mean spherical refractive error between the 2Win videorefractor and the subjective refraction, although the LoAs were large (ranging from −1.67 to +1.73 D, Fig. 2A). Despite the absence of a significant difference in MSER between the 2Win and subjective refraction, the 2Win showed a tendency to overestimate moderate-to-high myopia and a more pronounced underestimation of moderate-to-high hyperopia (as shown in Fig. 2B). Despite this, there were no significant range effects evident for the 2Win videorefractor. Similarly, the coefficients of determination of the mean difference scatter plots, spherical equivalent, and the J_0 cylinder component for either measurement session did not show any range effects. There was a statistically significant range effect, with the 2Win videorefractor, for the J_{45} cylindrical component in the first measurement session, but not in the second. The Topcon KR8800 autokeratorefractometer, on the other hand, showed statistically significant range effects in both sessions for all indices except the J_{45} cylindrical component, in which there was no significant range effect in either session. Together, these results suggest a greater range effect with the KR8800 than with the 2Win videorefractor and that subjects with a J_{45} cylindrical component (representing oblique astigmatism) were not numerous enough to enable a reliable assessment of range effects. The 2Win videorefractor has a limited operating range, precluding showing range effects with higher refractive errors.

The mean sphere and MSER measured by the 2Win videorefractor were within ±0.50 D of that found by subjective refraction in about 64 and 60% of all eyes, respectively. The 2Win videorefractor measured significantly higher negative cylinder values than the subjective refraction. About 72 and 94%, respectively, of the mean cylinder power measured by the 2Win videorefractor were within ±0.50 and ± 1.00 D of that found by subjective refraction (Table 2). These results suggest that the 2Win was not particularly accurate in estimating the subjective sphere and cylinder components in our adult subject sample. We assume that it would be even less accurate for young children.

However, the 2Win videorefractor is a screening device designed to pick up errors of refraction that could be amblyogenic; thus, getting within ±0.50 D of the subjective sphere or cylinder is perhaps not necessary. This means that the 2Win videorefractor should be limited to screening. For cylindrical vectors, no significant difference was observed in the J_0 and J_{45} vectors measured by the 2Win videorefractor and subjective refraction and the J_0 and J_{45} were within ±0.50 D of that found by subjective refraction in 84 and 77% of all eyes, respectively. These findings are comparable to or better than those reported for other photoscreeners/video screeners used in previous studies.[26,36,37] The MTI photoscreener measurements

TABLE 3.

The CoR values for sphere, MSER, cylinder power, and cylinder vector components at 0 degrees (J_0) and 45 degrees (J_{45}) measured by the 2Win videorefractor, subjective refraction, and the Topcon KR8800 autokeratorefractometer

Techniques	Sphere	MSER	Cyl	J_0	J_{45}
Topcon KR8800	0.70	0.69	0.44	0.85	0.87
2Win	1.18	1.09	0.86	1.66	1.31
Subjective refraction	0.42	0.83	0.41	1.00	1.01

CoR = 1.96 × SD of differences.

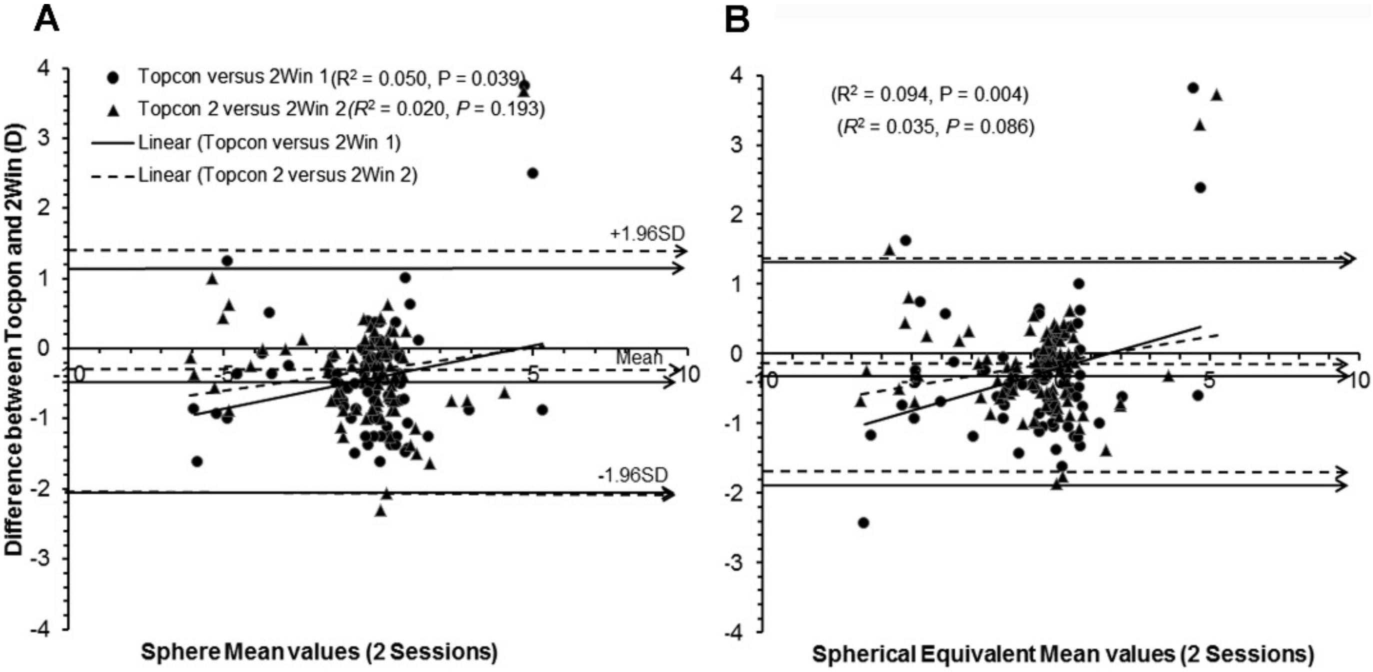

FIGURE 3.

Difference between Topcon KR8800 autorefractometer and 2Win videorefractor objective (A) mean sphere measures and (B) MSER measures. Solid lines, session 1; dotted lines, session 2.

were reported to be within ±0.50 D of the MSER measured by subjective refraction in 67% of all adult eyes, and 74% were within ±0.50 D of the cylindrical component of subjective refraction.[38] Unlike the 2Win videorefractor, the spherical values measured by the MTI photoscreener in that study[38] were statistically significantly more positive than those measured with subjective refraction, and the measured cylinder values were higher than those measured by subjective refraction in young adults. Schimitzek and Lagrèze[37] observed that the Plusoptix PowerRefractor leads to a considerable myopic shift in young subjects.

The Topcon KR8800 autorefractor measured significantly more negative and less positive values of sphere and MSER than subjective refraction but the LoAs were small (ranging from −1.35 to 0.74 D, Fig. 1). Even with the significant differences in measured values between the autorefractor and subjective refraction, about 61% of the spherical component and MSER measurements in all sessions were within ±0.50 D of the subjective refraction. Between the autorefractor and subjective refraction, the measured cylindrical power and vector components were similar. In all, about 94% of J_0 and 95% of J_{45} vector components estimated using the Topcon KR8800 autorefractor were within ±0.50 D. Almost all (99%) J_0 and J_{45} vector components were within ±1.00 D of subjective refraction. These results show that the Topcon KR8800 autorefractor tends to measure more negative values than subjective refraction and are consistent with previous reports on autorefractor measurements,[25,39–42] including a study using an earlier version of the Topcon autorefractometer (KR8000).[33]

Overall, measurements obtained by both instruments in this study compare well with the results reported for the validation of other autorefractors,[25,39–42] although the 2Win videorefractor–measured values were better than the Topcon KR8800 autorefractor–measured values. The cylindrical power component, returned by the 2Win videorefractor, was less reliable than the axis component, returning significantly higher negative cylinders than subjective refraction and the Topcon autorefractometer. The autorefractor measured significantly more minus spherical refractive error values than the videorefractor (Fig. 3). This finding is consistent with previous reports comparing videorefractor/photorefractor measurements with measurements obtained by autorefraction in adults.[19,26] The 2Win videorefractor should neither be confused with a tabletop

TABLE 4.

Results of correlation analysis between techniques for all measured refractive components in all sessions (expressed as Pearson correlation coefficient, *r*)

Between techniques	Sphere	SER	Cyl	J_0	J_{45}
2Win vs. subjective refraction	0.92	0.93	0.98	0.01	−0.26
p	<0.0001	<0.0001	<0.0001	0.93	0.0005
2Win vs. Topcon KR8800	0.92	0.93	0.90	0.29	−0.08
p	<0.0001	<0.0001	<0.0001	0.29	0.301
Topcon KR8800 vs. subjective refraction	0.97	0.89	0.57	0.57	0.61
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

J_0 and J_{45} are cylinder vector components at 0 and 45 degrees, respectively; p < 0.05 is considered significant.

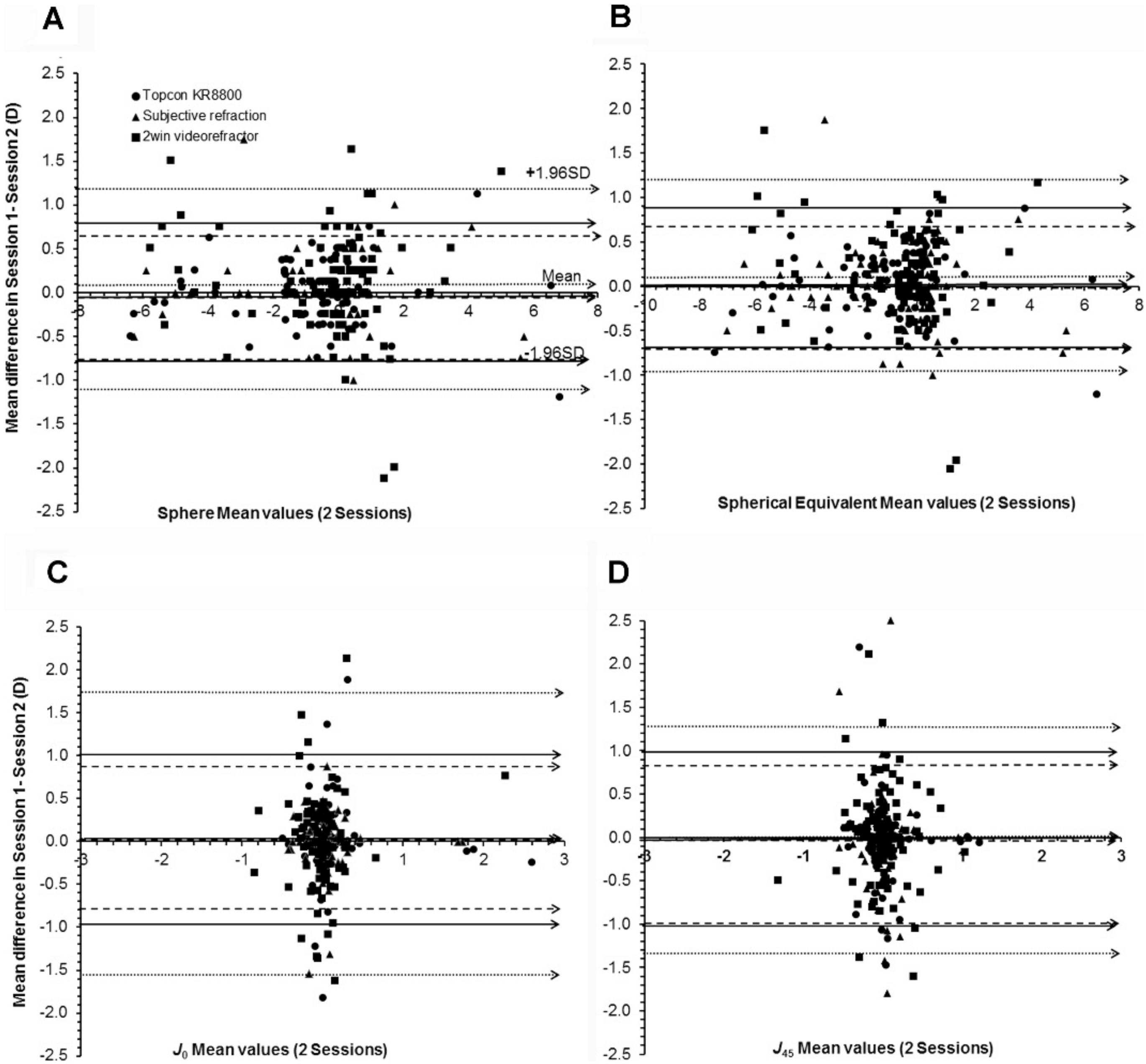

FIGURE 4.

Reproducibility plot of (A) mean sphere values, (B) MSER, and mean cylinder vector component values measured (C) at 0 degrees (J_0) and (D) at 45 degrees (J_{45}), measured by subjective refraction (solid lines), the Topcon KR8800 autokeratorefractometer (long dashed lines), and the 2Win videorefractor (dotted lines).

autorefractometer nor be considered a small portable autorefractometer as the manufacturer clearly warns. Unlike the 2Win videorefractor, autorefractors are designed to measure refractive errors of one eye at a time. Choi et al.[26] and Schimitzek and Lagrèze[37] also observed that the cylindrical refractive components measured by the autorefractor and the videorefractor were not significantly different.

That the 2Win videorefractor closely approximates (but returns more positive sphere readings than) subjective refraction indicates that it would be a useful addition in the eye care practitioner's clinic to examine certain categories of adult patients whom it would otherwise be difficult to refract. The 2Win could also be useful for screening very young children for the refractive causes of amblyopia. Its size, portability, and innovative features, in addition to reasonable preliminary results from this and earlier studies,[15] could enhance its screening use for eye care practitioners, pediatricians, and general practitioners.

Although photoscreeners are designed for use on very young children,[3,8,9,27] they are unreliable in some children as old as 3 years.[14] This unreliability is based on the large, variable accommodation and on poor cooperation for this age group.[15] The 2Win videorefractor was deliberately designed to return more positive spherical refractive error values than noncycloplegic refraction to help mitigate the effects of accommodation in young children (personal communication with the manufacturers).

All refractive measurements obtained by subjective refraction, the 2Win videorefractor, and the Topcon KR8800 autorefractor were reproducible (Fig. 4), but the Topcon KR8800–measured values were considerably more reproducible than those of the 2Win videorefractor (Table 2). Subjective refraction has CoR lower than the other techniques when the sphere and cylinder power were analyzed (Table 2) and, as such, can be used as a gold standard in studies on refraction in adults. In contrast, the 2Win videorefractor displayed the highest CoR with variability indices that were consistently large in comparison with other techniques. This was especially true for the cylinder vectors (Fig. 4), where the limits of reproducibility were double those of the Topcon KR8800 (Table 2). Nevertheless, the 2Win videorefractor reproducibility values were better than those reported for previous videorefractors,[5,42] although for a considerably smaller sample of adult subjects.

Cycloplegia, which increases the accuracy of autorefractometers,[39,40] was not used in this study mostly because we considered that, in the group of adult subjects whom we enrolled, the role of accommodation would be very small, such that subjective refraction would be a close approximation of the true refraction in most of these subjects. In addition, noncycloplegic subjective refraction is generally accepted by eye care practitioners for adult prescribing and has been widely used for validation of refraction techniques.[5,23–25,29]

On the other hand, retinoscopy was used as a starting point and not as a reference standard because, in adults, it plays a similar role as autorefractors.[5,28] We did not have reason to analyze the images of the 2Win videorefractor. We observed that the 2Win videorefractor slightly underestimated refraction values in high myopic subjects, but this tendency did not reach statistical significance probably because the subjects in this study were mostly emmetropes.

Our study population consisted only of adults, who would be expected to be significantly more cooperative than the young children the 2Win videorefractor was designed to screen. The use of adults made it possible to compare the refractive data returned by the 2Win with those of an autokeratorefractometer and subjective refraction.

In conclusion, the results suggest that the handheld 2Win videorefractor is a useful screening device for refraction over the range of refractive errors assessed in this study. However, its underestimation of moderate-to-high hyperopia is a concern, because significant hyperopia in very young children, which is associated with the development of amblyopia, may be missed. The device is more reliable in the estimation of cylindrical axis than it is for cylinder power. Reproducibility coefficients of sphere and cylinder measures were best for subjective refraction, followed by autorefraction, which also was best for estimation of the MSER and J_0 and J_{45} vector components. For all refractive measures, reproducibility was poor for the 2Win videorefractor in relation to the other techniques but may be acceptable for a screening device. Large-scale studies would need to be conducted to confirm these results.

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