A Comparison of Autorefraction and Subjective Refraction With and Without Cycloplegia in Primary School Children

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• PURPOSE: To evaluate the accuracy of autorefraction using three autorefractors comparing to subjective refraction in diagnosing refractive error in children.
• DESIGN: A cross-sectional study.
• METHODS: SETTING: Community based study. STUDY POPULATION: 117 children sampled from primary schools. PROCEDURES: All subjects underwent autorefraction using three auto refractors and subjective refraction with and without cycloplegia. MAIN OUTCOME MEASURES: Spherical power, cylindrical power, and spherical equivalence (SE).
• RESULTS: Without cycloplegia, the mean SE were significantly different for Retinomax K plus 2 (−1.55 diopters, SD 2.37 diopters; 95% CI −1.98 to −1.12; $P < .0001$) and Canon RF10 (−1.11 diopters; SD 2.61 diopters; 95% CI −1.59 to −0.64; $P = .0023$) compared with monocular subjective refraction (−0.80 diopters; SD 2.25 diopters; 95% CI −1.21 to −0.35). Mean SE was significantly different for Grand Seiko WR5100K (−0.79 diopters; SD 2.40 diopters; 95% CI −1.23 to −0.35; $P = .0002$) compared with binocular subjective refraction (−0.62 diopters; SD 2.51 diopters; 95% CI −1.07 to −0.16). With cycloplegia, there was no significant difference in mean SE between refraction methods. Sensitivity and specificity results for the diagnosis of myopia: Without cycloplegia: Retinomax K plus 2 (sensitivity 1.0, specificity 0.51); Canon RF10 (sensitivity 0.92, specificity 0.81); and Grand Seiko WR5100K (sensitivity 0.91, specificity 0.98). With cycloplegia: Retinomax K plus 2 (sensitivity 0.97, specificity 0.99); Canon RF10 (sensitivity 0.97, specificity 0.96); and Grand Seiko WR5100K (sensitivity 1.0, specificity 0.97).
• CONCLUSIONS: Under noncycloplegic conditions, all three autorefractors have a tendency towards minus over correction in children resulting in over diagnosis of myopia. However autorefractors were accurate under cycloplegic conditions. (Am J Ophthalmol 2006;142: 68–74. © 2006 by Elsevier Inc. All rights reserved.)

CYCLOPLEGIC RETINOSCOPY AND SUBJECTIVE REfraction remain the gold standard for measuring refractive status in children. However, cycloplegia is limited by the time needed to achieve full cycloplegia, its association with patient discomfort, inconvenience, and additional cost. More recently, autorefractors without cycloplegia have become widely used to obtain the objective refractive status of children in vision screening, clinical practice, or in research settings such as epidemiologic surveys, and clinical trials.[1–9] Their popularity in clinical practice is attributable to their ease of use, ready availability, and customers' acceptance. Most autorefractors have built-in automatic fogging mechanisms to avoid accommodation during measurement. There is evidence suggesting noncycloplegic autorefraction has reasonable accuracy and repeatability when compared with cycloplegic retinoscopy and subjective refraction.[2,4,10–19] Thus, there is some justification to the use of autorefractors for the purpose of vision screening in children.[2,18,20–22] However, there is also evidence that accommodative effort, when using these instruments, may not be completely neutralized resulting in reduced accuracy especially towards minus over correction.[1,19,23] This is especially pertinent in children who have high accommodative reserve. Additionally, there is an increasing body of evidence linking accommodative effort with myopic progression.[24–33] Children wearing glasses with minus over correction will have to increase their accommodative effort which may in turn predispose them to myopic progression. The accuracy of the autorefractors in obtaining the correct refractive error will assume great importance when prescription for refractive error is made based in part or solely on noncycloplegic autorefractor readings.

This situation is acute in countries where, because of the lack of qualified optometrists and ophthalmologists, full cycloplegic subjective refractions are not performed and

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glasses prescriptions are routinely given based solely on autorefraction readings.

The aim of the study is to evaluate the accuracy of noncycloplegic and cycloplegic autorefraction using three commonly available autorefractors compared with subjective refraction.

METHODS

THIS IS A CROSS-SECTIONAL STUDY DESIGNED TO DETERmine the measurement properties of three autorefractor techniques and instruments used in refraction in children.

• **STUDY POPULATION:** The study population consisted of 117 school aged children between 7 and 12 years old, who were sampled from schools that participated in the Refractive Error Study in Children (RESC), a World Health Organization (WHO) and Ministry of Health Malaysia (MOH) funded eye survey in Malaysia.[9] Written consent was obtained from a parent or guardian. The study conformed to the tenets of the Helsinki Declaration.

• **OBSERVATION PROCEDURES: AUTOREFRACTORS:** Three types of autorefractors (Retinomax K plus 2, Nikon Corp, Japan; Canon RK10 Autorefractor, Canon, Japan, and Grand Seiko WR-5100K [also known as Shin-Nippon NVision-K 5001], Japan) were used in this study. Retinomax K plus 2 and Canon RK 10 use automatic fogging mechanism to control accommodation.[17,34] In contrast, Grand Seiko WR-5100K uses an open-view arrangement to allow subjects an unrestricted binocular view of a distance target.[4,5,35,36]

• **EYE EXAMINATION:** Eye examination was conducted at schools where sampled children attended, by four trained and experienced health technicians, two optometrists, and one ophthalmologist. Visual acuity measurements at 4 m using a retro-illuminated LogMAR chart with tumbling-E optotypes (Precision Vision; La Salle, Chicago, Illinois, USA) were performed by an optometrist. For children wearing glasses, visual acuity was measured both with and without them. Lens power was measured with an autolensometer (LM-970; Nidek Corporation, Tokyo, Japan). Autorefraction without cycloplegia, using auto refractors was performed by two experienced optometrists. This was followed by noncycloplegic monocular and binocular subjective refraction. Monocular subjective refraction was performed based on subjective refinement of the autorefractor readings until best-corrected visual acuity was achieved. Binocular subjective refraction was performed in a similar way, except without occluding or fogging the fellow eye. The sequence of the types of autorefractor used during examination was random.

Cycloplegia was induced with two drops of cyclopentolate 1%, administered five minutes apart by ophthalmic assistants, with a third drop administered after 20 minutes. Cycloplegia and pupil dilation were evaluated after an additional 15 minutes. Autorefraction using all three autorefractors (random sequence) and subjective refraction were repeated following complete cycloplegia.

Children whose vision improved with refraction were prescribed and provided with free glasses. Children who needed medical or surgical treatment were referred to the local ophthalmology department.

Main outcome measures of the study were spherical power (SP), cylindrical power (CP), and spherical equivalence (SE).

• **STATISTICAL ANALYSIS:** The analysis set was comprised of subjects without missing data. As the refractive errors of two eyes are related, only data from the right eye were analyzed. Autorefraction measurements using Retinomax K plus 2 and Canon RK 10 were compared with monocular subjective refraction under both noncycloplegic and cycloplegic conditions. Since Grand Seiko WR-5100K uses an open-view arrangement to allow subjects an unrestricted binocular view of a distance target, measurements taken were compared with binocular subjective refraction under noncycloplegic and cycloplegic conditions. The mean spherical equivalence (SE) were calculated [the mean spherical equivalence = sphere + (cylinder/2)]. The comparison between measures (the mean difference, standard deviation, and 95% confidence limits) were calculated using paired two tailed *t* test and presented graphically using Bland-Altman plots. Sensitivity and specificity of the different methods of autorefraction in diagnosing myopia (≤ -0.50 diopters) and hypermetropia ($\geq +0.50$ diopters) under cycloplegic or noncycloplegic conditions were calculated.

RESULTS

COMPLETE DATA WERE COLLECTED FOR 117 CHILDREN aged 7 to 12 years old. Mean age was 9.6 (SD 1.7) years (range 7 to 12 years) with 51% male subjects. Based on cycloplegic monocular subjective refraction of the right eye, 35 (29.9%) were myopic and 60 (51.3%) were hypermetropic. Based on cycloplegic binocular subjective refraction of the right eye, 30 (25.6%) were myopic and 78 (66.7%) were hypermetropic. Tables 1 and 2 show the mean, standard deviation, and 95% confidence interval of refractive power using different methods of refraction, and their comparison with subjective refraction under both noncycloplegic and cycloplegic conditions, respectively. Table 3 shows the sensitivity and specificity of the autorefractors in the diagnosis of myopia and hypermetropia. Figures 1 to 6, show method comparison between autorefractors and subjective refraction using Bland-Altman plots.

• **COMPARISON OF MEAN-NONCYCLOPLEGIA:** With the exception of the axis, there was a marked difference

TABLE 1. Mean, Standard Deviation, and 95% Confidence Interval of Refraction Power Using Different Methods of Autorefraction and Their Comparison With Subjective Refraction Under Noncycloplegic Conditions

	Sphere (D)				Cylinder (D)				Axis (degrees)				Spherical Equivalence (D)			
Noncycloplegic	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value
Retinomax*	−1.31	2.21	−1.71 to −0.90	<.0001	−0.50	0.78	−0.64 to −0.35	.0160	99.1	65.3	82.7 to 115.6	.5378	−1.55	2.37	−1.98 to −1.12	<.0001
Canon*	−0.88	2.44	−1.32 to −0.43	.0005	−0.47	0.78	−0.61 to −0.33	<.0001	94.3	68.8	77.1 to 111.5	.4446	−1.11	2.61	−1.59 to −0.64	.0023
Grand Seiko†	−0.46	2.19	−0.86 to −0.06	.0036	−0.66	0.77	−0.80 to −0.52	.0022	93.4	68.2	79.0 to 107.9	.75	−0.79	2.4	−1.23 to −0.35	.0002
Monocular subjective*	−0.51	2.08	−0.89 to −0.13		−0.58	0.74	−0.71 to −0.44		93.8	68.3	76.7 to 115.7		−0.80	2.25	−1.21 to −0.39	
Binocular subjective†	−0.33	2.32	−0.75 to 0.10		−0.58	0.74	−0.71 to −0.44		90.6	65.9	76.6 to 104.6		−0.62	2.51	−1.07 to −0.16	

*Retinomax K plus 2 and Canon RK10 were compared with monocular subjective refraction.
†Grand Seiko was compared with binocular subjective refraction.

TABLE 2. Mean, Standard Deviation, and 95% Confidence Interval of Refraction Power Using Different Methods of Autorefraction and Their Comparison With Subjective Refraction Under Cycloplegic Conditions

	Sphere (D)				Cylinder (D)				Axis (degrees)				Spherical Equivalence (D)			
Cycloplegic	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value	Mean	SD	95% CI	*P* value
Retinomax*	−0.31	2.34	−0.74 to 0.12	.1292	−0.46	0.75	−0.59 to −0.32	<.0001	79.4	65.4	63.2 to 95.6	.1367	−0.54	2.48	−0.99 to −0.08	1.0000
Canon*	−0.29	2.33	−0.72 to 0.13	.0653	−0.54	0.9	−0.70 to −0.37	.0448	99.1	72.4	81.6 to 116.6	.56	−0.56	2.51	−1.02 to −0.103	.6140
Grand Seiko†	−0.07	2.26	−0.49 to 0.34	.6521	−0.73	0.89	−0.89 to −0.57	.0575	91.1	70.9	76.2 to 106.0	.54	−0.44	2.48	−0.89 to 0.02	.2128
Monocular subjective*	−0.22	2.38	−0.66 to 0.21		−0.63	0.77	−0.77 to −0.49		93.3	68.0	76.5 to 110.2		−0.54	2.57	−1.01 to −0.07	
Binocular subjective†	−0.05	2.42	−0.49 to 0.39		−0.63	0.77	−0.78 to −0.49		96.6	67.5	82.4 to 110.8		−0.37	2.61	−0.85 to 0.11	

*Retinomax K plus 2 and Canon RK10 were compared with monocular subjective refraction.
†Grand Seiko was compared with binocular subjective refraction.

TABLE 3. Sensitivity and Specificity of Autorefractors for the Diagnosis of Myopia and Hypermetropia

	Non Cycloplegia			Cycloplegia		
Myopia	Retinomax	Canon	Grand Seiko	Retinomax	Canon	Grand Seiko
Sensitivity (true positive ratio)	1.00	0.92	0.91	0.97	0.97	1.00
Specificity (true negative ratio)	0.51	0.81	0.98	0.99	0.96	0.97
Positive predictive value	0.20	0.38	0.82	0.91	0.77	0.78
Negative predictive value	1.00	0.99	0.99	1.00	1.00	1.00
	Non Cycloplegia			Cycloplegia		
Hypermetropia	Retinomax	Canon	Grand Seiko	Retinomax	Canon	Grand Seiko
Sensitivity (true positive ratio)	0.24	0.53	0.47	0.84	0.86	0.80
Specificity (true negative ratio)	0.98	0.93	0.94	0.82	0.88	0.94
Positive predictive value	0.59	0.48	0.50	0.36	0.48	0.61
Negative predictive value	0.91	0.94	0.93	0.98	0.98	0.97

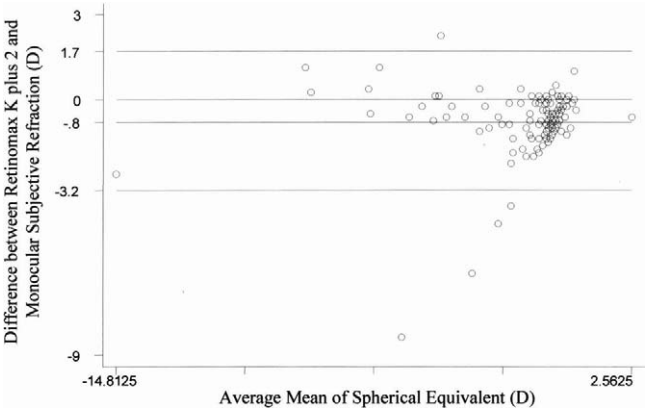

FIGURE 1. Method comparison between Retinomax K plus 2 and monocular subjective refraction (noncycloplegia) using Bland-Altman plot (right eye only).

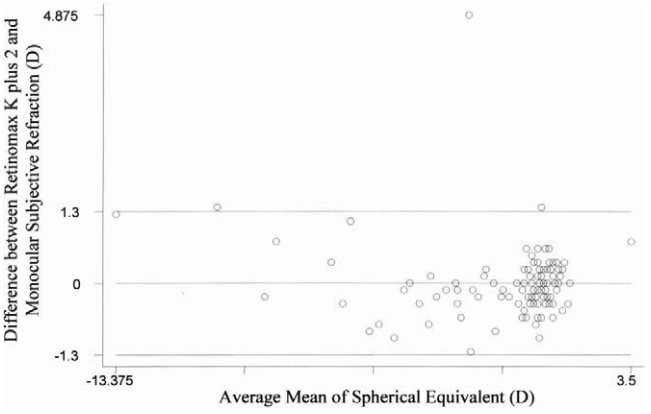

FIGURE 2. Method comparison between Retinomax K plus 2 and monocular subjective refraction (cycloplegia) using Bland-Altman plot (right eye only).

between noncycloplegic refraction using autorefractors and subjective refraction in all parameters (sphere, cylinder, and spherical equivalence) (Table 1). There was tendency towards minus over correction with Retinomax K plus 2 having the greatest tendency, followed by Canon RK 10 and Grand Seiko WR-5100K.

• **COMPARISON OF MEAN-CYCLOPLEGIA:** Overall, there was no marked difference between cycloplegic refraction using autorefractors and subjective refraction in sphere or spherical equivalence parameters (Table 2). There was a significant difference in cylindrical power between Retinomax K plus 2 ($P < .0001$) and Canon RK 10 ($P = .0448$) compared with subjective refraction.

• **SENSITIVITY AND SPECIFICITY FOR DIAGNOSIS OF MYOPIA- SPHERICAL EQUIVALENCE:** Under noncycloplegic conditions, sensitivity was high for all three autorefractors (Retinomax K plus 2, 1.00; Canon RK 10, 0.92; and Grand Seiko WR-5100K, 0.91). Retinomax K plus 2 has the lowest specificity of 0.51, followed by Canon RK 10 (0.81) (Table 2). Grand Seiko WR-5100K has the highest specificity of 0.97. Autorefraction under cycloplegic conditions resulted in high sensitivity and specificity for all three autorefractors.

• **SENSITIVITY AND SPECIFICITY FOR DIAGNOSIS OF HYPERMETROPIA-SPHERICAL EQUIVALENCE:** Under noncycloplegic conditions, sensitivity was low for all three refractors (Retinomax K plus 2, 0.24; Canon RK 10, 0.53; and Grand Seiko WR-5100K, 0.47) (Table 2). All three autorefractors have high specificity (Retinomax K plus 2, 0.98; Canon RK 10, 0.93; and Grand Seiko WR-5100K, 0.94).

Under cycloplegic conditions, sensitivity improved for all three autorefractors but with corresponding reduction of specificity (Sensitivity: Retinomax K plus 2, 0.84; Canon RK 10, 0.86; and Grand Seiko WR-5100K, 0.80. Specificity: Retinomax K plus 2, 0.82; Canon RK 10, 0.88; and Grand Seiko WR-5100K, 0.94).

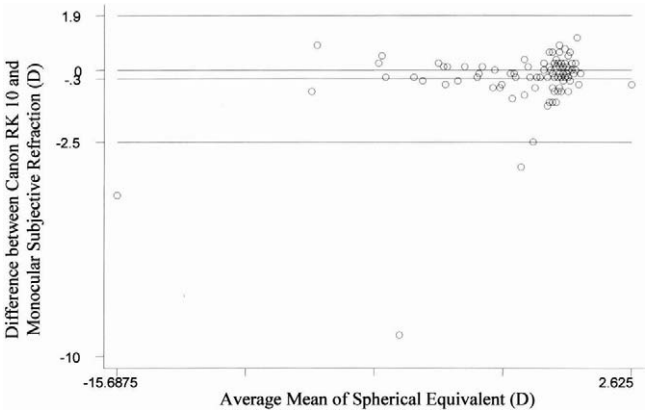

FIGURE 3. Method comparison between Canon RK 10 and monocular subjective refraction (noncycloplegia) using Bland-Altman plot (right eye only).

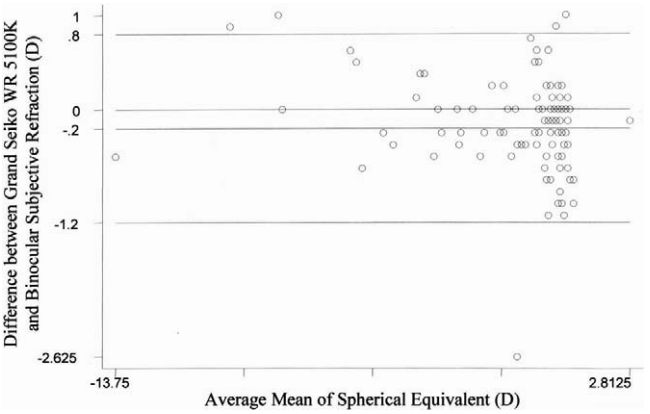

FIGURE 5. Method comparison between Grand Seiko WR 5100K and binocular subjective refraction (noncycloplegia) using Bland-Altman plot (right eye only).

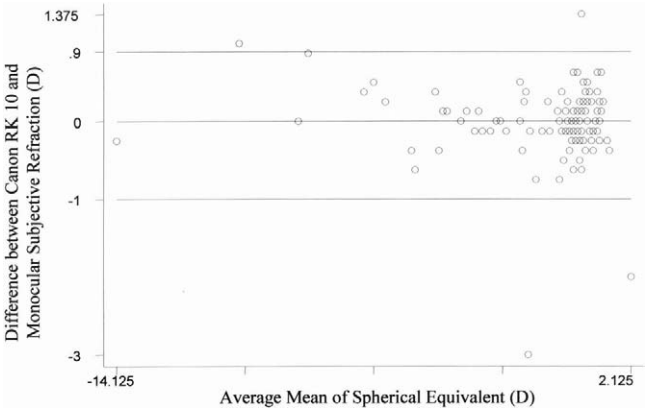

FIGURE 4. Method comparison between Canon RK 10 and monocular subjective refraction (cycloplegia) using Bland-Altman plot (right eye only).

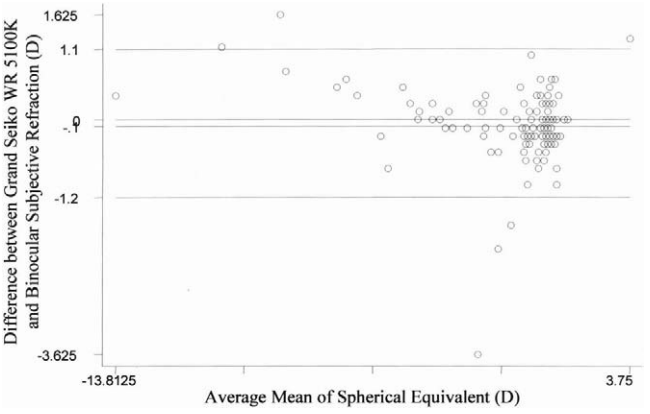

FIGURE 6. Method comparison between Grand Seiko WR 5100K and binocular subjective refraction (cycloplegia) using Bland-Altman plot (right eye only).

DISCUSSION

THERE WAS A TENDENCY TOWARDS MINUS OVER CORRECtion when the autorefractors were used under noncycloplegic conditions. However, this tendency disappeared when autorefractors were used with cycloplegia. Overall, myopic over correction was most marked using Retinomax K plus 2.

Under noncycloplegic conditions all three autorefractors have high sensitivity for myopia. However, a major disadvantage was low specificity which resulted in incorrectly diagnosing eyes without myopia as having myopia. This was marked with Retinomax K plus 2 autorefractor with a false positive error of 0.49 (spherical equivalent). Previous comparative studies using Retinomax K plus 2 autorefractor revealed a mixed picture. Some studies showed that screening with Retinomax autorefractor under noncycloplegic conditions resulted in over correction and too many false positive referrals.[19,23] Other studies that compared Retinomax K plus 2 with cycloplegic refraction showed moderate to good agreement and suggested that it could be a useful screening tool for refractive error in children screening.[2,15,17,21,34,37] It is worth noting that all the above studies were conducted in Western populations whose children have a lower rate of myopia and a corresponding higher rate of hypermetropia compared with our study sample. While the autorefractor may be an adequate and useful tool for children screening in Western populations, its usefulness in an Asian population is not proven. Additionally, there were studies showing inadequate agreement[19,23] particularly under noncycloplegic conditions. Of the three autorefractors, Grand Seiko WR-5100K has the best overall accuracy with high sensitivity and specificity.

The performance of Grand Seiko WR-5100K may be attributed to its binocular open field-of-view mechanism which allows the accommodative state to be monitored while a natural environment is viewed.[4,5,35,36] It differs from Retinomax K plus 2 and Canon RK 10, which use fogging mechanisms to control for accommodation.[17,34] Fogging mechanisms may be inadequate as an accommodative control mechanism as there are other factors in-

volved such as proximal accommodation, which may not be adequately neutralized using fogging mechanisms.

The prevalence of myopia among children in Malaysia and other countries is on the rise.[6,8,26,38–44] Various genetic and environmental factors have been implicated in the development of myopia.[45] The contribution of these factors and their relative importance has been subjected to much research and debate. One of the possible factors contributing to this rise is excess accommodation.[46,47] Children wearing glasses with minus over correction would need to exert excess accommodative effort to overcome the minus over correction. If indeed excess accommodation contributes to the development of myopia then prescription of glasses based solely on noncycloplegic autorefraction may predispose to myopic progression. Therefore the practice of using noncycloplegia autorefraction should be subjected to closer scrutiny especially if glasses prescriptions are made based solely on these readings.

There are several limitations to our study. As observed by Zhao and associates, the negative bias with autorefraction was more marked among hypermetropic children where the definition of spherical equivalent hypermetropia of at least +2.00 diopters was used.[1] However, there is only one child who fulfilled this definition in this study. The study may show more significant bias in noncycloplegic autorefraction if a larger sample of children with at least +2.00 diopters hypermetropic were assessed. Additionally, reliability study using intra-observer measurement (test retest) and inter-observer measurement was not performed. This decision was made in view of the time constraint as the study was performed during school hours. Additionally, we encountered difficulty in performing repeated measurements in young children whose concentration and cooperation deteriorated with time.

In conclusion, our study shows that under noncycloplegic conditions, all three autorefractors have a tendency towards minus over correction in children. This may assume greater importance if minus over correction in such children predisposes them to developing myopia. This information is important when establishing standard practice guidelines for vision screening and glasses prescription in children.

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Biosketch

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