Original Article

The Difference of Refraction Between the Cycloplegic Retinoscopy and Non-Cycloplegic Subjective Refraction in Children Aged 6 to 15 Years

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Objective: To determine the difference of refraction measured by cycloplegic retinoscopy (CR) and non-cycloplegic subjective refraction (NS).

Materials and Methods: The present descriptive study included normal children aged 6 to 15 years with refractive error. The refractive status was measured by CR and cycloplegic autorefractometer (CA) at the initial visit. At 2-week follow-up, the refraction was measured with non-cycloplegic autorefractometer (NA) and NS. The spherical equivalent (SE) from participants' right eye was used in the data analyses.

Results: Forty-four participants were included in this study with a mean age of 9±3 years and 22 (50%) were male. Overall, the median (Q_1, Q_3) of SE by CR, CA, NS, and NA were –1.00 (–2.50, 0.25), –1.63 (–2.63, –0.50), –1.63 (–2.50, –1.00), and –1.88 (–2.88, –1.13) diopters (D), respectively. The SE by CR was 0.56 D more than NS (p<0.001), and 0.38 D more than CA (p<0.001). The SE by NS was 0.25 D more than NA (p=0.008). By using the CR method, 11 (25%) participants were classified in the hyperopic group (positive SE) and 33 (75%) in the myopic group (negative SE). In the hyperopic group, the median (Q_1, Q_3) of SE by CR and NS were 0.75 (0.50, 1.75) and –0.63 (–1.00, 1.38) D, respectively. The refraction by CR was 1.50 D more than by NS (p=0.003). In the myopic group, the median (Q_1, Q_3) of SE by CR and NS were –1.50 (–2.50, –0.75) and –2.00 (–3.25, –1.50) D, respectively. The refraction by CR was 0.50 D more than NS (p<0.001).

Conclusion: The refraction in children aged 6 to 15 years measured by CR was significantly more than NS in the participants. The authors should decrease the number of refractions obtained from CR when prescribing glasses to hyperopic children.

Keywords: Refractive error, Children, Cycloplegic retinoscopy, Subjective refraction, Cycloplegic autorefractor, Manifest autorefractor

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Refractive error is one of the world most common and important cause of preventable visual impairment and blindness[1,2]. A global prevalence of visual impairment from uncorrected or inadequately corrected refractive errors in children aged 5 to 15 years is 0.96%, which is higher in urban areas than in rural areas. In this age group, the prevalence of myopia, hyperopia, and astigmatism ranges from 3% to 35%, 0.4% to 17%, and 2.2% to 34% respectively[3]. In Bangkok, Thailand, the prevalence of myopia, hyperopia, and astigmatism in primary school children was 11.1%, 1.4%, and 0.3%, respectively[4]. The uncorrected refractive error in children may have a significant impact on their learning capability and educational potential[5].

At present, cycloplegic retinoscopy (CR) is the gold standard for the refractive error measurement in children[6]. It is widely used as the most accurate

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objective tool to quantify an actual refractive error especially in children due to their large accommodative power[7]. It is also an important diagnostic tool for most of the childhood strabismus diseases. In normal children without strabismus, the authors usually do not prescribe glasses with the actual power obtained from the CR due to the fact that children, especially with hyperopia, generally cannot see well with those glasses. This is because of the accommodative power they normally used during their daily activities in life. For this reason, the non-cycloplegic subjective refraction (NS) should also be done in these children to reassure that they can see well with the glasses prescribed. The present study aimed to determine the difference of refraction by these two methods. The advantage of this knowledge would be helpful for ophthalmologist to prescribe glasses to children who are unable to co-operate or unable to do subjective refraction.

Materials and Methods

Study population

The present retro-prospective descriptive study was conducted at the Ophthalmology clinic, King Chulalongkorn Memorial Hospital (KCHM) and Rutnin Eye Hospital between July 2017 and June 2018. Participants aged between 6 to 15 years old who had uncorrected visual acuity (UCVA) of their right eye equal or worse than 20/40 by Snellen chart with no prior history of glasses prescription were included in the study. The exclusion criteria were children with a previous diagnosis of severe amblyopia, a best corrected visual acuity (BCVA) worse than 20/80, strabismus disorders, other structural ocular diseases, developmental delay, inability to co-operate during the examination, inability to communicate, and contraindication to cycloplegic drug. The hyperopic and myopic subgroups were defined as a positive and negative spherical equivalent (SE) obtained from the CR. The informed consent by parents and verbal assent by children were done. The study protocol was approved by the Institutional Review Boards (IRB) of KCHM and conducted according to the Declaration of Helsinki.

Methodology and data collection

Baseline demographic and characteristic data including age, gender, and underlying medical problems were collected. At the first clinic visit, all children had a complete eye examination including UCVA at distance of both eyes, anterior segment examination by slit lamp biomicroscopy, fundus examination by indirect ophthalmoscopy, and manual CR. The non-cycloplegic autorefraction (NA) was first measured three times with a single autorefractometer (KR-800 Auto Kerato-Refractometer; Topcon Corporation, Tokyo, Japan). Then, one drop of tetracaine 0.5% was instilled before three drops of cyclopentolate 1% were instilled 10 minutes apart to both eyes[8]. The cycloplegic autorefraction (CA) and the CR were performed 60 minutes after the first cycloplegic eye drop to insure the full relaxation of accommodation. The CR was performed by one of two pediatric ophthalmologists (Honglertnapakul W and Pukrushpan P). The examiners were masked by the result of refraction from the cycloplegic autorefractor. At two-week-follow-up, the NA was obtained, and the NS was performed using a trial frame and lenses. The proper eyeglasses were prescribed base on the NS with the best corrected visual acuity (BCVA) at distance.

Statistical analysis

The SE of participants' right eye measured by the CR, CA, NS, and NA was analyzed using median (Q_1, Q_3). The difference of refraction between 1) CR and NS, 2) CA and NS, 3) CR and CA, and 4) NS and NA were compared using Wilcoxon signed-rank test. The difference of each two methods between the hyperopic and myopic subgroups were compared using Mann-Whitney U test. The linear regression analysis was used to establish a predictive equation between CR and NS. The R-square was used to evaluate the performance of the predictive equation. Statistical significance was considered at p-value lower than 0.05. All statistical analyses were done by Stata, version 14.0 (StataCorp LP, College Station, TX, USA).

Results

Of 44 children included in the present study, 22 (50%) were male. The age ranged from 6 to 15 years old. Baseline characteristics are shown in Table 1.

In overall participants, the median of difference of refraction was highest in the CR group, followed by CA, NS, and NA, respectively. There were 11 (25%) participants in the hyperopic group and 33 (75%) in the myopic group. The trends of refraction measured by these four methods were similar in both subgroups. The range and median (Q_1, Q_3) of each measurement methods of overall participants and both subgroups are shown in Table 2.

The median of difference of refraction between the CR and the NS (CR-NS), the CA and the NS (CA-NS), the CR and the CA (CR-CA), and the NS and the

Table 1. Baseline characteristics (n=44)

Characteristics	n (%)
Sex	
Male	22 (50)
• Myopia	18 (82)
• Hyperopia	4 (18)
Female	22 (50)
• Myopia	15 (68)
• Hyperopia	7 (32)
Age (year); mean±SD	9±3
UCVA (%)	
20/40 to 20/80	25 (57)
20/100 to 20/400	17 (39)
Worse than 20/400	2 (4)

SD=standard deviation; UCVA=uncorrected visual acuity

NA (NS-NA) in the overall, the hyperopic, and the myopic groups are shown in Table 3. The refraction measured by the CR was significantly higher than the NS (CR-NS) and the CA (CR-CA) in all groups. The refraction measured by the CA was significantly higher than the NS (CA-NS) only in the overall and in the hyperopic group. The refraction measured by the NS was significantly higher than the NA (NS-NA) only in the overall and in the myopic groups. Comparing between the hyperopic and the myopic subgroup, the difference of refraction between the CR and the NS (CR-NS), and the difference of refraction between the CA and the NS (CA-NS) in the hyperopic subgroup were significantly higher than in the myopic subgroup ($p<0.001$). However, the difference between the CR and the CA (CR-CA), and the difference between the NS and the NA (NS-NA) in the hyperopic and the myopic subgroups were not significantly different ($p=0.665$ and 1.000, respectively).

To predict the NS from the CR, a linear regression analysis was performed in the overall, the hyperopic and the myopic groups. It showed a high correlation (R^2=91%, 95%, and 82%, respectively) in all groups. In the overall group, the predictive equation of NS was "NS = –0.90+0.82 (CR)" as shown in Figure 1A. The predictive equation of NS in the hyperopic and in the myopic subgroups were "NS = –1.24+0.90 (CR)" and NS = –0.71+0.88 (CR)" as shown in Figure 1B. There was no correlation found between the difference of refraction measured by the CR and the NS and the age of children.

Discussion

The present study showed that the SE obtained from the CR was the most in the hyperopic and less in the myopic among all four methods of refraction used. The SE was highest with the CR, followed by the CA, the NS, and the NA, respectively. The median of SE measured by the CR was significantly higher than by the NS in the overall, the hyperopic, and the myopic groups. Especially in the hyperopic subgroup, the median of difference of SE between the two methods was 1.50 D. However, this difference of SE in the myopic group was 0.50 D, which was lower than in the hyperopic group. The authors also found that the median of difference of SE obtained from the CA was significantly higher than from the NS only in the overall and the hyperopic groups with the highest difference (1.00 D) in the hyperopic

Table 2. The median of spherical equivalence of refraction measured by CR, CA, NS, and NA in overall, hyperopic, and myopic groups

Measurement methods	Range of refraction in overall group (D)	Refraction in overall group (D) Median (Q_1, Q_3)	Refraction in hyperopic group (D) Median (Q_1, Q_3)	Refraction in myopic group (D) Median (Q_1, Q_3)
CR	–6.88 to 7.00	–1.00 (–2.38, 0.00) n=44	0.75 (0.50, 1.75) n=11	–1.50 (–2.50, –0.75) n=33
CA	–5.38 to 6.88	–1.63 (–2.63, –0.50) n=43	0.63 (0.13, 1.75) n=10	–2.0 (–3.25, –1.50) n=33
NS	–6.50 to 5.00	–1.75 (–2.75, –1.00) n=44	–0.63 (–1.00, 1.38) n=11	–2.00 (–3.50, –1.50) n=33
NA	–6.63 to 6.63	–1.88 (–2.88, –1.13) n=38	–0.63 (–1.00, 0.75) n=10	–2.38 (–3.69, –1.63) n=28

CR=cycloplegic retinoscopy; CA=cycloplegic autorefraction; NS=non-cycloplegic subjective refraction; NA=non-cycloplegic autorefraction; D=diopter

Positive value: hyperopia, Negative value: myopia

Table 3. The median of the differences of refraction between CR and NS, CA and NS, CR and CA, and NS and NA in overall, hyperopic, and myopic groups

Measurement methods	Difference of refraction in overall group (D) Median (Q_1, Q_3)	Difference of refraction in hyperopic group (D) Median (Q_1, Q_3)	Difference of refraction in myopic group (D) Median (Q_1, Q_3)	p-value[a]
CR-NS (n=44)	0.56 (0.00, 1.25)	1.50 (1.25, 2.00)	0.50 (0.00, 0.75)	<0.001*
p-value[b]	<0.001*	0.003*	<0.001*	
CA-NS (n=43)	0.13 (–0.25, 0.63)	1.06 (0.50, 1.25)	0.00 (–0.25, 0.38)	<0.001*
p-value[b]	0.021*	0.005*	0.687	
CR-CA (n=43)	0.38 (0.00, 0.75)	0.25 (0.00, 0.75)	0.38 (0.00, 0.75)	0.665
p-value[b]	<0.001*	0.021*	0.001*	
NS-NA (n=38)	0.25 (–0.13, 0.50)	0.13 (–0.25, 1.13)	0.25 (0.06, 0.44)	1.000
p-value[b]	0.008*	0.474	0.007*	

CR=cycloplegic retinoscopy; CA=cycloplegic autorefraction; NS=non-cycloplegic subjective refraction; NA=non-cycloplegic autorefraction; D=diopter

[a] p-value compared between hyperopic and myopic groups using Mann-Whitney U test, [b] p-value compared between each measurement methods using Wilcoxon signed-rank test, * Statistically significance defined by p<0.05

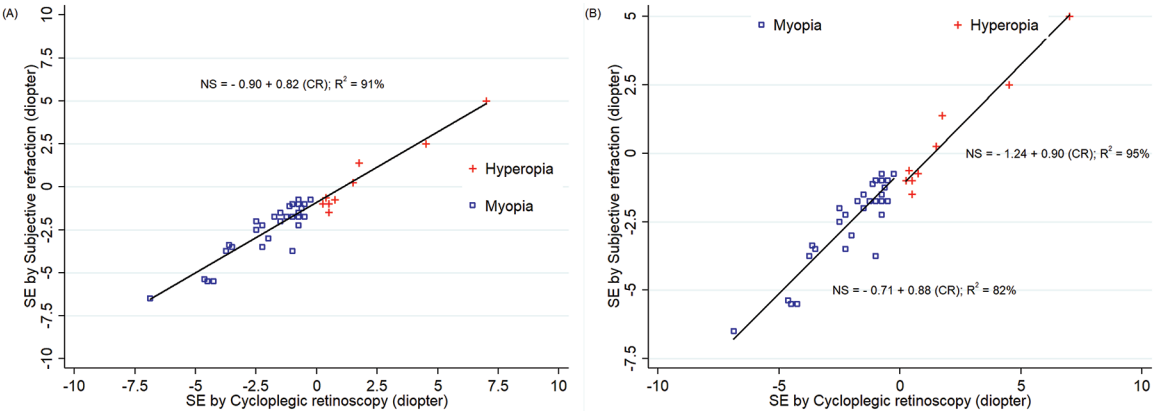

Figure 1. (A) showed a linear regression analysis of the refraction in spherical equivalent (SE) measured by cycloplegic retinoscopy (CR) and non-cycloplegic subjective refraction (NS) in overall group and (B) in hyperopic and myopic groups.

group. The differences of SE between the cycloplegic refraction (CR and CA) and the NS in the hyperopic subgroups were considered clinically significant. Based on this finding, the ophthalmologist may be able to use these number as a guideline in prescribing appropriate hyperopic glasses in normal children aged 6 to 15 years who are unable to co-operate in subjective refraction. Although, the differences of SE between the CR and the CA in the overall, the hyperopic, and the myopic groups were statistically significant (Table 3), the actual value of differences were not considered clinically significant. Even though, the median of differences of SE between the NS and the NA in the overall and the myopic groups were statistically significant, the actual values in both groups were not considered clinically significant.

Several studies compared the cycloplegic and non-cycloplegic refraction obtained from various methods. The largest one, which was composed of 3,483 participants with the age ranged from 5 to 92 years, was the Tehran Eye Study[9]. In the present study, they compared the CA to NS and found that the largest difference between these two methods was found in children aged 5 to 10 years. The difference of refraction in this age group was 1.11±0.06 D, which was more than in the overall group in the 6 to 15 years old children in the present study. The present study also found inter-method difference of refraction in the hyperopic subjects (0.96 D) was larger than in the myopic subjects (0.19 D) (p<0.001), which was similar to the present study. Another study[10] compared three different means (NA, CA, and CR) to

measure the refraction in children aged 3 to 15 years. In 69 myopic children, the sphere power obtained from the NA was significantly more in the myopic than the CA (–2.35±2.50 D versus –1.60±2.60 D, p=0.0001) and CR (–2.35±2.50 D versus –1.65±2.60 D, p=0.0001), which was similar to the present results. In 73 emmetropic and hyperopic children, the sphere power obtained from the NA was significantly less in the hyperopic than the CA (1.70±1.80 D versus 2.45±2.00 D, p=0.0001) and the CR (1.70±1.80 D versus 2.30±2.10 D, p=0.0001). Although the average of hyperopia found in their study was higher than the present study, the differences of refraction between methods were similar. Likewise, a cross sectional study from Southern Thailand[11] studied the refraction obtained from three different methods (NA, non-cycloplegic retinoscopy [NR], and NS) and compared with the CR. They found that the difference of refraction between the three non-cycloplegic methods and the CR was highest in the NA group, which had the greatest tendency towards minus over-correction and plus under-correction. The percentage of agreements of SE between the NA, NR, and NS with the CR within ±0.5 D were 31.25%, 80.84%, and 81.66%, respectively. They also claimed that the NR and NS were clinically accurate and can be applied for refractive error screening in primary school children. However, Pokupec et al[12] found that even though a NA can be used as a screening method in refractive error detection, the refraction obtained from it was not accurate. A more accurate measurement could be achieved under cycloplegia with either a retinoscopy or a refractometer.

In the present study, the refractions measured by CR and NS in the overall group were highly correlated (R^2=91%). Accounting for the predictive equation in the overall group, the NS increased 0.82 D per 1 D increment of SE measured by CR. In the hyperopic and myopic groups, the NS increased 0.90 and 0.88 D per 1 D increment of CR. There was also a high correlation between the CR and the NS in both subgroups. Conversely, the prediction of cycloplegic from non-cycloplegic refraction obtained from an automated refractometer was studied in 6,017 Chinese children aged 4 to 15 years[13]. As expected, NA was more myopic than the CA (paired difference: 0.63±0.65 D, 95% CI 0.612 to 0.65 D). A high correlation (R^2=90%) was also found between the CA and NA with the prediction that the CA increased 1.07 D with 1 D increment of NA. In the present study, the NA could correctly classify the eyes as being myopic, emmetropic, or hyperopic for only 61%. Interestingly, the age and UCVA was able to accurately classify the eyes for 77%. By only using the UCVA, the refractive status that was correctly classified improved to 80% and further improved to 97.5% by using an UCVA worse than or equal to 6/18. In contrast to the present study, no correlation was found between the difference of refraction measured by CR and NS and the age of children.

The strength of the present study was that the cycloplegic refraction was measured with a retinoscopy technique by either one of the two experienced pediatric ophthalmologists. The CR was considered a gold standard for cycloplegic refraction[14]. It provides more accurate refraction with less measurement error than the automated refractometer[15-17]. In addition, the measurement error in the present study was controlled by having only two pediatric ophthalmologists perform the CR. The authors also analyzed the data separately in the hyperopic and the myopic groups, which provided more useful information for the current practice of spectacles prescription. However, there were some limitations in the present study. Due to the retro-prospective nature of the study, there was one missing data in the CA and five in the NA groups from the retrospective chart reviews. The small sample size was another limitation of the present study, especially in the hyperopic group. The authors suggest that a prospective cohort with more participants should be carried out for future studies.

Conclusion

In conclusion, the refraction in children aged 6 to 15 years measured by the CR was significantly more than the NS in overall participants, especially in children with hyperopia. The overall highest value of SE could be obtained from the CR. The autorefractometer tended to report under plus in the hyperopic group and over minus in the myopic group either with or without cycloplegia. The ophthalmologist should consider decreasing the number of refractions measured by the CR when prescribing glasses especially in hyperopic children. The results from the present study will also be helpful for pediatric ophthalmologists in prescribing glasses to children who are unable to co-operate or unable to do the subjective refraction.

What is already known on this topic?

Due to the high accommodative power in children, it is important to measure their refraction under cycloplegia. The cycloplegic refraction by

various methods is likely to be higher than the non-cycloplegic refraction, especially in hyperopic children.

What this study adds?

In this study, the authors compared different methods of measurement of cycloplegic and non-cycloplegic refraction. The authors found that the refraction of Central Thai children aged 6 to 15 years measured by CR was significantly higher than NS in overall participants (0.56 D, $p<0.001$), especially in the hyperopic group (1.50, $p=0.003$). In the myopic group, the refraction by CR was 0.50 D more than NS ($p<0.001$). The ophthalmologist should decrease the number of refraction obtained from the cycloplegic retinoscopy when prescribing glasses to hyperopic children.

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Conflicts of interest

The authors declare no conflict of interest.

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