Relative peripheral refraction in school children with different refractive errors using a novel multispectral refraction topographer

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Abstract

• AIM: To compare relative peripheral refraction (RPR) in Chinese school children with different refractive errors using multispectral refraction topography (MRT).

• METHODS: A total of 713 eyes of primary school children [172 emmetropia (E), 429 low myopia (LM), 80 moderate myopia (MM), and 32 low hypermetropia (LH)] aged 10 to 13y were analyzed. RPRs were measured using MRT without mydriasis. MRT results showed RPR at 0-15° (RPR 0-15), 15°-30° (RPR 15-30), and 30°-45° (RPR 30-45) annular in the inferior (RPR-I), superior (RPR-S), nasal (RPR-N), and temporal (RPR-T) quadrants. Spherical equivalent (SE) was detected and calculated using an autorefractor.

• RESULTS: There were significant differences of RPR 15-30 between groups MM [0.02 (-0.12; 0.18)] and LH [-0.13 (-0.36; 0.12)] (P<0.05), MM and E [-0.06 (-0.20; 0.10)] (P<0.05), and LM [-0.02 (-0.15; 0.15)] and E (P<0.05). There were also significant differences of RPR 30-45 between groups MM [0.45 (0.18; 0.74)] and E [0.29 (-0.09; 0.67)] (P<0.05), and LM [0.44 (0.14; 0.76)] and E (P<0.001). RPR values increased from the hyperopic to medium myopic group in each annular. There were significant differences of RPR-S between groups MM [-0.02 (-0.60; 0.30)] and E [-0.44 (-0.89; -0.04)] (P<0.001), and LM [-0.28 (-0.71; 0.12)] and E (P<0.05). There were also significant differences of RPR-T between groups MM [0.37 (0.21; 0.78)] and LH [0.14 (-0.52; 0.50)] (P<0.05), LM [0.41 (0.06; 0.84)] and LH (P<0.05), and LM and E [0.29 (-0.10; 0.68), P<0.05]. A Spearman’s correlation analysis showed a negative correlation between RPR and SE in the 15°-30° (P=0.005), 30°-45° (P<0.05) annular (P=0.002), superior (P<0.001), and temporal (P=0.001) quadrants.

• CONCLUSION: Without pupil dilation, values for RPR 15-30, 30-45, RPR-S, and T shows significant differences between myopic eyes and emmetropia, and the differences are negatively correlated with SE.

• KEYWORDS: relative peripheral refraction; myopia; school children; multispectral refraction topography

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INTRODUCTION

The rising prevalence of myopia has become a significant public health issue. The global population affected by myopia is estimated to increase to 4.76 billion (49.8%) by 2050[1]. Accordingly, efforts are being made to better understand the mechanisms of myopia and identify therapeutic targets. The effect of peripheral refraction on myopia progression has recently received increased attention[2-4]. Several contact and spectacle lenses intended to slow myopia progression by inducing relative peripheral myopia have been proven to inhibit eye elongation[5-6]. However, the optimal amount of peripheral defocus has not yet been well determined[7]. One reason may be that traditional peripheral refraction measurement methods do not accurately detect the peripheral defocus in each region of the retina, and their time-consuming process has high requirements for patient cooperation[8-10]. Multispectral refraction topography (MRT, Thondar, Inc., China), based on imaging and spectroscopy, was designed to measure the spherical refraction of a 53-degree fundus field of view within 2-3s. MRT simultaneously obtains the
refractive power of the central and peripheral retina with good repeatability and accuracy\cite{8, 11}. After calculating the refractive value of each checkpoint through a deep-developed algorithm formula, the corresponding topographic map is generated, which provides a comprehensive analysis of peripheral refraction of the regional retina\cite{3}. Lu et al\cite{11} studied relative peripheral refraction (RPR) in different degrees of myopia by MRT after mydriasis. However, data has shown that a larger pupil size might change the pattern of RPR\cite{12}. Therefore, in this study, we compared RPR without cycloplegia, which mimics daily life conditions in myopia, hypermetropia, and emmetropia eyes, for the purpose of evaluating its correlation with spherical equivalent (SE). We present the following article in accordance with the STROBE reporting checklist.

SUBJECTS AND METHODS

Ethical Approval This study was a descriptive cross-sectional study, and the protocol was approved by the Medical Ethics Committee of Shenzhen Eye Hospital (2021KYPJ006-01). All study subjects were treated according to tenets in the Declaration of Helsinki. Signed written informed consent was obtained from each subject’s parents or guardians.

Subject Selection A total of 713 subjects (713 eyes) who underwent an eye health examination at school from March to July, 2022 were enrolled in the study. The inclusion criteria were as follows: aged 10 to 13y, a best corrected visual acuity of 20/20 or better, with both MRT and autorefractometer results. The exclusion criteria were as follows: a history of ocular disease or surgery, such as orthokeratology, a history of keratopathy, and incomplete MRT or autorefraction data.

Refraction Measurement Refraction measurements were automatically performed using an autorefractor (NIDEK AR-1; NIDEK Co., Ltd., Tokyo, Japan) without a cycloplegic agent. The instrument was calibrated daily prior to use. A mean value was provided based on three measurements. All subjects were required to remove their glasses before the test was performed. SE was calculated in diopters (D) as sphere plus half cylinder. The eyes were classified into four categories according to SE\cite{3}: low hypermetropia (LH) group (between $+0.5$ and $+3.0$ D), emmetropia (E) group (between $-0.5$ and $+0.5$ D), low myopia (LM) group (between $-0.5$ and $-3.0$ D), and moderate myopia (MM) group (between $-3.0$ and $-6.0$ D).

Multispectral Refraction Topography Measurement MRT was used to measure the retinal refractive value. Subjects were positioned on a chinrest and their attention was fixed to an internal target. To ensure intact tear film coating, the subjects were asked to blink twice before each measurement. All MRT measurements were performed by the same experienced doctor in a dark room. Pictures of the fundus were taken with a 53° field of view. Images with poor-quality were excluded.

RESULTS

Subject Characteristics A total of 713 subjects (713 eyes) were enrolled in this study. The mean age of the participants was $11.36\pm1.06$y (range: 10-13y), and there were 341 males and 372 females. There was no significant difference in gender...
or age among the groups. Demographic information for each group is shown in Table 1.

**Comparison of RPR Values** A histogram of SE and RPR frequency in this study is shown in Figure 3. There was a significant difference of RPR 15-30 between groups MM [-0.12; 0.18] and LH [-0.36; 0.12], \( P<0.05 \), MM and E [-0.06; 0.10], \( P<0.05 \), and LM [-0.15; 0.15] and E \( P<0.05 \). There was also a significant difference of RPR 30-45 between groups MM [0.45 (0.18; 0.74)] and E [0.29 (0.09; 0.67), \( P<0.05 \), and LM [0.44 (0.14; 0.76)] and E.
There was no significant difference in four groups of RPR 0-15 (Figure 4). Violin plots of RPR 0-15, 15-30 and 30-45 in each group are shown in Figure 4. The dot in the middle is the median, the box shows the interquartile range, and whiskers show the 95% confidence interval. The shape of the violin represents frequencies of the RPR values.

In the MM group, the RPR values increased from 0-15° to 30°-45°. Subjects in the MM group had relative hyperopia at all annular, whereas those in the LM, E, and LH groups had relative hyperopia only at 30°-45°. RPR values increased from the LH group to MM group in each annular (Figure 5).

There were significant differences of RPR-S between groups MM [-0.02 (-0.60; 0.30)] and E [-0.44 (-0.89; -0.04), \( P < 0.001 \)], and LM [-0.28 (-0.71; 0.12)] and E \( P < 0.05 \). There were also significant differences of RPR-T between groups MM [0.37 (0.21; 0.78)] and LH [0.14 (-0.52; 0.50), \( P < 0.05 \)], LM [0.41 (0.06; 0.84)] and LH \( P < 0.05 \), and LM and E [0.29 (-0.10; 0.68), \( P < 0.05 \)]. No significant difference was found in RPR-I and RPR-N in all groups. Violin plots for RPR-S, I, T, and N in each group are shown in Figure 6.

A Spearman’s correlation analysis showed a negative correlation between RPR and SE in the 15°-30°, 30°-45° annular, superior, and temporal quadrants (Figure 7). However, there were no significant relationships between RPR and SE in the 0-15° annular, inferior or nasal quadrants (Table 2).
DISCUSSION

Uncorrected refractive errors are important causes of avoidable visual impairment[19]. Recently, increased attention has been focused on peripheral refraction in incident myopia and myopic progression[15-17]. MRT, a rapid, accurate, and noninvasive refractometer method, has been used in many studies of peripheral refraction. MRT has been proven to be an objective method for measuring peripheral defocus of the retina, as it shows good repeatability of refraction measurements[11] and is in high agreement with autorefractor data for central refraction measurements[8]. MRT results have shown that eccentricities between 20°-35° peripheral refractive errors may be closely related to refractive development and eye growth in young Chinese individuals aged 18-28y[4]. In children aged 5-18y, the peripheral refraction of RPR 30-45 measured by MRT may be closely related to the development of myopia[3]. In a MRT study of myopic children wearing orthokeratology (OK) lenses, the peripheral retina showed relative myopic defocus, and the growth rate of axial length was smaller with more negative peripheral refraction[5].

However, most studies using MRT measurements have been performed after pupil dilation. Pupil size influences the amount of light penetrating the eye. More peripheral light penetrates through larger pupils than through smaller ones[18]. A previous study found that pupil diameter had a great impact on mean sphere at the periphery[19]. This is the first study of MRT peripheral refraction measurements in school children conducted under photopic conditions and without pupil dilation, and mimics daily life conditions.

A study has underscored the significance of early identification and correction of refractive errors in school-aged children as a means to alleviate the impact of visual impairments[20]. Sng et al[11] found that children with low myopia had relative hyperopia only at 30° and not at 15°, whereas those with high and moderate myopia had relative hyperopia at all peripheral eccentricities. With regard to RPR 0-15 measurements, Lu et al[11] found a significant difference of RPR 0-15 between myopic eyes and emmetropia. However, there was no difference found at 0-15° in our study. These different results may be due to pupil size or group composition. Thirty percent low myopia was included in the study by Lu et al[11], while 60.2% low myopia was included in this study.

There was a significant difference of RPR 15-30 and 30-45 between myopic eyes and emmetropia. A negative correlation was also found between RPR 15-30, 30-45, and SE in this study. RPR values increased from the hyperopic group to moderate myopic group in each annular. These findings were consistent with previous studies conducted using MRT[14], and may indicate that 15°-45° peripheral defocus is not affected by pupil size.

Ehsaei et al[22] found that in myopic eyes, the nasal-temporal retinal shape is not symmetrical, and the temporal retinal shape is steeper than the nasal retinal shape. Our study found significant differences of RPR-T between the MM and LH, LM and LH, and LM and E groups. Furthermore, a negative correlation was found between RPR-T and SE. This finding is consistent with an experiment conducted using the chick model, which found that deprivation of the temporal retina generated more central myopia than deprivation of the nasal retina[21]. However, Tian et al[14] found that SE negatively correlated with RPR-N after pupil dilation. The reason for this difference may be that after cycloplegia, myopic children have less hyperopia in temporal peripheral refraction.

Our study has several limitations. First, the study subjects were all Chinese school children, and no other ethnic groups were involved. Second, we did not perform follow-up of the subjects. Longitudinal studies may further reveal peripheral refraction progression. Third, the sample size was small, and a larger sample size is needed to confirm our findings.

This could be the first study investigating peripheral refraction under photopic conditions without pupil dilation by use of MRT in myopic, hyperopic, and emmetropic school children. Our results provide useful information concerning myopia development and can be used to develop a myopia control strategy that can be used in daily real-life conditions.

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