Int J Ophthalmol, Vol. 17, No. 8, Aug. 18, 2024 www.ijo.cn
Tel: 8629-82245172 8629-82210956 Email: ijopress@163.com

• Clinical Research •

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

Hui-Ling Hu[1], *Serena Zhe-Chuang Li*[2], *Ai-Ying Feng*[1], *Hao-Xi Zhong*[1], *Jing-Feng Mu*[1], *Mei-Zhou Liu*[1]

[1]Shenzhen Eye Hospital, Jinan University, Shenzhen Eye Institute, Shenzhen 518040, Guangdong Province, China
[2]NIMO Ophthalmology Research Institute, Beijing 100176, China

Correspondence to: Jing-Feng Mu and Mei-Zhou Liu. Shenzhen Eye Hospital, 18 Zetian Road, Futian District, Shenzhen 518040, Guangdong Province, China. 1014120300@qq.com; meizhou666@126.com
Received: 2023-12-13 Accepted: 2024-05-10

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

DOI:10.18240/ijo.2024.08.13

Citation: Hu HL, Li SZC, Feng AY, Zhong HX, Mu JF, Liu MZ. Relative peripheral refraction in school children with different refractive errors using a novel multispectral refraction topographer. *Int J Ophthalmol* 2024;17(8):1477-1482

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[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[3]. Lu *et al*[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[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 heath 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 corneal contact lens, incomplete MRT or autorefractometer 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[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 -60 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.

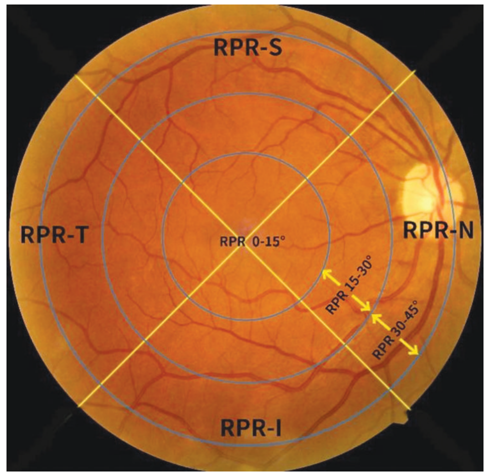

Figure 1 Schematic map for area of retinal refractive measurement Three concentric rings were used to divide the map into three zones (RPR 0-15°, RPR 15°-30°, and RPR 30°-45°). Quadrantal division was performed to divide the map into four zones (RPR-S, RPR-N, RPR-I, and RPR-T). RPR: Relative peripheral refraction; S: Superior; N: Nasal; I: Inferior; T: Temporal.

The parameters measured using MRT were as follows: central refractive error (CRE), relative peripheral refraction-15 (RPR 0-15), relative peripheral refraction-30 (RPR 15-30), and relative peripheral refraction-45 (RPR 30-45), which indicate the average paracentral refractive error in a visual field of 0-15°,15-30°, and 30°-45° centered on the macular fovea, respectively. Relative peripheral refraction-inferior (RPR-I), relative peripheral refraction-superior (RPR-S), relative peripheral refraction-nasal (RPR-N), and relative peripheral refraction-temporal (RPR-T) showed the data in different quadrants (Figure 1). Representative three-dimensional images from each group from direct viewing of the relative fraction status of the retina are shown in Figure 2.

Statistical Analysis All statistical analyses were performed using SPSS software (version 25.0; IBM Corporation, Armonk, NY, USA). The normal distribution of all data was checked using the Shapiro-Wilk test. Data with a non-normal distribution is expressed in quartiles: P50 (P25; P75). Multiple comparisons among groups were performed using the Kruskal-Wallis test followed by the Tukey or Dunn's post-test for sequential pairwise comparisons. A $P<0.05$ was considered to be statistically significant. Violin plots were created using genescloud tools, which is a free online platform for data analysis (https://www.genescloud.cn)[13]. Spearman's correlation coefficient was used to analyze correlations between SE and RPR parameters.

RESULTS

Subject Characteristics A total of 713 subjects (713 eyes) were enrolled in this study. The mean age of the participants was 11.36±1.06y (range: 10-13y), and there were 341 males and 372 females. There was no significant difference in gender

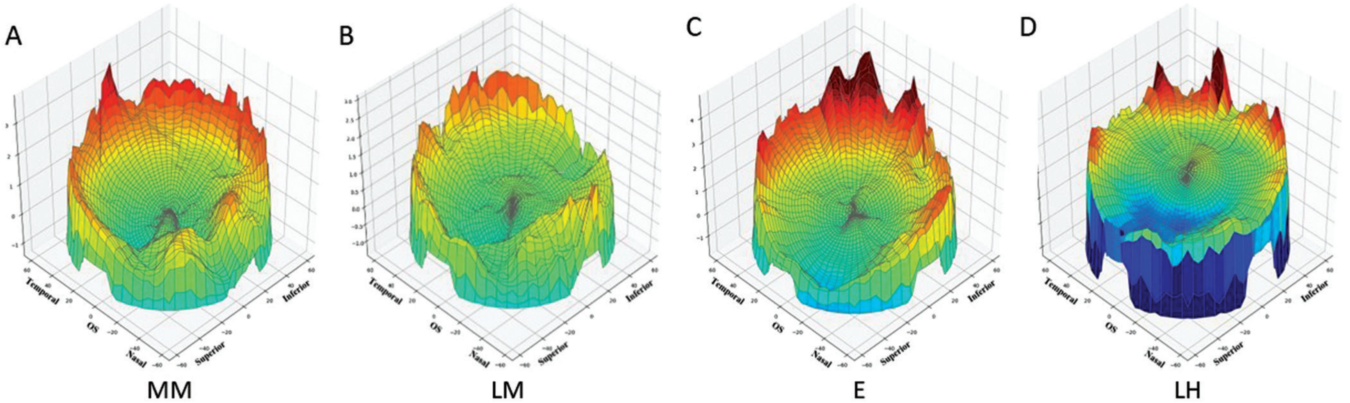

Figure 2 Representative three-dimensional images for direct viewing of the relative retinal fraction status in groups MM, LM, E, and LH MM: Moderate myopia; LM: Low myopia; E: Emmetropia; LH: Low hypermetropia.

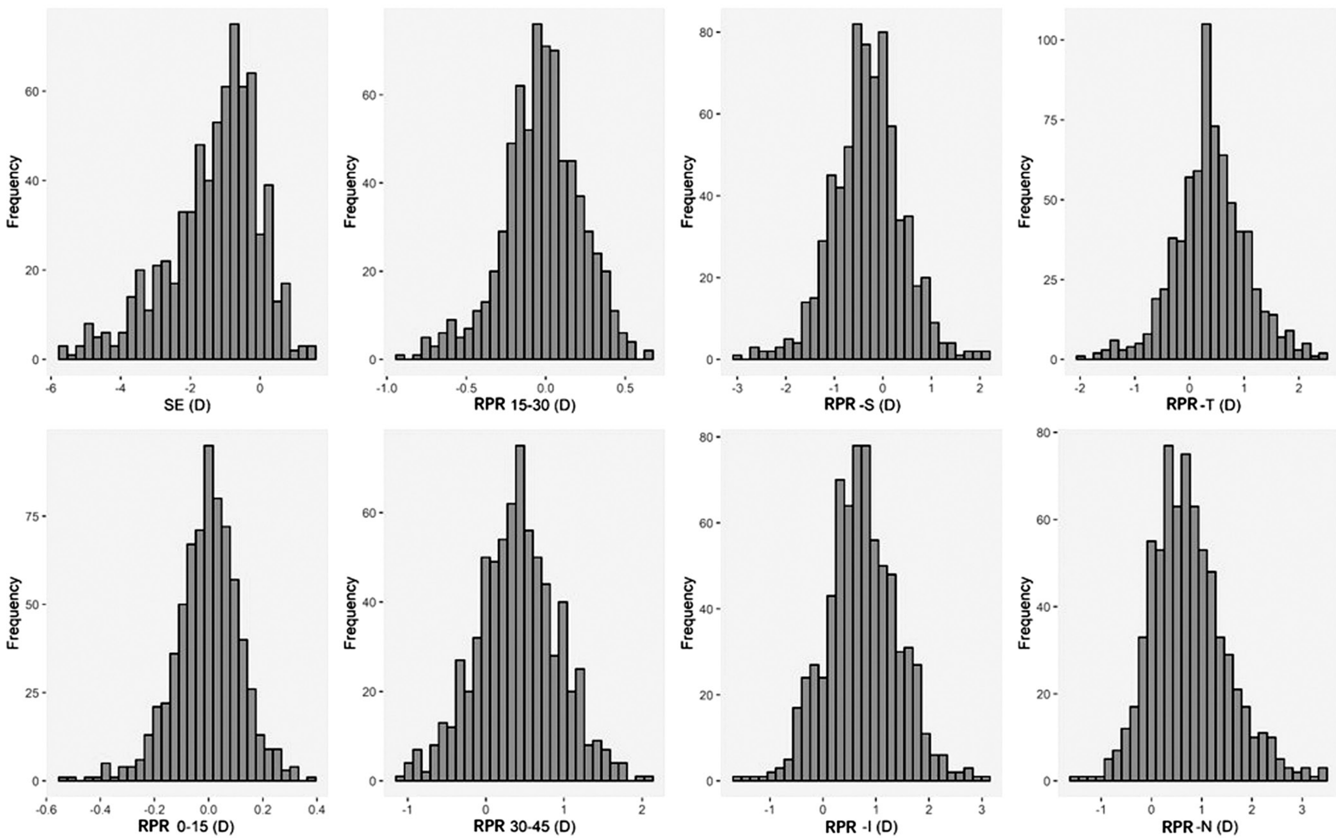

Figure 3 Frequency of SE and RPRs in the study SE: Spherical equivalent; RPR: Relative peripheral refraction; D: Diopter.

Table 1 Demographic information for subjects in groups MM, LM, E, and LH

Group	Age (y)	No. of eyes	Right:left	Gender (male:female)	SE (D)
MM	11.65±0.12	80	45:35	36:44	-3.69 (-4.59; -3.05)
LM	11.41±0.05	429	225:204	201:228	-1.25 (-2.00; -0.88)
E	11.06±0.11	172	77:95	89:83	-0.13 (-0.25;0.13)
LH	11.22±0.16	32	14:18	15:17	0.63 (0.63; 0.84)

SE: Spherical equivalent; MM: Moderate myopia; LM: Low myopia; E: Emmetropia; LH: Low hypermetropia. Age is expressed as a mean value and standard error. SE is expressed in quartiles: P50 (P25; P75).

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 [0.02 (-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 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

Table 2 Correlation between RPR values and SE at different annular and quadrants

Parameters	RPR annular			RPR quadrant			
	RPR 0-15	RPR 15-30	RPR 30-45	RPR-S	RPR-I	RPR-T	RPR-N
r	-0.034	-0.105	-0.114	-0.146	-0.016	-0.127	-0.041
P	0.052	0.005	0.002	<0.001	0.666	0.001	0.279

RPR: Relative peripheral refraction; S: Superior; N: Nasal; I: Inferior; T: Temporal; SE: Spherical equivalent.

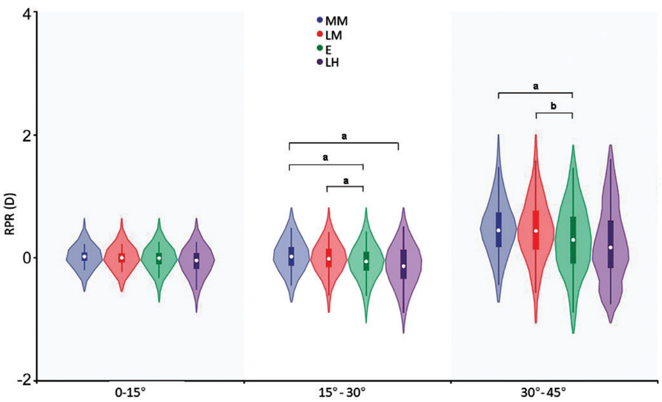

Figure 4 Comparisons of RPR 0-15, 15-30, and 30-45 in four groups RPR values in three annular of each group ([a]$P<0.05$, [b]$P<0.001$). RPR: Relative peripheral refraction; D: Diopter; MM: Moderate myopia; LM: Low myopia; E: Emmetropia; LH: Low hypermetropia.

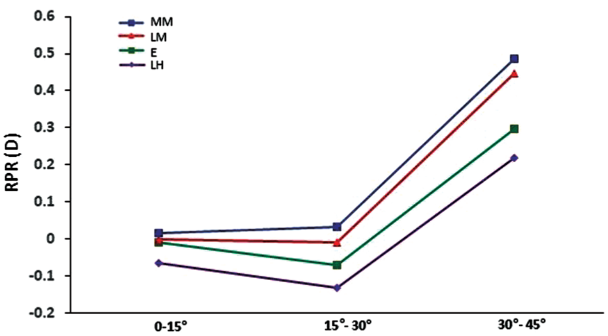

Figure 5 Trends of RPR in different annular of each group MM: Moderate myopia; LM: Low myopia; E: Emmetropia; LH: Low hypermetropia; RPR: Relative peripheral refraction.

(*P*<0.001). 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

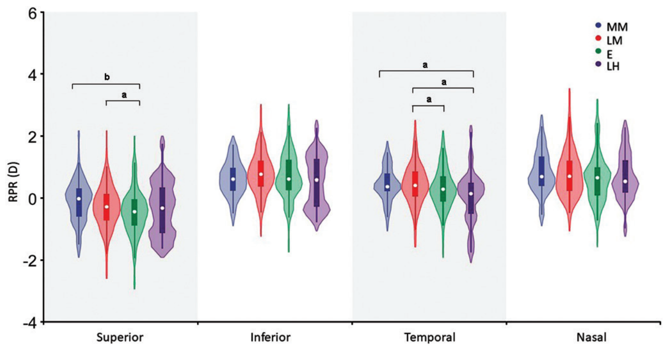

Figure 6 Comparisons of RPR superior, inferior, temporal, and nasal in four groups ([a]*P*<0.05, [b]*P*<0.001) MM: Moderate myopia; LM: Low myopia; E: Emmetropia; LH: Low hypermetropia; RPR: Relative peripheral refraction.

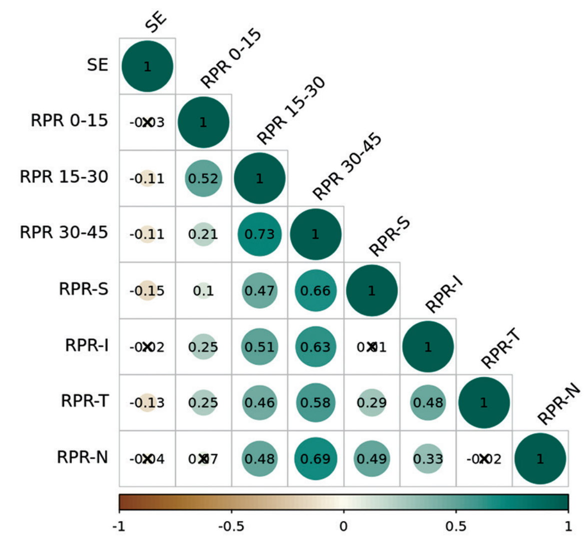

Figure 7 SE was negatively correlated with RPR 15-30, RPR 30-45, RPR-S, and RPR-T Data in circles show the correlation coefficient. Data with × show that there is no significant correlation. RPR: Relative peripheral refraction; S: Superior; N: Nasal; I: Inferior; T: Temporal; SE: Spherical equivalent.

(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.

Relationship between RPR Values and SE 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[14]. 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 impairment[20]. Sng *et al*[21] 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[1,4], 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[23]. However, Tian *et al*[24] 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.

ACKNOWLEDGEMENTS

Foundation: Supported by the Shenzhen Science and Technology Program (No.JCYJ20210324142800001).

Conflicts of Interest: Hu HL, None; **Li SZC,** None; **Feng AY,** None; **Zhong HX,** None; **Mu JF,** None; **Liu MZ,** None.

REFERENCES

1 Holden BA, Fricke TR, Wilson DA, Jong M, Naidoo KS, Sankaridurg P, Wong TY, Naduvilath TJ, Resnikoff S. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology* 2016;123(5):1036-1042.

2 Qi LS, Yao L, Wang XF, Zhao J, Liu Y, Wu TY, Yang QH, Zhao C, Zou ZK. Relative peripheral refraction and its role in myopia onset in teenage students. *Int J Ophthalmol* 2022;15(7):1108-1115.

3 Xiaoli L, Xiangyue Z, Lihua L, Yuting H, Chuni L, Yujie X, Zhao W, Xiaoyi Y. Comparative study of relative peripheral refraction in children with different degrees of myopia. *Front Med* (*Lausanne*) 2022;9:800653.

4 Zheng XY, Cheng DJ, Lu XL, Yu XY, Huang YT, Xia YJ, Lin CN, Wang Z. Relationship between peripheral refraction in different retinal regions and myopia development of young Chinese people. *Front Med* 2021;8:802706.

5 Li T, Chen ZY, She M, Zhou XD. Relative peripheral refraction in myopic children wearing orthokeratology lenses using a novel multispectral refraction topographer. *Clin Exp Optom* 2023;106(7): 746-751.

6 Lam CSY, Tang WC, Tse DY, Lee RPK, Chun RKM, Hasegawa K, Qi H, Hatanaka T, To CH. Defocus incorporated multiple segments (DIMS) spectacle lenses slow myopia progression: a 2-year randomised clinical trial. *Br J Ophthalmol* 2020;104(3):363-368.

7 Zhang HY, Lam CSY, Tang WC, Leung M, Qi H, Lee PH, To CH. Myopia control effect is influenced by baseline relative peripheral refraction in children wearing defocus incorporated multiple segments (DIMS) spectacle lenses. *J Clin Med* 2022;11(9):2294.

8 Liao YR, Yang ZL, Li ZJ, Zeng R, Wang J, Zhang YC, Lan YQ. A quantitative comparison of multispectral refraction topography and autorefractometer in young adults. *Front Med (Lausanne)* 2021;8:715640.

9 Fedtke C, Ehrmann K, Holden BA. A review of peripheral refraction techniques. *Optom Vis Sci* 2009;86(5):429-446.

10 Fernandez EJ, Sager S, Lin ZH, Hao JD, Roca J, Prieto PM, Yang ZK, Lan WZ, Artal P. Instrument for fast whole-field peripheral refraction in the human eye. *Biomed Opt Express* 2022;13(5):2947-2959.

11 Lu WC, Ji RY, Ding WZ, Tian YY, Long KL, Guo Z, Leng L. Agreement and repeatability of central and peripheral refraction by one novel multispectral-based refractor. *Front Med (Lausanne)* 2021;8:777685.

12 Faria-Ribeiro M, Navarro R, González-Méijome JM. Effect of pupil size on wavefront refraction during orthokeratology. *Optom Vis Sci* 2016;93(11):1399-1408.

13 Li QH, Chai YM, Shao QW, Wang ZM, Xie W, Zhou YD, Sun D, Xie XH, Zhang DS. Metabarcoding survey of meroplankton communities in the South China Sea and Philippine Sea: shedding light on inter-basin biogeography in the West Pacific. *Front Mar Sci* 2022;9:968666.

14 Németh J, Daiki T, Sándor GL, Keve H, Szabó D, Tóth G, Dankovics G, Barna I, Limburg H, Nagy ZZ. Uncorrected refractive errors are important causes of avoidable visual impairment in Hungary: re-evaluation of two existing national data sets. *Int J Ophthalmol* 2023;16(6):955-961.

15 Sun HY, Lu WY, You JY, Kuo HY. Peripheral refraction in myopic children with and without atropine usage. *J Ophthalmol* 2020;2020:4919154.

16 Zhang HY, Lam CSY, Tang WC, Leung M, To CH. Defocus incorporated multiple segments spectacle lenses changed the relative peripheral refraction: a 2-year randomized clinical trial. *Invest Ophthalmol Vis Sci* 2020;61(5):53.

17 Russo A, Boldini A, Romano D, Mazza G, Bignotti S, Morescalchi F, Semeraro F. Myopia: mechanisms and strategies to slow down its progression. *J Ophthalmol* 2022;2022:1004977.

18 Chen Z, Niu LL, Xue F, Qu XM, Zhou ZM, Zhou XT, Chu RY. Impact of pupil diameter on axial growth in orthokeratology. *Optom Vis Sci* 2012;89(11):1636-1640.

19 Rodriguez-Vallejo M, Benlloch J, Pons A, Monsoriu JA, Furlan WD. The effect of fractal contact lenses on peripheral refraction in myopic model eyes. *Curr Eye Res* 2014;39(12):1151-1160.

20 Signes-Soler I, Ragot A, Nangena S, Wekesa A, Montalbán Llamusí R. Prevalence of visual impairment and estimation of refractive errors among school children in Kakamega, Kenya. *Int J Ophthalmol* 2024;17(5):932-939.

21 Sng CC, Lin XY, Gazzard G, Chang B, Dirani M, Chia A, Selvaraj P, Ian K, Drobe B, Wong TY, Saw SM. Peripheral refraction and refractive error in Singapore Chinese children. *Invest Ophthalmol Vis Sci* 2011;52(2):1181-1190.

22 Ehsaei A, Chisholm CM, Pacey IE, Mallen EA. Off-axis partial coherence interferometry in myopes and emmetropes. *Ophthalmic Physiol Opt* 2013;33(1):26-34.

23 Stone RA, Pendrak K, Sugimoto R, Lin T, Gill AS, Capehart C, Liu J. Local patterns of image degradation differentially affect refraction and eye shape in chick. *Curr Eye Res* 2006;31(1):91-105.

24 Tian JX, Wei SF, Li SM, An WZ, Bai WL, Liang XT, Du JL, Wang NL. The effect of atropine 0.01% eyedrops on relative peripheral refraction in myopic children. *Eye (Lond)* 2023;37(2):356-361.