

## Relative peripheral refraction among children in Kuala Lumpur

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### Abstract

**This study describes the baseline data of peripheral refraction among Chinese schoolchildren in Kuala Lumpur. A total of 130 Chinese schoolchildren aged between 7 to 12 years were recruited. Peripheral refraction was conducted under cycloplegic condition using the Grand Seiko WR5100-k. An eye rotation method to view eccentric target was used. The mean age of the subjects was  $9.46 \pm 1.59$  years. There were 32 (24.6%) schoolchildren with moderate myopia, 40 (30.8%) with low myopia, 17 (13.1%) with emmetropia and 41 (31.5%) with low hyperopia. The M component and Relative Peripheral Refractive Error (RPRE) for moderate and low myopes exhibited a hyperopic defocus; emmetropes showed a flat to slightly myopic profile and low hyperopes had a myopic shift at both eccentricities. A comparison between refractive groups showed a significant difference in M component at all eccentricities. A symmetrical pattern was observed for M component for all refractive groups except for low hyperopes at  $30^\circ$  eccentricity. Our study was able to provide a baseline peripheral profile pattern across the horizontal meridian among Chinese schoolchildren in Kuala Lumpur.**

Keywords—Peripheral refraction, relative peripheral refractive error, myopia, Chinese children, schoolchildren, hyperopic defocus.

### I. INTRODUCTION

The idea of image focus in the peripheral retina has lately captured the interest of many researchers. Studies that pursued their interest in refractive errors in the peripheral retina showed influences in the eye growth mechanism (Mutti et al., 2007; Smith et al., 2005; Wallman & Winawer, 2004). Peripheral refractive errors have been investigated for more than seven decades now and it is suggested that a myopic eye usually has a hyperopic defocus at the peripheral eccentricities (Logan et al., 2004; Schmid, 2003; Seidemann et al., 2002). Since then, numerous animal studies have contributed in this research area.

Landmark studies (Smith et al., 2005; Smith et al., 2007) have suggested that peripheral retina has a comprehensive influence on central refractive error development. One of the studies revealed that form deprivation resulted in axial myopia in the presence of unrestricted fovea vision (Smith et al., 2005). Additionally foveal photoablation did not interfere with the emmetropization process or the form deprivation myopia (Smith et al.,

2007). Peripheral deprivation with unrestricted central vision causing in axial myopia was also typically seen in chicks (Stone et al., 2006) which suggests peripheral retina signals are able to outshine fovea signals causing an overall ocular growth.

Global attention to the importance of peripheral refraction and its impact on myopia is eminent. Researchers have identified the peripheral pattern (Atchison et al., 2006) with different techniques (Fedtke et al., 2009) and have ventured into treatment modalities with peripheral correction using Orthokeratology (Charman et al., 2006) novel spectacle lenses (Sankaridurg et al., 2010) as well as contact lenses (Anstice & Philips, 2011) at the international level.

To the best of our knowledge, no research has been conducted to evaluate the peripheral refraction in Malaysia. This study allows us to determine the peripheral refraction of myopic and non-myopic Chinese schoolchildren in Kuala Lumpur.

## II. METHODS

### A. *Study Population*

The participants were all Chinese schoolchildren of 7 to 12 years of age with the following inclusion criteria: no ocular disease, healthy medically as well as mentally and had agreed for cycloplegic instillation.

### B. *Eye Examinations*

Preliminary evaluation and entrance test was conducted to ensure that all subjects adhered to the inclusion criteria. Subjective refraction with an endpoint of maximum plus or minimum minus with the best visual acuity was obtained. Cycloplegic effect was introduced with the instillation of two drops of Cyclopentolate 1% administered 5 minutes apart. After half an hour, the autorefractometer was performed.

Peripheral refraction was measured using an open field infrared autorefractor (Grandseiko WR5100-k autorefractometer). The left eye was occluded while the right eye was measured. The machine was calibrated every two weeks to ensure its accuracy of the data.

Thirteen eccentricities target was marked on a blank wall horizontally separated by an angular distance at every 5 degrees up to 30 degrees on both sides. The instrument was placed at four metres measuring from the wall to the corneal vertex of the subjects' eye. A red coloured laser light was used to point at the specific target for the subjects to look at while taking the measurements. Subjects first fixated on the centre target and were followed by the others as it were shown one by one at different eccentricities. The subjects fixated at each target by moving only their eyes and keeping their head stationary. All measurements were conducted in a semi-dark room to assist in pupil dilation of at least 5mm or more.

The mire of the instrument on the cornea was aligned and kept in focus in the centre of the pupil at all eccentricities. Fixation to the right side of the subject corresponds to the nasal visual field and fixation to the left side corresponds to the temporal visual field for the right eye. Only the right eye data are presented in this study.

### C. Ethical Approval

This research follows the tenets of the declaration of Helsinki and was approved by the ethical committee of University Kebangsaan Malaysia (UKM). Informed and written consent was obtained from the parents of each subject after explaining the purpose and nature of the study.

### D. Definitions

Myopic eye was divided into two groups defined as low myopia with mean spherical equivalent of -0.50D to -3.00D and moderate myopia of -3.01D to -6.00D, whereas emmetropic eye was defined as between -0.49D and +0.50D and low hyperopia as +0.51D to +2.00D.

Results from the autorefractor were converted into vector component as the derived equations (Thibos 1997) by representing the sphere (S) and cylinder (C):

$$M = S + 1/2 C \quad (1)$$

M representing the spherical equivalent of the autorefractor result. In addition, relative peripheral refraction (RPR) of the eye was calculated:

$$RPR = M_{eccentricity} - M_{centre} \quad (2)$$

Relative peripheral refractive (RPR) is defined as the spherical at that particular eccentricity subtracted with the central spherical equivalent.

### E. Statistical Analysis

Collected data was analyzed using the Statistical Product and Service Solution (SPSS) software version 20.0. One way repeated measure ANOVA was used to describe the raw peripheral profile between groups of refractive status. Finally, the paired t-test was used to see the asymmetry profile between the temporal and nasal eccentricities. A critical value of 0.05 was chosen to denote statistical significance for all analysis.

## III. RESULTS

130 Chinese children consisting of 76 female and 53 male children agreed to be part of this study. All of them were Chinese as both parents belonged to the ethnic Chinese community. The subjects' average age was  $9.46 \pm 1.59$  years. Figure 1.0 show the peripheral refraction for mean spherical equivalent for the entire refractive error group accordingly.

A significant difference in the refraction profile within the group was found in the moderate myopes, low myopes and low hyperopes with  $F(2.523, 78.225) = 12.209, p = 0.000$ ,  $F(2.004, 78.168) = 15.750, p = 0.000$  and  $F(2.644, 105.777) = 24.955, p = 0.000$  respectively. Nonetheless, emmetropes refraction profile showed a non-significant result,  $F(1.617, 25.878) = 1.989, p = 0.164$ .

An ANOVA test was conducted to analyze the peripheral refraction at all eccentricities. A significant difference in spherical equivalent was found between all four groups for all eccentricities. With a post hoc analysis, using the Dunnett T3 test, 25 and 30 degrees of the temporal visual field angle showed no significant difference between low hyperopic and emmetropic refractive error group,  $p = 0.78$  and  $p = 0.339$  respectively.

Assessing the symmetry of the peripheral refraction profile, the spherical equivalent component, myope and emmetrope refractive error groups showed symmetrical pattern between both extreme angles however the low hyperope group showed asymmetrical peripheral pattern profile. Moderate myope had mean spherical equivalent about  $+0.94D \pm 0.99$  hyperopic defocus at 30 degree temporal visual field and  $+1.01D \pm 0.66$  at 30 degree nasal visual field. For low myope,  $+0.95D \pm 1.03$  of hyperopic defocus was found in the temporal 30 degree, which is almost similar to the moderate myopes. On the nasal 30 degree extremities, we found a slightly lower value of,  $+0.83D \pm 0.87$  for low myopes. The emmetropes showed a small myopic shift at both extreme 30 degree of temporal and nasal visual field with  $-0.20D \pm 0.71$  and  $-0.23D \pm 0.80$  respectively. Lastly, for the low hyperopic group, they were having myopic defocus at 30 degree temporal visual field as well as the nasal visual field with  $-0.87D \pm 0.91$  and  $-0.56D \pm 0.68$  respectively. The temporal eccentricity happens to be more myopic compared to the nasal side. Figure 1 shows mean relative peripheral refraction of mean spherical equivalent for all groups of refractive status group.

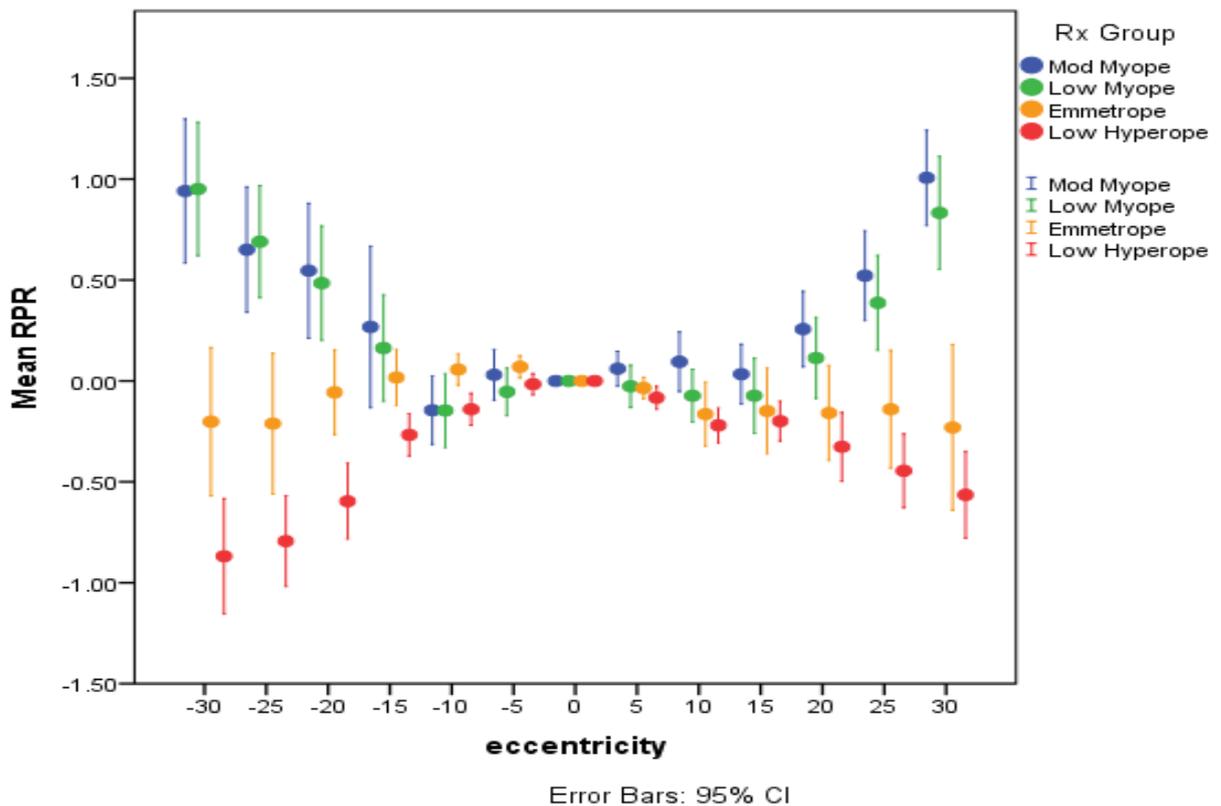


Figure 1 Graph of mean relative peripheral refraction of mean spherical equivalent for all groups of refractive status group. The negative eccentricity denotes the temporal visual field and the positive eccentricity denotes nasal visual field.

#### IV. DISCUSSION

The spherical equivalent (M) profile demonstrated a hyperopic defocus at both temporal and nasal eccentricity of the visual field among the moderate and low myope group. Similar to earlier publications, the result affirms that along the horizontal meridian the moderate myopes characterize the prolate shape of the eye (Atchison et al., 2006; Logan et al., 2004; Ehsaei et al., 2011). However later studies showed that low myopes demonstrated emmetropic peripheral refraction across the horizontal meridian (Kang et al., 2011; Calver et al., 2007). There were only very small variations with eccentricities in the low myopes, which were contradictory to our findings. Both of the contradicting studies used age groups ranging from 18 to 38 years as their subjects. Age factor could be one of the factors for low myopes to differ in the peripheral refraction pattern. Other similar studies found low myopes exhibiting a hyperopic shift with a lesser extent at the periphery visual field (Chen et al., 2010; Sng et al., 2011a).

Emmetropes showed a flat to slightly myopic shift at the periphery in the present study. The myopic shift is insignificant compared to central refraction. Most studies are in agreement with this result (Atchison et al., 2005; Mutti et al., 2007). Low hyperopic eye in the present study exhibited a more myopic shift at both temporal and nasal periphery consistent with the findings from other studies (Lee & Cho 2013).

In the current study, peripheral refraction of the spherical equivalent profile showed a symmetrical pattern for all groups except for the low hyperopic group. In a very recent study (Lee & Cho 2013), they found a symmetrical shape of an optical shell in all groups at a baseline measurement. However, the optical shell became more asymmetrical after 12 months. The present study did not have the privilege of obtaining a follow up measurement to detect any asymmetrical pattern. Another study reported that the nasal temporal asymmetry was only statistically significant at 30 degrees along the horizontal meridian (Ehsaei et al., 2013).

Development of myopia axially may have contributed to the asymmetry in peripheral refraction profile. Some studies suggested that angle lambda (angle alpha) (Bernsten et al., 2008; Calver et al., 2007) and corneal asymmetry (Atchison et al., 2006) explain the irregularity of the peripheral profiles at both eccentricities in refractive error groups. Another opinion proposed by a recent study states that different rates of ocular changes in different meridians during myopia progression causes the asymmetry (Lee & Cho 2013).

The human eye increases in axial length with a corresponding increase in the orbital volume as from birth to adolescence (Chau et al., 2004). For the adult eye, the lateral pole happens to be closer to the orbital socket wall, concluding to a smaller orbital space laterally (Dektoris et al., 2010). However, a smaller cavity by the temporal boundary causing the asymmetry is unclear, as it is not similar among children.

Another possible idea may be that the presence of the optic nerve head on the temporal visual field might limit the ocular growth at one side compared to the other (Smith et al., 2010). In our study, we did not observe any significant asymmetrical profile. This may be possibly due to the child's eyes which were in the growing stage where it has not completely expanded. The hyperopes experienced an asymmetry although the differences were very small, clinically. The difference among refractive groups' peripheral pattern, may

be because of the difference in anatomical characteristics, which would have eventually caused the constraints against growth. The present study also did not take into account of the status of the refractive error whether it was progressive or otherwise. Nonetheless, further analysis is required to conclude the reasons for the presence or non-presence of asymmetry profile. Focusing on the myopic group in this present study, a hyperopic defocus of  $+0.94D \pm 0.99$  and  $+1.01D \pm 0.66$  at temporal and nasal visual field was seen respectively among the moderate myopes. On the other hand, low myopes had a similar outcome with  $+0.95D \pm 1.03$  at the temporal visual field and  $+0.83D \pm 0.87$  at the nasal visual field.

As we compare to the study conducted in our neighboring country (Sng et al., 2011b), they found that high to moderate myope groups had  $+1.23D \pm 0.89$  and  $+1.93D \pm 1.28$  of hyperopia defocus at temporal and nasal visual field respectively. However, a lesser defocus of  $+0.09D \pm 0.88D$  at the temporal visual field and  $+0.50D \pm 0.99$  at the nasal visual field was observed among their low myope group. It is clear that although both the neighboring countries believed to have a similar population, the results did differ much especially for the low myopic group.

Studies which focused on peripheral refraction measurements among Chinese children aged 8 to 15 years old from China found much higher hyperopic defocus value at both extremities compared to the present study (Lin et al., 2010) which portrayed about  $+2.53D \pm 1.31$  at the temporal and  $+3.12D \pm 1.08$  at the nasal visual field among the moderate myopes and equally high results for low myopes with  $+1.73D \pm 1.00$  and  $2.75D \pm 1.31$  respectively.

Among the Caucasian population, hyperopic shift of  $0.5D$  was observed at 30 degrees nasal visual field among myopes (Millidot, 1981) and another similar study obtained a slightly higher hyperopic shift of about  $0.8D$  at the same angle (30 degrees of nasal visual field) (Mutti et al., 2000). Comparing the same eccentricity, a later study exhibits about  $1D$  of hyperopic defocus for their moderate myope with mean central refractive error of  $-4D$  and a smaller shift of approximately  $0.5D$  for their  $-3D$  group (Atchison et al., 2006).

A study comparing peripheral patterns among different ethnicities found a statistical significant difference in moderate myope group between the Whites and East Asian population (Kang et al., 2010). Generally, their East Asian moderate myopes had a greater degree of relative peripheral hyperopia compared to the White's eye with similar central refractive error.

The large variability of relative peripheral refractions in myopic subjects may be due to reasons such as difference in accommodation patterns, interaction of peripheral refraction with central refraction being different among subjects and possible influence of the higher order aberration resulting in the difference in peripheral refraction patterns as well (Taberner et al., 2011).

With all the possible consideration, the amount of peripheral myopia required to retard central myopia progression requires a more comprehensive studies. A uniform treatment regime may not show a successful outcome. Customizing treatment regime according to individual peripheral refraction pattern might be the ultimate way to enhance the purpose of retarding myopia development.

The major strength of the current study is the assembly and evaluation of the peripheral refraction profile among the young Chinese children in Kuala Lumpur, Malaysia, in whom the prevalence of myopia is high. The baseline data of peripheral refraction in Malaysian Chinese children shows the range and limits of hyperopic defocus at the periphery, which may differ from a Caucasians child's eyes. Additionally, assessment of peripheral refraction at the horizontal plane at every 5 degrees interval up to 30 degrees for both extremities allowed plotting a more complete graph of the peripheral refraction profile.

On the other hand, some limitations should also be addressed in the interpretation of the present study. First and foremost, this study was unable to establish the relationship between hyperopic defocus at the periphery and the onset of myopia as this is a cross sectional study deriving the profile pattern among Malaysian children with different refractive error centrally. Secondly, the horizontal peripheral profile was only investigated up to 30 degrees for both eccentricities. Reading beyond 30 degree was challenging mainly due to the setting where the target is at 4 meters. Another reason could be due to the patient's pupil size which was not large enough as the eye was only cyclopleged.

## V. CONCLUSION

In summary, the results from the present study are particularly relevant to the design of the commercial ophthalmic spectacle lenses that manipulates peripheral refractive error of human eyes with an aim to minimize the development of myopia based on multiple axis analysis rather than just the central refractive errors. The importance of evaluating the multi-axis globe shape dissimilarities among different eyes of various ethnicities, age and refractive error condition is crucial. This may lead to the fact that peripheral image shell modifications will need to be tailored to a given retinal surface profile in the future.

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