International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 9 No. 4 Dec. 2014, pp. 1598-1608

http://www.ijias.issr-journals.org/

Undercorrection Induces Peripheral Myopic Defocus in School Children in Kumasi, Ghana

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ABSTRACT: The purpose of this study was to determine whether undercorrection single vision lenses altered the peripheral refractive error of myopic school children when targets are viewed at 2m. Seventy four children with mean age of 12.28 ± 1.33 years were assigned to full correction and undercorrection groups. Central and peripheral refraction was measured to 30° in the nasal and temporal retina using a free-space autorefractor. Full correction spectacle lenses caused a hyperopic shift in spherical equivalence (M) in all peripheral locations (all p=0.001) whereas undercorrection caused a myopic defocus at 4 of the 6 retinal locations (all p=0.001). There were temporal–nasal asymmetries in J180 and J45 astigmatism. Undercorrection spectacle lenses induced more against- the- rule astigmatism at 30° nasal retina than with full correction. At temporal retina, full correction induced more against- the -rule astigmatism than with undercorrection. Undercorrection resulted in a myopic shift in the horizontal retina of the myopic eye. Children who wear uncorrected spectacle lenses are more likely to have a reduction in myopia progression.

KEYWORDS: undercorrection, peripheral refractive error, myopia.

1 INTRODUCTION

Myopia is associated with serious sight threatening conditions like glaucoma, cataract and retinal detachment and its prevalence is increasing worldwide. Myopia affects about a third of the adult population in the United States [81]. In Asia, its prevalence is increasing to epidemic proportions: about 84% of children between 16 and 18 years [48] and 80% of young adults are affected [65]. The prevalence of myopia among school children in the Durban area of South Africa, Chile, rural and urban India were 2.74% [57], 12.8% [51], 5% [19] and 9% [53] respectively. In Ghana, its prevalence was 54.2% among those who self-reported to eye care facilities and 69.2% of this number were aged between 10 and 19 years [45].

Consequently, there are attempts to either halt or reduce the rate of myopia progression with optical interventions such as undercorrection single vision lenses [1],[17],[80], bifocal lenses [26], progressive addition lenses [11],[31],[36],[38],[87], novel contact lens designs [2],[62], and Orthokeratology lenses [15],[16],[39],[42],[63],[82]. Most of these studies have assumed that visual signals from the fovea dominate refractive development and progression [83].

Studies of the mechanisms that regulate refractive development and progression, suggest that optical strategies that alter the peripheral retinal refraction might change the rate of axial length elongation and myopia progression [40],[76]. This hypothesis is supported by studies in monkeys which demonstrate that visual signals from the fovea play a minimal role in myopia progression and that peripheral visual signals may independently induce a refractive change [73]. In addition, when there are conflicting visual signals in the central and peripheral retina, those in the peripheral retina can dominate and regulate axial growth and myopia progression [72].

In a 2-year study randomized trial, myopic children in the undercorrection group had a 0.23D increase in myopia progression compared to those in the full correction group [17]. Reference [1] found no significant difference between the fully corrected and the undercorrected myopic children. However, in a 3-year randomized study, [31] found a 0.20D reduction in myopia progression among myopia children corrected with PALs. This result probably suggests that PALs cause myopic defocus centrally and peripherally which resulted in reduced myopia progression. The performance of these two optical lenses can be compared because undercorrecting myopia by +0.50 is similar to full correction with PALs with an addition of +0.50D. The studies by [17] and [1] appropriately evaluated the progression when children wore undercorrection spectacles; they did not measure the accommodative state or the peripheral refraction of the children. The relationship between undercorrection and myopia progression is still obscure and needs to be resolved. The purpose of this study therefore was to determine the influence of undercorrection or full correction single vision lenses on peripheral retina of myopic children in Ghana

2 Methods

The Committee on Human Research, Publications and Ethics of the Kwame Nkrumah University of Science and Technology, School of Medical Sciences and Komfo Anokye Teaching Hospital, reviewed and approved the study. Approval was also obtained from the Ashanti Regional Health Directorate and Education Service. This study conformed to the tenets of the Declaration of Helsinki because benefits and risks involved in the study were explained to the children and their parents. Before assessing eligibility of children to the study, parents and children agreed by signing informed consent forms and by verbal assent respectively.

2.1 Subjects

Seventy four healthy children aged from 10 to 15years (made up of 46 girls and 28 boys) were enrolled in this study. The inclusion criteria were: visual acuity of log MAR 0.20 or better with habitual spectacles, spherical equivalence refraction (SER) of -1.25 to -4.50D in each meridian as measured by autorefractor, astigmatism ≥ -1.25D, anisometropia ≤ 1.00D, normal binocular function (no manifest strabismus or amblyopia) and no ocular pathology.

2.2 Phoria Measurement

Distance and near phoria were measured by the prism cover test while the children wore the study spectacles. During measurement of distance phoria, the child fixated a letter, 2 lines above the threshold on the Early Treatment Diabetic Retinopathy Study (ETDRS) distance chart. Near phoria was measured at 40 cm while the child wore the same correction and fixated a crowded N10 standard letter E.

2.3 Objective Measurement Of Central And Peripheral Refractive Error

Baseline measurements of central and peripheral refractive error were done by an experienced optometrist who was trained on study protocol. A Shin-Nippon (Grand Seiko) NVision- K5001 was used to measure central and the horizontal meridian of the peripheral retina. Measurements were done while children wore no correction and also when they wore their habitual spectacles. The fixation targets was a 6 -Watts red incandescent bulb fixed on a costume-made straight bar wooden frame that stood 2m away . The red bulb allowed children to maintain fixation even when they did not have their spectacles on. The frame allowed the target to be moved to the required eccentricity within the visual field. Because children viewed the fixation target on a straight bar, the instrument-to-fixation target distance was 2m to 2.5m but will be referred to as 2m in this study.

Five measurements of refraction were taken in both eyes. Measurements were taken at the 0º (foveal), 10º, 20º and 30º in both the temporal (nasal retina) and nasal (temporal retina) visual fields.

Children turned their eyes and kept their heads stationary when they had to view the target in the nasal or temporal field [59],[69]. Measurements were done under ambient lighting conditions between 120 and 130 Lux.

2.4 DATA ANALYSIS

Data analysis was performed using Microsoft Excel and STATA 11 software. Measurements in the right eye only was used for analysis because Pearson correlation coefficient was as high as 0.90 between the two eyes. Sphero-cylindrical refractive error was decomposed into power vector form according to the equation by [79]

$$M = S + C/2 \qquad (1)$$
$$J180 = -C\cos 2\theta/2 \qquad (2)$$
$$J45 = -C\sin 2\theta/2 \qquad (3)$$

S, C and θ are the spherical, cylindrical and cylindrical axis components of the sphero-cylindrical refractive error. M is the mean spherical equivalent refractive error, J_{180} is the with and against- the –rule astigmatism and J_{45} is for oblique angles from 45 to 135 degree.

A relative peripheral refractive error (RPRE) was calculated as the difference between the foveal refraction and the respective peripheral refractive error.

3 RESULTS

One hundred and four school children voluntarily responded to verbal and written advertisements in three schools. 95 of them returned with the signed consent forms. These children were screened between September 13, 2011 and March 5, 2012 and 80 met the inclusion criteria. However, the first 74 children comprising 46 girls (62.16 %) and 28 boys (37.84%) were enrolled because of the calculated sample size. .

The mean age ± SD of the 74 children was 12.28 ± 1.33 years and 40 children entered the study with habitual undercorrection of +0.50D spectacle lenses while 34 wore habitual full corrections. Mean age ± SD of children in the undercorrection and full correction groups was 13.04 ± 1.3 and 12.9 ± 1.2 years respectively (p=0.63). The baseline mean cycloplegic SER of the children was -1.95 ± 0. 57 was -1.89 ± 0.54D and -2.04 ± 0.55D in the undercorrection and full correction groups p= 0.24. However, the habitual spectacle prescription was -2.41 ± 0.55 and -1.89 ± 0.54D in the full correction and undercorrection groups respectively p= 0.0001.

Near phoria was measured at 40 cm while the child wore the same correction and fixated a crowded N10 standard letter E. The children were classified as orthophoric when they exhibited less than 5 Δ or no ocular movement, exophoric when they exhibited 5Δ or more and any amount of Esophoria was esophoric as shown in Table 1, a classification similar to that by [1].

Table 1: Baseline distance phoria when measured with their habitual spectacles

	Full correction	undercorrection
Orthophoria	21	24
Exophoria	12	14
Esophoria	1	2

3.1 MEAN SPHERE POWER (M)

The mean change in spherical equivalence (M) between children in the two groups in the uncorrected and corrected states is shown in figure 1 below. In the uncorrected state there was no significant difference in M between children who wore full correction or undercorrection groups (p=0.86). M was however significantly different by retinal location in all children. This difference did not depend on whether the child was in the full correction or undercorrection group (all p≤ 0.0001). Both groups showed asymmetry between the nasal and temporal groups. Negative values were measured at both visual fields and the values showed relative hyperopia.
In the corrected state, there were differences in M between the 2 groups which depended on the assigned group as shown in figure 1 below. For children in the full correction group M was more hyperopic than in the undercorrection group. The values measured in peripheral retina with full correction was significantly more hyperopic than the measurement at the fovea $F_{(6,210)}$ =16.15, p=0.0001.

Negative values were measured at 10º, -10º,-20º and -30º eccentricity in the undercorrection group. Repeated Anova revealed a significant difference between all eccentricities at 2m with undercorrection F $_{(6, 210)}$ = 18.31, p=0.001.

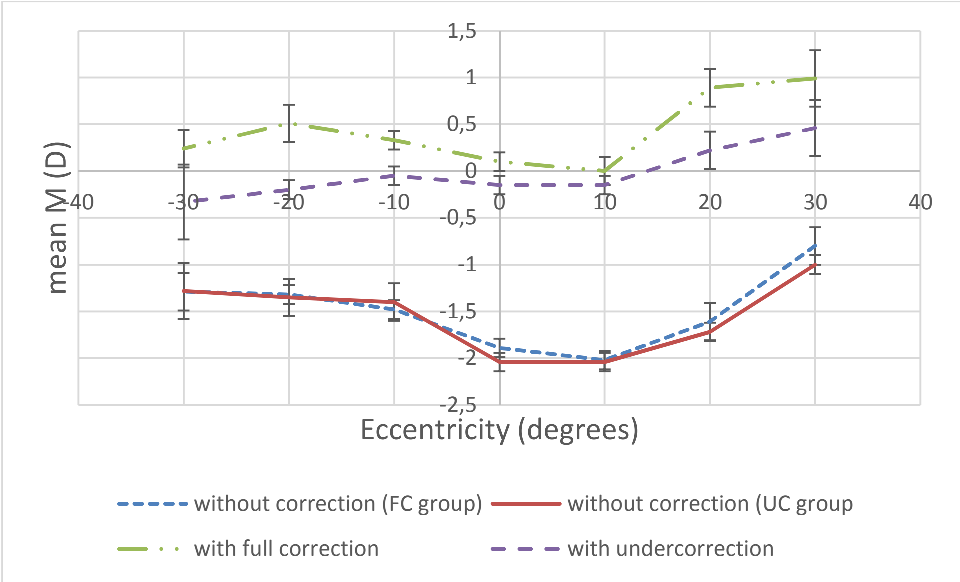

Figure 1: shows the mean spherical equivalence (M) of uncorrected myopic and fully corrected and undercorrected children who viewed a distant target at far (2m). Error bars indicate ± SEM

3.2 Peripheral Astigmatism (J_{180} and J_{45})

There was no statistical difference between the two uncorrected groups p=0.51. As shown in figure 2, the mean magnitude of J_{180} at all eccentricities was greater than at the fovea in both full correction and undercorrection groups (all p ≤0.05). The magnitude of J_{180} shows temporal-nasal asymmetry in both groups. At 30° nasal retina (temporal field) the J_{180} component in the full correction and undercorrection groups were 0.69D and 0.30D respectively more than the corresponding temporal retina (nasal field). The difference in J_{180} between the two groups was statistically not different (all p ≤ 0.05). There was significant interaction between eccentricity and group (F =5.47; p= 0.0062).

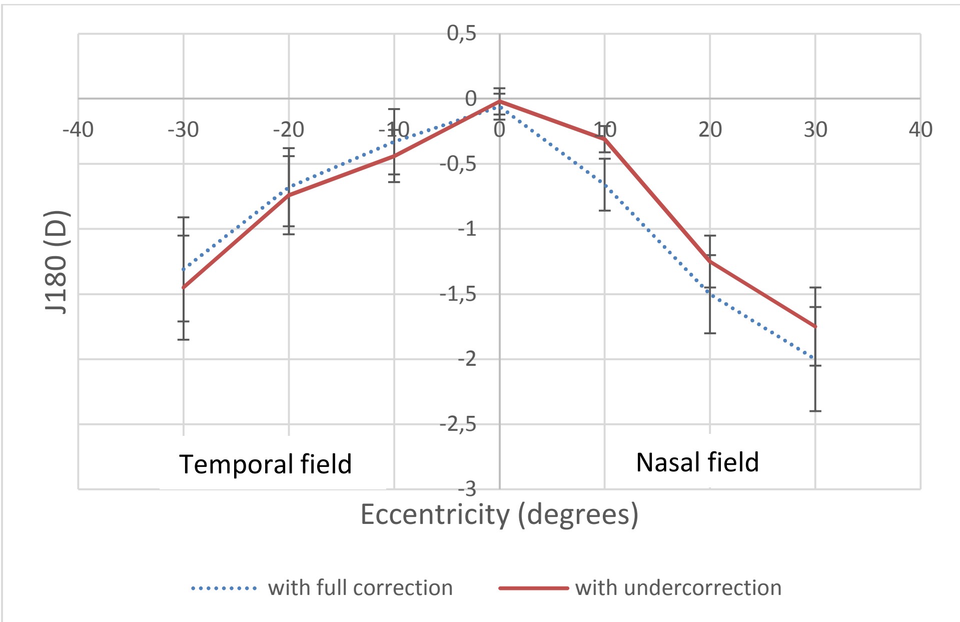

Figure 2: Variation in power vector component J180 with eccentricity at 2m whiles children wore either full correction or undercorrection spectacles. Error bars indicate ± SEM

There was no statistical difference in J_{45} seen between the two uncorrected groups p=0.62 (figure 3). The magnitude of the J_{45} (oblique astigmatism) shows temporal-nasal asymmetry with greater increase in against-the- rule astigmatism on the nasal retina than the temporal retina when corrected. The mean magnitude of J_{45} at all eccentricities was greater than at the fovea in both groups ($p \leq 0.05$). There was no statistical difference in J_{45} seen at all eccentricity between the full correction and undercorrection groups $p > 0.05$. There was no significant main effect or interaction between eccentricity and group p>0.05.

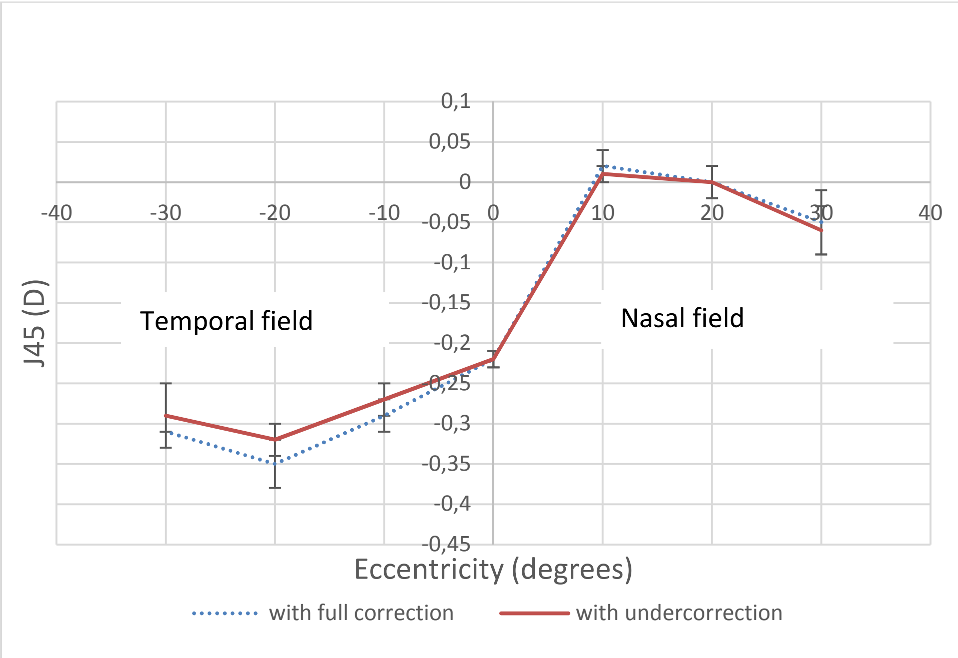

Figure 3: Variation in power vector component J_{45} with eccentricity whiles children wore either full correction or undercorrection and viewed targets at 2m. Error bars indicate ± SEM

Figure 4 shows a comparison between the variation in RPRE as a function of eccentricity in the uncorrected and corrected states during distance viewing. In the uncorrected state, relative hyperopia increased steadily with eccentricity in both groups and there was no significant difference between the two groups at all eccentricities p>0.05. When children worn full correction spectacles, the group showed increased relative hyperopia as eccentricity increased but at 10° nasal field myopic defocus was seen. Repeated Anova revealed a statistical significant difference between eccentricities with full correction $F_{(6,511)} = 1060$, p=0.0001.

The undercorrection group showed less increased relative hyperopia as eccentricity increased. However, at -20° and -30° in the temporal field negative results were recorded. Eccentricity with significantly different as revealed with repeated Anova $F_{(6,511)} = 2015$, p=0.0001.

There was substantial asymmetry seen between the temporal and nasal fields in both groups. The full correction group showed 0.75 more hyperopia 30° nasal field than its corresponding 30° temporal field. Whereas, the undercorrection group showed 0.61 hyperopia in the nasal field and -0.18 myopia in the temporal field, there were no significant main effects or interaction seen in both groups.

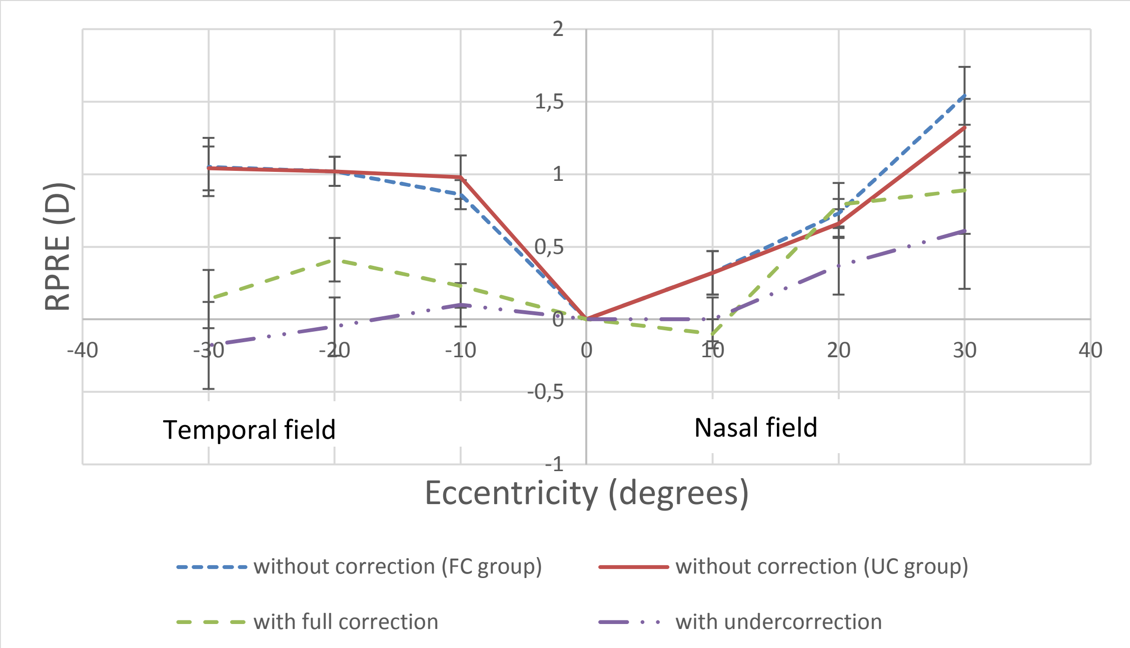

Figure 4: Comparing variations in relative peripheral refractive error (RPRE) profile with eccentricity whiles myopic children either full correction or undercorrection viewed distant target at 2m. Error bars indicate ± SEM

4 DISCUSSION

The uncorrected and corrected myopic eye shown in figures 1 and 4 demonstrate relative peripheral hyperopic defocus within the horizontal peripheral retina. This result is consistent with that seen by [6],[52],[69]. The relative peripheral hyperopic defocus within the horizontal retina suggests that the shape of the uncorrected eye is less oblate during distance viewing. This ocular shape is attributed to an axial length that exceeds the equatorial diameter [7],[54].

When children in this current study wore their full correction spectacles lens, there was significant increase in relative peripheral hyperopic defocus at all measured retinal locations (all p≤ 0.05). This finding is consistent with that found by [9],[12],[49]. In contrast, undercorrection spectacle lenses induced relative myopic defocus at 4 (10°,-10°, -20° and,-30°) out of 6 positions in the peripheral retina as shown in figures 1 and 4. The induced relative peripheral myopic defocus and unclear distant vision seen in the undercorrected children might be due to the residual myopia. [78] induced relative peripheral myopic defocus and unclear foveal image with radial refractive gradient (RRG) lenses in myopic adult aged 25 to 30year. RRG lenses were novel lenses designed to have steady increase in power in all radial directions and with no optical power in the center. PALs caused relative myopic shifts in nasal, temporal and superior but not the inferior quadrant. The largest myopic defocus was seen at the superior quadrant because it corresponds to the PAL corridor [12]. Myopic defocus seen in the peripheral retina of undercorrected children is also consistent with results seen by [43]. Reference [43] showed that undercorrection contact lenses induced less hyperopic defocus compared to full and over correction in adults which is in agreement with that seen with undercorrection spectacle lenses.

The central refraction of children in this study was between -1.25 and -4.50D and were not divided into low and moderate myopes. However, [49] and [43] divided their subjects into low and moderate myopes and showed that full correction single vision lenses caused increased hyperopic defocus in the horizontal retina of moderate myopes than in low myopes [9],[49],[78]. Undercorrection spectacle lenses might have caused increased myopic defocus in the low myopic children (-1.25 to -3.00D) and reduced hyperopic defocus in the moderate myopic children. This present study cannot evaluate the effect of peripheral myopic defocus on myopia progression because it is cross sectional. However, that PALs caused statistically significant myopic defocus (less hyperopia) while full correction SVLs caused an increase in hyperopic defocus in the nasal and temporal retina in children. The induced myopic defocus probably resulted in reduced myopia progression with PALs [11]. However, clinical trials evaluating the efficacy of PALs myopia progression in children found inconsistent results [11],[31],[36],[38],[46],[87]. Myopic defocus induced by under correcting myopia might also be protective and reduce the rate myopia progression

Although, the mechanism for PALs treatment effect is not clear, decreasing the lag of accommodation and reducing hyperopic defocus is the rational for fitting myopia children with PALs [11],[14],[28],[30],[31],[35],[38],[87]. In studies that evaluated myopia progression with PALs, fitted children with PALs with the top above the pupils. This fitting protocol was done to encourage the use of near addition portion of the lenses [36],[37],[38]. Children in these previous studies therefore had residual myopia for distance vision which is similar to the experience of the undercorrected in this study.

If relative peripheral myopia reduces the rate of axial length elongation and myopia progression [67],[69],[72],[74] then undercorrection spectacles might be protective against increased myopia progression. Animal studies also suggest that undercorrection could cause myopic defocus and result in a reduction in myopia progression [66],[75],[83].

References [17],[80] appropriately evaluated the effect of undercorrection on myopia progression and found that undercorrecting myopia rather increased myopia progression. This finding is contrary to that found in animals and several humans studies. Positive lenses and multifocal lenses cause myopic defocus and a reduction in myopia progression in animals and human respectively. The studies by [17],[1],[80], suggest reasons to the negative results. .

There is evidence of different rates of myopia progression among children from different ethnic backgrounds [22],[56],[61]. Myopic children of the similar ages, but from different ethnic backgrounds might respond differently to the same magnitude of hyperopic blur. While undercorrection caused myopia progression in Chinese children, there was no difference in myopia progression between the fully corrected and undercorrected Israeli children [1],[17]. Although, [80] did not indicate the ethnic backgrounds of the children they worked on, it is likely that Chinese children were included in their retrospective study. The progression rates of children vary in different countries and different ethnic groups [44],[84],[86]. The cause of the difference is still not clear, as researchers are not certain on whether environmental or genes play a more important role [64]. It is possible that the interaction between environmental and genetic factors is different in different ethnic groups and the difference is responsible for the varied rates of myopia progression.

Several studies suggest that outdoor activity is protective against myopia progression [20],[21],[25],[32],[41],[55],[60]. In addition, animal studies suggest that elevated light levels slow the rate of axial length elongation [4],[5],[70],[71]. In humans, Reference [23] found that the progression of myopia significantly increased in winter than during summer because the illuminance level of being outdoors in summer is much higher than in winter. During summer, the amount of light reaching the retina, while outdoors, is higher than staying indoors [25],[33].

Studies in Asia show a more rigorous schooling system and long hours of studying indoors as being the reason why myopia progression is highest compared to other ethnic groups [8],[18],[47],[88]. Chinese children might therefore have lower levels of light reaching their eyes compared to children of the similar age and school grade in Ghana who typically walk home from school. It is assumed that higher light intensity outdoors might increase the depth of field and reduce the hyperopic blur [58]. The Sydney myopia study found no association between both near work and outdoor activities.

Myopic children with near phoria have faster rate of myopia than those without Esophoria. Esophoric children have reduced accommodative levels and larger hyperopic defocus leading to the suggestion that Esophoric children must relax accommodation to reduce accommodative convergence and attain and maintain single binocular vision [27],[29],[34],[37]. Reference [1] had enrolled esophoric myopic children but did not measure their accommodative responses to near targets. It is therefore difficult to suggest whether the faster progression of 0.55 and 0.60D/ year seen by [1] compared to 0.38 and 0.5D/year for the fully corrected and undercorrected respectively in the study by Chung et al., 2002 is as a result of the interaction between accommodation convergence on lag of accommodation [17],[68]. Three children in this study exhibited Esophoria, however it is not possible to determine whether myopia progression might be influenced because it is a cross sectional study.

In agreement with previous studies, asymmetry was seen in the peripheral retina of the corrected and uncorrected myope [7],[12],[50],[54]. In the uncorrected eye, the temporal retina (nasal field) showed more hyperopia compared to the nasal retina (temporal field) as shown in figures 1 and 4. However, several studies have found no association between uncorrected peripheral defocus and myopia progression [12],[56],[77].

Full correction single vision lenses caused no change in asymmetry in both fields; however, undercorrection lenses induced relative myopia at -30° (nasal retina) and less hyperopia at 30° in the temporal retina. This finding is in agreement with that found by [12] who found myopic defocus in the nasal retina than the temporal retina when children wore PALs. A combination of induced myopic defocus and higher levels of retinal illumination could provide reasons why undercorrection might cause reduced central myopia progression in Ghanaian children. Future studies that would measure the rate of myopia progression in undercorrected children exposed to different levels of retinal illumination is needed.

In agreement with previous studies, the magnitude of J0 and J45 increased with increasing eccentricity in both groups as shown in figure 3 and 4 [6],[13],[85]. The magnitude of J0 and J45 components (figure 2 and 3) showed temporal-nasal asymmetry with measurement taken at 30º in the temporal retina being greater than its corresponding location in the nasal retina. The asymmetry is assumed to be caused by combined aberrations from the cornea, crystalline lens and the retina [3],[6],[10],[24].

Single vision lenses correcting higher magnitudes of myopia resulted in higher relative hyperopic defocus than single vision lenses correcting lower magnitudes of myopia. If higher amounts of peripheral defocus resulted in increased myopia progression, then this present study should have found the influence of undercorrection lenses on moderate and low myopia separately.

5 Conclusion

In conclusion, undercorrection by +0.50D resulted in myopic shift in the horizontal retina of the myopic children with mean myopia of -1.95±0.57. The potent effect of outdoor sunlight overrides the effect of central and peripheral hyperopic defocus and renders a reduced myopia progression in undercorrected myopic children. If greater amounts of peripheral hyperopic defocus results in increased myopia progression, then undercorrection reduces peripheral hyperopic defocus and can be considered as an alternative to PALs and bifocal in reducing myopia progression.

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