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*Original Research Article*

# Undercorrection of Myopia Reduces Lag of Accommodation in School Children in Kumasi, Ghana

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## ABSTRACT

**Purpose:** This study sought to explore decreased lag of accommodation as a possible explanation for decreased myopia progression in undercorrected myopic children. This study also compared the accommodative stimulus-response curves (ASRC) of myopic children (-1.25 to -4.50D) who wore full correction with those who were under-corrected by +0.50D.
**Methods:** The ASRCs of 75 children (10 to 15 years) in either a full correction or undercorrection group were measured with the open-field Grand Seiko WR-5100K autorefractor (Japan) under binocular and monocular viewing conditions. The accommodative responses of 75 children in each of the two groups were taken while viewing letter targets at 4m, 40cm, 33cm and 25cm distances. Due to the high Pearson’s correlation coefficient between the two eyes (+0.9), only measurements from the right eye are presented in this paper. The ASRC slopes for each group was calculated and compared at 5% level of significance.
**Results:** Children who wore full correction accommodated significantly less to real targets at near distances compared to those who wore undercorrection. The ASRC slopes with full correction and undercorrection were 0.65 and 0.79 respectively (p=0.0005) under monocular viewing. Under binocular viewing, the ASRC were 0.86 and 0.97 with full correction and undercorrection respectively (p = 0.001).
**Conclusion:** When children with myopia between -1.25 and -4.50D were undercorrected by +0.50D, accommodative accuracy to reading materials improved significantly compared to those who were fully corrected. If hyperopic defocus increases lag of accommodation and the rate of myopia progression, then reduced hyperopic defocus induced by under-correcting myopic children could contribute to a reduction in lag of accommodation and control of myopia progression.

***Keywords:*** Hyperopic defocus, myopic defocus, accommodative response, lag of accommodation.

## INTRODUCTION

Myopia is a common disorder that affects about a third of the adult population in the United States. [1] In Asia, its prevalence is increasing to epidemic proportions: about 84% of children between 16 and 18 years [2] and 80% of young adults are affected. [3] The prevalence of myopia among school children in the Durban area of South Africa, Chile, rural and urban India were 2.74%, [4] 12.8%, [5] 5% [6] and 9% [7] 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. [8]

When the young human eye performs near work for an extensive period of time, it may eventually develop myopia which progresses up until the middle to late teen ages when it ceases. [9] Although there is evidence that associates extensive reading with myopia, [10] there has not been any controlled study that shows a cause-and-effect relationship. [11] The mechanism underlying the progression of myopia once it starts is still unknown.

Typically, when normal eyes read at near, the accommodative effort used is not exact but about 0.50D to 0.75D less than what is required to keep the reading material in focus. This under accommodation is known as lag of accommodation and it is calculated as the algebraic difference between the accommodative stimuli (demand) and the spherical equivalence of the accommodative response.

One current assumption to myopia progression is that hyperopic defocus due to increased lag of accommodation during near work might increase myopia progression. [12] The rate of myopia progression might therefore be controlled when lag of accommodation is reduced by increasing accommodative response to near targets.

In an attempt to increase accommodative response and retard myopia progression in children, multiple optical lenses are being investigated. These include undercorrection single vision lenses, [13-15] novel spectacle lens design, [16] orthokeratology contact lenses, [17-19] bifocal [20,21] and progression addition lenses. [22-26]

Previous studies that investigated the effect of undercorrection single vision lenses on the progression of myopia have shown inconsistent results. In a controlled study among 9 to 14 year old Hong Kong children, myopia progressed faster by 0.23D in children who wore undercorrection single vision lenses (SVLs) compared to those who wore full correction SVLs. [14] A second study, conducted on a smaller sample size of 43 Israeli children found no significant difference in myopia progression between the undercorrected and fully corrected. [13] The third which was a retrospective study conducted in Glendale, Arizona in the USA, also found faster myopia progression among children and adults who were undercorrected compared to those who wore full corrections. [15]

Although, these previous studies appropriately evaluated the relationship between undercorrection and myopia progression, it is not clear whether undercorrecting myopia increases the rate of progression as a result of increased lag of accommodation. The objective of this study therefore, was to explore decreased lag of accommodation as a possible explanation for decreased myopia progression in undercorrected myopic children. This was done by evaluating the accommodative responses of the fully corrected and the undercorrected children during binocular and monocular viewing conditions.

This study presents baseline data for the progression of myopia over 2-years in Ghanaian school children.

## MATERIALS AND METHODS

Seventy–four children made up of fifty six (56) girls and eighteen (18) boys were included in this study. Informed consent and verbal consent was obtained from parents and children respectively before testing was done. Inclusion criteria were: healthy children aged from 10 years to 15 years, spherical equivalence refraction (SER) of -1.25 to -4.50D, and visual acuity (VA) of 0.2 log MAR or worse with habitual spectacles, VA of 0.00log MAR after full subjective correction. Also, those with astigmatism worse than 1.00D, anisometropia more than 1.00D, strabismus by cover test at far (2m) and near (0.33m), and any ocular disease were excluded.

The children were randomly assigned to full correction (FC) and undercorrection (UC) groups using randomized schedule of block sizes generated from random tables and placed in sealed envelopes with sequential patient identification numbers. The blocks were made based on two categorical characteristics, school and gender. Assignment of children to treatment groups was based on a randomized procedure as described by Fulk et al. [(21)] Before the measurement of accommodative response the children were refracted with non-cycloplegic autorefraction for an Early Treatment Diabetic Retinopathy Study (ETDRS) distance chart at 4m.

***Intervention***

Children assigned to the FC group wore full correction SVLs and the other group was undercorrected by +0.50D (children were left 0.50D myopic). Undercorrection of +0.50D was chosen because on average, childhood myopia progresses by - 0.50D /year. [(21,23)] In the UC group the maximum distance monocular VA was log MAR 0.20 (6/9 or 20/32) in each eye and was achieved by +0.50D addition after full subjective correction. Any child in the UC group whose habitual correction resulted in a logMAR VA worse than 0.2 was given a new correction that resulted in the reference undercorrection VA. Children in both groups wore study spectacles forat least seven days before phoria and accommodative response were measured.

***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 ETDRS distance chart. Near phoria was measured at 33 cm and 28.5cm while the child wore either the FC or UC respectively and fixated a crowded 4x4 array standard E letters of N10 sizes.

***Accommodative Response and Peripheral Refraction***

Accommodative response was measured with the open-field Autorefractor (Grand Seiko WR 5100K, Japan) that allowed targets to be viewed at any distance. Children were instructed to fixate binocularly on targets and keep it clear. During monocular testing the right eye was measured and the left was occluded with an opaque patch, however, during binocular testing, measurement was done in the right eye only and the left eye was not occluded. Children in the FC group looked at a far distance target at 4m, and near targets at 40cm, 30cm and 25 cm. While the UC group looked at a far distance target at 2m and near targets at 33cm, 28.5cm and 22.2cm. The target at 4m or 2m was the logMAR 1 letter while near targets were 4x4 array standard E letters. Before any measurement was taken at near, the child viewed the target for about five seconds with the prescribed lenses. The instruction to every child was to "look at the appropriate letter size at near and keep it clear". The target was illuminated by ambient room lighting at 130 cd/m$^2$.

Peripheral refraction within 30° visual field (nasal and temporal fields) was also measured for targets at 40cm or 33cm. Although, Seidemann et al., (2002) and Radhakrishna & Charman, (2008) suggest that there is no difference between the head and eye movement methods for measuring eccentric refraction using the autorefractor, children were asked to rotate their eyes to fixate on targets while their head remained stationary. [27,28]

The Committee on Human Research, Publications and Ethics of the School of Medical Sciences, Kwame Nkrumah University of Science and Technology, and Komfo Anokye Teaching Hospital reviewed and approved the study. Approval was also obtained from the Regional Directorate and the Regional Education Service, Ashanti region. In addition, the parents signed the informed consent forms and the children verbally assented. The study was conducted in accordance with the tenets of the Declaration of Helsinki.

***Statistical Analysis***

Analysis was performed with Microsoft Office Excel 2010 and STATA 11. All autorefraction readings were entered into excel in the negative cylinder form and then decomposed into power vector components where M is the mean spherical equivalence, $J_0$ is the with and against- the – rule astigmatism and $J_{45}$ is for oblique angles from 45 to 135 degree according to conventional formula for astigmatic decomposition. The decomposition allowed grouping of data and analysis. [29]

$M = S + C/2$ (1a)

$J0 = -C\cos 2\theta/2$ (1b)

$J45 = -C\sin 2\theta/2$ (1c)

S, C and θ are the spherical, cylindrical and cylindrical axis components of the sphero-cylindrical refraction.

The effective accommodative demand and response were calculated using the equations by Gwiazda et al. (1993) [12]

Effective Accommodation Demand = $\frac{{}^{1}/_{DTE} - LENS + Rx + {}^{DLE}/_{DTE}(LENS - Rx)}{1 - DLE(LENS + Rx)}$ ……... (1)

Effective Accommodative Response = $\frac{{}^{Rx}/_{1-(DLE \times Rx)-LENS}}{1 - DLE \times LENS - R}$ …………………..... (2)

Accommodative Lag = $(1) - (2)$………(3)

Rx = M of the subjective refraction lens.

R = mean refractive value given by the autorefractor.

DTE = distance between the accommodative target and the corneal apex (m)

DLE = distance between the correcting lens and the corneal apex (0.012m)

LENS = SE of the spectacles worn.

These equations correct for the effectivity of a spectacle lens worn 12mm from the eye. The slopes of each group's accommodative stimulus response curve (ASRC) were calculated by linear regression of accommodative response on accommodative demand. The mean of the slopes for the undercorrected and fully corrected were calculated and compared. Pearson correlation coefficient was used to test the relationship between the two eyes.

## RESULTS

One hundred and five school children voluntarily responded to verbal and written advertisements in their schools, ninety nine (99) of them returned with the signed consent forms. These children were screened between September 13, 2010 and March 5, 2011 and seventy nine (79) met the inclusion criteria. However, 56 girls (75.7 %) and 18 boys (24.3%) were enrolled because of the calculated sample size. The mean (± SD) age of the seventy four (74) children was 12.39 ± 1.23 years and thirty seven (37) of them were assigned to each group. Table 1 below shows that there was no statistical difference between baseline measures of children in the two groups.

**Table 1: Baseline characteristics of children in the two treatment groups**

| Variables | FC (n=37) | UC (n =37) | significance |
|---|---|---|---|
| Mean age ± SD | 12.41 ±1.15 | 12.37 ±1.39 | ns p= 0.84 |
| Mean non-cycloplegic autorefraction M (D) | -1.89 ± 0.57 | -2.04± 0.54 | ns p=0.26 |
| Initial near phoria(Δ) | | | |
| Esophoria | 5(0.71±1.14) | 6(0.65±2.16) | Ns |
| Exophoria | 9 | 7 | |
| Orthophoria | 20 | 21 | |
| Males | 9 | 9 | Ns |
| Females | 28 | 28 | |

Abbreviations: FC; full correction, UC; undercorrection, ns; not significance

Children in both FC and UC groups accommodated to targets at decreasing distance as shown in figure 1 below. The M (D) after non-cycloplegic subjective refraction was –1.97 ± 0.41 for the group. When children in the undercorrection group were undercorrected by 0.50 D, the M (D) changed to -1.57 ± 0.52D.

The effective accommodative demand and the accommodative lag for targets placed at the respective distances are shown in Table 2 below. Table 2 shows a significantly smaller effective accommodative demand in the undercorrection group than in the fully corrected group (p= 0.001). There was significantly greater accommodative lag in the FC group than in the UC group (p=0.001) and under monocular viewing conditions than under binocular condition (p=0.001).

Accommodative responses were plotted against accommodative demand and the regression lines between FC and UC were compared in figure 1(a) and 1(b) below. Both groups showed the typical increase in accommodative response as accommodative demand increased. Accommodative response was significantly reduced under monocular conditions compared to binocular viewing conditions in both groups. The mean ASRC during binocular viewing was significantly steeper with UC (y= 0.97 -0.11) than with FC (y=0.86 +0.1) p=0.001. Again, the mean ASRC during monocular viewing was significantly steeper with UC (y=0.79 + 0.12) than with FC monocular (y= 0.65 +0.46), p=0.0005.

The $J_0$ and $J_{45}$ of children while wearing assigned spectacles (FC or UC) are shown in Table 3. Difference in $J_0$ and $J_{45}$ at 30º nasal and temporal did not depend on the assigned lens. $J_0$ and $J_{45}$values of the undercorrection lenses were not significantly different (p<0.05).

**Table 2: Effective accommodative demand and the accommodative lag at their respective distances**

| | | Target distances | | | |
|---|---|---|---|---|---|
| | | 400 cm | 40 cm | 33 cm | 25 cm |
| Effective accommodative demand (D) | FC group | 0.23 ± 0.22 | 2.3± 0.31 | 3.17 ± 0.31 | 3.91 ± 0.32 |
| | UC group | 0.01 ± 0.28 | 1.9 ± 0.32 | 2.68 ± 0.34 | 2.99 ± 0.32 |
| Accommodative lag under monocular conditions (D) | FC group | -0.54 ± 0.21 | 0.37 ±0.20 | 0.55 ± 0.23 | 0.79 ± 0.25 |
| | UC group | -0.11 ± 0.23 | 0.23 ± 0.23 | 0.32 ± 0.26 | 0.58 ± 0.24 |
| Accommodative lag under binocular conditions (D) | FC group | -0.61 ± 0. 25 | 0.27 ± 0.27 | 0.11 ± 0.28 | 0.41 ± 0.29 |
| | U C group | -0.1 ± 0.27 | 0.18 ± 0.30 | 0.15 ± 0.31 | 0.24 ± 0.32 |

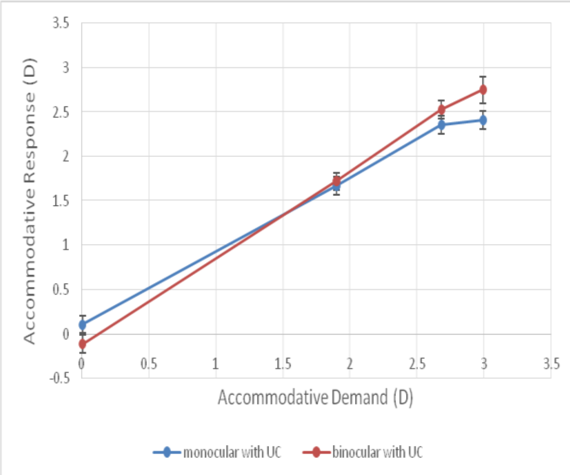


**Fig 1a: Accommodative stimulus- response curve (ASRC) shown by undercorrected myopic eyes during binocular and monocular viewing. Error bars represent the standard error of the mean for each data point.**

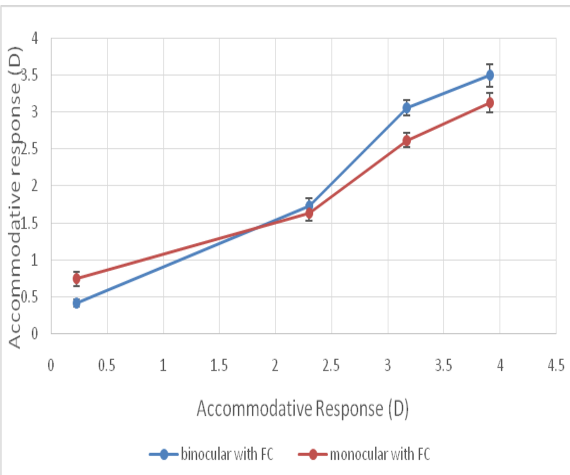


**Fig 1b: Accommodative stimulus response curve (ASRC) shown by fully corrected myopic eyes during binocular and monocular viewing. Error bars represent the standard error of the mean for each data point.**

**Table 3: Mean (± SD) J0 and J45 by retinal location for children in the FC and UC groups while wearing their study spectacles**

| | | | |
|---|---|---|---|
| $J_0$ at 30º | | | |
| nasal retina | -1.56± 0.50 | -1.69 ± 0.62 | p = 0.33 |
| temporal retina | -2.50 ± 0.87 | -2.24 ± 0.75 | p = 0.20 |
| $J_{45}$ at 30º | | | |
| nasal retina | -0.24 ± 0.23 | -0.29 ± 0.23 | p = 0.37 |
| temporal retina | -0.06 ± 0.21 | -0.15 ± 0. 25 | p = 0.11 |

Abbreviations: FC; full correction, UC; undercorrection, ns; not significance

## DISCUSSION

This study showed the following 1. Under correcting of myopia by +0.50D, significantly increased accommodative response and reduced accommodative lag. 2. No significant difference between the magnitude of horizontal/vertical astigmatism during accommodation with full correction or undercorrection.

***ASRC and accommodative lag under monocular viewing conditions***

Children in both groups demonstrated lead of accommodation to targets at far distances and increased lag of accommodation to near targets. However, the mean ASRC slope of 0.79 for children who wore undercorrection was significantly higher than 0.65 for the full correction group. At 33cm and 25cm, the two closest near distances, children who wore undercorrection accommodated significantly more than those with full correction ($p \leq 0.05$). The mean accommodative lag at these distances showed 0.32 D versus 0.55 D at 0.33m for undercorrection and full correction respectively. At 0.25m, the mean lag was 0.58 D versus 0.79D at 0.25m for undercorrection and full correction respectively. Larger accommodative lag at near found with full correction in this study is in agreement with that found by Gwiazda *et al.* (1993) The larger lag of accommodation found in children aged 5 to 17 years with progressing myopia compared to emmetropic eyes led Gwiazda *et al.* (1993) to suggest that increased lag of accommodation leads to increased rate of myopia progression. [12] The effective accommodative demand (equation 1) calculated for the undercorrection group was lower than that for the full correction group. This is because accommodative demand decreases with increasing power of convex lens and also due to the back vertex distance of the spectacle lens. The goal of myopia correction is to under correct when spectacles are prescribed. [24] The undercorrection thus decreases the accommodative demand for clear vision of objects by the amount of undercorrection.

The residual myopia in the undercorrection group was thus larger compared to the full correction group. The degree of accommodative lag is normally within the accommodative range of the individual and also proportional to the accommodative demand. The reduced accommodative lag for the undercorrection group was probably due to the smaller accommodative demand. Abbott *et al.* (1998) and Nakatsuka *et al.* (2003) also evaluated accommodative response and associated accommodative error to real targets at different distances. (30,31) The subjects were adults who were either emmetropic, early onset myopes or late onset myopes and wore full correction contact lenses. Both teams reported lower ranges of lag of accommodation for their adult myopic group. The lower lag of accommodation shown among adults suggests that the higher lag of accommodation found among school children might decrease when their myopia eventually stabilizes in their later teens.

***Accommodative stimulus-response function under binocular viewing conditions.***

Although both treatment groups showed improved accommodative response under binocular viewing than under monocular viewing, the mean ASRC gradient with undercorrection (0.97) was significantly steeper compared to 0.86 with full correction. The steep slopes shown under binocular vision indicate a higher accommodative response and smaller mean lag of accommodation for targets viewed binocularly compared to monocular viewing. The studies by Nakatsuka *et al*. (2005) and Bhardwaj& Candy (2009) also showed that the mean lag during monocular viewing was higher than binocular viewing. (32-34) This is because during binocular viewing, cues such as retinal disparity, nearness of target and blur stimulate improved accommodative response to real physical targets. The ASRC slope under binocular viewing conditions for myopic adults of early onset myopia (EOM), myopia before age 15 years was 0.88. (35) This was similar to the 0.86 found for the full correction group but lower than 0.97 found for the full correction group. While the myopes in this study wore full correction spectacles, those in the study by McBrien and Millodot (1986) wore full correction contact lenses, which probably resulted in differences in accommodative response. (35)

The assumption is that the lower the accommodative response, the higher the lag of accommodation which results in a higher magnitude of hyperopic defocus and faster rate of myopia progression. (36-40) Results from studies that have investigated the relationship between myopia progression and lag of accommodation have been inconsistent. Allen & O`Leary (2006) found increased lag of accommodation to be associated with myopia progression in adults while Weizhong *et al.*(2008) and Berntsen et al. (2011) found no relationship between lag and myopia progression in children. (41-43) Another study found reduced lag of accommodation to be associated with myopia progression in adults. (44) While there is controversy regarding the relationship between myopia progression and lag of accommodation, several studies suggest that myopic children and adults have increased lag of accommodation. (30,32,35,39,45) Gwiazda et al. found increased lag of accommodation in pre-myopic children two years before myopia started. (46) Contrary to this report, Mutti et al. reported that accommodative lag is not increased up until the year after myopia has started. (47) Rosenfield reported of low lag of accommodation in young adults before and after myopia started. (44)

Multiple optical treatments that change lag of accommodation of subjects and result in altered rate of progression are being investigated. These lenses include bifocals, [48,49] PALs, [22-24,26] contact lenses, [17-19,50-53] and undercorrection single vision lenses [13-15] but have shown inconsistent results.

Chung *et al.*(2002) performed a randomized trial on 94 myopic Hong Kong children aged 9 to 14 years. The children assigned to a full correction and undercorrection by +0.75D that allowed the children to maintain a distance VA of at least 20/40. In other words, if the child's full correction was -2.25D, she/he would be prescribed -1.50D. The VA for the full correction group was 6/6 or 0.00log MAR. The mean baseline refraction in both groups was -2.68D. The rate of myopia progression in the undercorrection (0.5D/year) was found to be significantly faster ($p<0.01$) than (0.38D/year) in the full correction group. The team speculated that the human eye cannot detect the sign of blur-only-based retinal defocus and that both myopic and hyperopic defocus might be myopiagenic.

Vasudevan *et al.*(2014) confirmed the results obtained by Chung *et al*. (2002). Vasedevan *et al.* (2014) conducted a retrospective study on myopic patients who visited a private optometric practice in Glendale, Arizona, USA. All records used in the investigation belonged to one optometrist who had the majority of the patients at each visit over a period of 6 to 8 years. Seventy six subjects, 61 were children aged between 11 and 19years and the remaining 15 were adults aged between 20 to 33 years. Subjective refraction was initially performed on these subjects and then they were assigned to either a full correction or an undercorrection whose range of undercorrection was from zero to 0.50. Undercorrected subjects showed a significant increase in myopia progression compared to those in the full correction group ($p<0.01$).

Adler and Millodot (2006) showed the rate of myopia progression was significantly not different between fully corrected and undercorrected children. This result conflicted with the previous two. The study was conducted in 48 myopic Israeli children aged between 6 to 15 years. The children were assigned to either a full correction or an undercorrection by +0.50D spectacles. Both groups had the same mean baseline refractive error of -2.90D which was similar to -2.68D in Chung et al., 2002. At the end of the 18months study, the mean rate of myopia progression was statistically not different ($F=0.3$; $p=0.51$) between the full correction (0.55D/year) and 0.66D/year in the undercorrection group (Adler & Millodot, 2006). In the study by Adler & Millodot, there was slight interaction effect (0.06) found between the treatment effect and whether the child had low myopia (less than -3.00D) or moderate myopia of -3.00D or more. There was also a slight interaction between of 0.06 between whether the child was Esophoria or orthophoric and the treatment group which did not change the rate of myopia progression between the two groups. In a 3-year clinical study, Tokoro & Kabe (1965) compared the rate of myopia progression, corneal power, crystalline lens power, and axial length in 33children assigned to either a full correction or an undercorrection group. [54] All children in this group were low myopes and children in the undercorrection group were undercorrected by one dioptre or more. Thirteen of the children were prescribed full correction and advised to wear them all waking hours, ten wore undercorrection of one dioptre or more at all waking hours and the remaining ten wore full correction but were advised to wear them when it was needed. The mean refractive change was 0. 47D and 0.83D in the undercorrection and full correction groups respectively. In addition, the axial length increase and crystalline lens power were greater in the full correction groups. The sample size of the study by Tokoro & Kobe was smaller and larger magnitudes of undercorrection were used. Tokoro &Kobe found a significantly lower change in mean refraction in the undercorrected group compared to the full correction group. Tokoro and Kobe used a simpler sample size and included in their study, subjects who were receiving pharmaceutical agents such as neosynephrine and tropicamide as part of another study. Goss (1982), on reviewing the study concluded that the statistical treatment of the data was faulty. The mechanism by which undercorrection resulted in increased myopia progression is not clear. Animal studies have consistently showed that full correction rather increased myopia progression and positive lenses caused reduction in progression. [55-57]

As modelled by Flitcroft, the presence of esophoria might suggest the influence of environmental factors and oculomotor imbalances for the associated myopia compared to orthophoria. [58] There is a shift towards esophoria as myopia progresses and progression is faster in children with esophoria. The child with esophoria suffers decreased accommodative response and increased hyperopic defocus which results in faster myopia progression. In this study, esophoric children were included in both groups, but lag of accommodation seem to depend on assigned lens and not on the level of esophoria

Cross linked interaction between accommodation and convergence might interact with the residual myopia (in the undercorrection group) and uncorrected heterophoria and influence accommodative lag and myopia progression. [59,60] In this study, both fully corrected and undercorrected children showed no ocular deviation during cover test at near. The children in the undercorrection group showed no deviation at near and exhibited increased accommodative response, suggesting low AC/A ratio. It is likely that the rate of myopia progression among children in the undercorrection group depended on other factors than the cross link interaction between accommodation and convergence interacting with residual myopia and uncorrected heterophoria.

***Comparisons between binocular and monocular viewing conditions***

The accommodative response to real physical targets at near was not significantly different whether under binocular or monocular viewing conditions. When children do near work, both eyes change their accommodative state equally to view the target at a particular near distance. The neural input to accommodation in both eyes is therefore symmetrical and equal. The accommodative response amplitude of the occluded eye during monocular viewing suggests that there is a common control center that is responsible for equal innervation of the ciliary apparatus of the two eyes. [61] In addition, increased lag of accommodation might not be myopiagenic because even in the absence of accommodation, myopia progresses in response to hyperopic blur. Form deprivation myopia may be induced in young animal eyes even when accommodation was surgically abolished by Edinger-Westphal nucleus destruction or optic nerve section. [47,62]

***Influence of Single Vision Spectacle Lenses on Peripheral Defocus***

Based on more recent studies in primates, [63,64] it is assumed that peripheral hyperopic defocus as a result of near work and reading, results in increased axial elongation. Optical lenses that reduce the peripheral hyperopic defocus might slow myopia progression in children. [65] Previous studies have shown that full correction SVLs cause increased hyperopic defocus in the horizontal meridian of children with moderate myopia than in low myopes. [66-68] A limitation of this study is that the peripheral refraction of undercorrected low and moderate myopes was not done.

Previous studies indicate that relative peripheral refraction increased with increasing amounts of accommodation and that relative myopic shifts were induced as accommodation increased. [69] In addition, as accommodation increased peripheral astigmatism also increase. Off-axis $J_0$ astigmatism increased as eccentricity increased beyond 30º. [70,71] Another limitation of this study is that peripheral astigmatic defocus through lens locations beyond 30º were not done. Increased peripheral astigmatism during accommodation could influence myopia progression and needs to be investigated further.

## CONCLUSION

Undercorrecting children with myopia between -1.25 and -4.50D significantly reduced lag of accommodation compared to full correction in Ghanaian school children. Under correcting myopia reduces hyperopic blur and is protective against faster myopia progression

## REFERENCES


1. Vitale S, Sperduto RD, Ferris FL. Increased prevalence of myopia in the United States between 1971-1972 and 1999-2004. Archives of ophthalmology. 2009;127(12):1632-9.
2. Lin LL, Shih YF, Tsai CB, et al. Epidemiologic study of ocular refraction among schoolchildren in Taiwan in 1995. Optometry and vision science : official publication of the American Academy of Optometry. 1999 May;76(5):275-81. PubMed PMID: 10375241. Epub 1999/06/22. eng.
3. Saw SM, Gazzard G, Au Eong KG, et al. Utility values and myopia in teenage school students. The British journal of ophthalmology. 2003 Mar;87(3):341-5. PubMed PMID: 12598451. Pubmed Central PMCID: PMC1771541. Epub 2003/02/25. eng.
4. Naidoo KS, Raghunandan A, Mashige KP, et al. Refractive error and visual impairment in African children in South Africa. Investigative ophthalmology & visual science. 2003 Sep;44(9):3764-70. PubMed PMID: 12939289.
5. Maul E, Barroso S, Munoz SR, et al. Refractive Error Study in Children: results from La Florida, Chile. American journal of ophthalmology. 2000 Apr; 129(4):445-54. PubMed PMID: 10764851. Epub 2000/04/15. eng.
6. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. Investigative ophthalmology & visual science. 2002;43(3):615-22.
7. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. Investigative ophthalmology & visual science. 2002 Mar;43(3):623-31. PubMed PMID: 11867576. Epub 2002/02/28. eng.
8. Koomson NY, Lartey SY, Adjah KK. Prevalence of myopia among patients with refractive error in the Kumasi metropolis of Ghana. Journal of science and technology. 2013;33(2):75-83.
9. Goss DA. Nearwork and myopia. The Lancet. 2000;356(9240):1456-7.
10. Zadnik K, Satariano WA, Mutti DO, et al. The effect of parental history of myopia on children's eye size. JAMA : the journal of the American Medical Association. 1994 May 4;271(17):1323-7. PubMed PMID: 8158816.
11. Wallman J, Winawer J. Homeostasis of eye growth and the question of myopia. Neuron. 2004 Aug 19;43(4):447-68. PubMed PMID: 15312645.
12. Gwiazda J, Thorn F, Bauer J, et al. Myopic children show insufficient accommodative response to blur. Investigative ophthalmology & visual

science. 1993 Mar;34(3):690-4. PubMed PMID: 8449687. Epub 1993/03/01. eng.
13. Adler D, Millodot M. The possible effect of undercorrection on myopic progression in children. Clinical and Experimental Optometry. 2006;89(5): 315-21.
14. Chung K, Mohidin N, O'Leary DJ. Undercorrection of myopia enhances rather than inhibits myopia progression. Vision research. 2002;42(22):2555-9.
15. Vasudevan B, Esposito C, Peterson C, et al. Under-correction of human myopia--is it myopigenic?: a retrospective analysis of clinical refraction data. Journal of optometry. 2014 Jul-Sep;7(3):147-52. PubMed PMID: 25000870. Pubmed Central PMCID: 4087177.
16. Sankaridurg P, Donovan L, Varnas S, et al. Spectacle lenses designed to reduce progression of myopia: 12-month results. Optometry & Vision Science. 2010;87(9):631-41.
17. Cho P, Cheung SW, Edwards M. The longitudinal orthokeratology research in children (LORIC) in Hong Kong: a pilot study on refractive changes and myopic control. Current eye research. 2005; 30(1):71-80.
18. Santodomingo-Rubido J, Villa-Collar C, Gilmartin B, et al. Myopia control with orthokeratology contact lenses in Spain: refractive and biometric changes. Investigative ophthalmology & visual science. 2012;53(8):5060-5.
19. Walline JJ, Jones LA, Sinnott LT. Corneal reshaping and myopia progression. Br J Ophthalmol. 2009 Sep;93(9):1181-5. PubMed PMID: 19416935.
20. Fulk GW, Cyert LA. Can bifocals slow myopia progression? Journal of the American Optometric Association. 1996 Dec;67(12):749-54. PubMed PMID: 9286316.
21. Fulk GW, Cyert LA, Parker DE. A randomized trial of the effect of single-vision vs. bifocal lenses on myopia progression in children with esophoria. Optometry and vision science : official publication of the American Academy of Optometry. 2000 Aug;77(8):395-401. PubMed PMID: 10966065.
22. Berntsen DA, Sinnott LT, Mutti DO, et al. A randomized trial using progressive addition lenses to evaluate theories of myopia progression in children with a high lag of accommodation. Investigative ophthalmology & visual science. 2012 Feb;53(2):640-9. PubMed PMID: 22205604. Pubmed Central PMCID: 3317412.
23. Gwiazda J, Hyman L, Hussein M, et al. A randomized clinical trial of progressive addition lenses versus single vision lenses on the progression of myopia in children. Investigative ophthalmology & visual science. 2003 Apr;44(4):1492-500. PubMed PMID: 12657584.
24. Hasebe S, Ohtsuki H, Nonaka T, et al. Effect of progressive addition lenses on myopia progression in Japanese children: a prospective, randomized, double-masked, crossover trial. Investigative ophthalmology & visual science. 2008 Jul;49(7):2781-9. PubMed PMID: 18579755.
25. Horner DG, Soni PS, Salmon TO, et al. Myopia progression in adolescent wearers of soft contact lenses and spectacles. Optometry and vision science : official publication of the American Academy of Optometry. 1999 Jul;76(7):474-9. PubMed PMID: 10445639.
26. Yang Z, Lan W, Ge J, et al. The effectiveness of progressive addition lenses on the progression of myopia in Chinese children. Ophthalmic & physiological optics : the journal of the British College of Ophthalmic Opticians. 2009 Jan;29(1):41-8. PubMed PMID: 19154279.
27. Seidemann A, Schaeffel F, Guirao A, et al. Peripheral refractive errors in myopic, emmetropic, and hyperopic young subjects. JOSA A. 2002;19 (12): 2363-73.

28. Radhakrishnan H, Charman WN. Peripheral refraction measurement: does it matter if one turns the eye or the head? Ophthalmic and Physiological Optics. 2008;28(1):73-82.
29. Thibos LN, Wheeler W, Horner D. Power vectors: an application of Fourier analysis to the description and statistical analysis of refractive error. Optometry and vision science : official publication of the American Academy of Optometry. 1997 Jun;74(6):367-75. PubMed PMID: 9255814.
30. Abbott ML, Schmid KL, Strang NC. Differences in the accommodation stimulus response curves of adult myopes and emmetropes. Ophthalmic and Physiological Optics. 1998;18(1): 13-20.
31. Nakatsuka C, Hasebe S, Nonaka F, et al. Accommodative lag under habitual seeing conditions: comparison between adult myopes and emmetropes. Japanese journal of ophthalmology. 2003 May-Jun;47(3):291-8. PubMed PMID: 12782167. Epub 2003/06/05. eng.
32. Nakatsuka C, Hasebe S, Nonaka F, et al. Accommodative lag under habitual seeing conditions: comparison between myopic and emmetropic children. Japanese journal of ophthalmology. 2005;49(3):189-94.
33. Bharadwaj SR, Candy TR. Cues for the control of ocular accommodation and vergence during postnatal human development. Journal of vision. 2008; 8(16):14.
34. Bharadwaj SR, Candy TR. Accommodative and vergence responses to conflicting blur and disparity stimuli during development. Journal of vision. 2009;9(11):4.
35. McBrien NA, Millodot M. The effect of refractive error on the accommodative response gradient. Ophthalmic & physiological optics : the journal of the British College of Ophthalmic Opticians. 1986;6(2):145-9. PubMed PMID: 3748560.
36. Charman WN. Near vision, lags of accommodation and myopia. Ophthalmic & physiological optics : the journal of the British College of Ophthalmic Opticians. 1999 Mar;19(2): 126-33. PubMed PMID: 10615448.
37. Goss DA, Hampton MJ, Wickham MG. Selected review on genetic factors in myopia. Journal of the American Optometric Association. 1988 Nov; 59 (11):875-84. PubMed PMID: 3068279.
38. Goss DA, Rainey BB. Relationship of accommodative response and nearpoint phoria in a sample of myopic children. Optometry and vision science : official publication of the American Academy of Optometry. 1999 May;76(5):292-4. PubMed PMID: 10375244.
39. Gwiazda J, Thorn F, Bauer J, et al. Myopic children show insufficient accommodative response to blur. Investigative ophthalmology & visual science. 1993;34(3):690-4.
40. Irving EL, Robertson KM. Monocular components of the fixation disparity curve. Optometry and vision science : official publication of the American Academy of Optometry. 1991 Feb; 68(2):117-26. PubMed PMID: 2027650.
41. Allen PM, O'Leary DJ. Accommodation functions: co-dependency and relationship to refractive error. Vision research. 2006;46(4):491-505.
42. Weizhong L, Zhikuan Y, Wen L, et al. A longitudinal study on the relationship between myopia development and near accommodation lag in myopic children. Ophthalmic and Physiological Optics. 2008;28(1):57-61.
43. Berntsen DA, Sinnott LT, Mutti DO, et al. Accommodative lag and juvenile-onset myopia progression in children wearing refractive correction. Vision research. 2011 May 11;51(9):1039-46. PubMed PMID: 21342658. Pubmed Central PMCID: 3111954.
44. Rosenfield M, Desai R, Portello JK. Do progressing myopes show reduced accommodative responses? Optometry & Vision Science. 2002;79(4):268-73.

45. Bullimore MA, Gilmartin B, Royston JM. Steady-state accommodation and ocular biometry in late-onset myopia. Documenta ophthalmologica. 1992; 80(2):143-55.
46. Gwiazda J, Thorn F, Held R. Accommodation, accommodative convergence, and response AC/A ratios before and at the onset of myopia in children. Optometry & Vision Science. 2005;82(4):273-8.
47. Mutti DO, Mitchell GL, Hayes JR, et al. Accommodative lag before and after the onset of myopia. Investigative ophthalmology & visual science. 2006; 47(3):837-46.
48. Fulk GW, Cyert LA, Parker DE. A randomized clinical trial of bifocal glasses for myopic children with esophoria: results after 54 months. Optometry. 2002 Aug;73(8):470-6. PubMed PMID: 12365670.
49. Goss DA. Effect of bifocal lenses on the rate of childhood myopia progression. American journal of optometry and physiological optics. 1986 Feb;63 (2):135-41. PubMed PMID: 3953756.
50. Caelli T, Oguztoreli MN. Some task and signal dependent rules for spatial vision. Spat Vis. 1987;2(4):295-315. PubMed PMID: 3154953.
51. Kakita T, Hiraoka T, Oshika T. Influence of overnight orthokeratology on axial elongation in childhood myopia. Investigative ophthalmology & visual science. 2011;52(5):2170-4.
52. Hiraoka T, Kakita T, Okamoto F, et al. Long-term effect of overnight orthokeratology on axial length elongation in childhood myopia: a 5-year follow-up study. Investigative ophthalmology & visual science. 2012;53(7):3913-9.
53. Cho P, Cheung S-W. Retardation of myopia in Orthokeratology (ROMIO) study: a 2-year randomized clinical trial. Investigative ophthalmology & visual science. 2012;53(11):7077-85.
54. Tokoro T, Kabe S. Treatment of the myopia and the changes in optical components. Report II. Full-or under-correction of myopia by glasses. Nippon Ganka Gakkai zasshi. 1965;69(2):140.
55. Hung LF, Crawford ML, Smith EL. Spectacle lenses alter eye growth and the refractive status of young monkeys. Nat Med. 1995 Aug;1(8):761-5. PubMed PMID: 7585177.
56. Schaeffel F, Glasser A, Howland HC. Accommodation, refractive error and eye growth in chickens. Vision research. 1988;28(5):639-57. PubMed PMID: 3195068.
57. Whatham AR, Judge SJ. Compensatory changes in eye growth and refraction induced by daily wear of soft contact lenses in young marmosets. Vision research. 2001 Feb;41(3):267-73. PubMed PMID: 11164443.
58. Flitcroft D. A model of the contribution of oculomotor and optical factors to emmetropization and myopia. Vision research. 1998;38(19):2869-79.
59. Gwiazda J, Marsh-Tootle WL, Hyman L, et al. Baseline refractive and ocular component measures of children enrolled in the correction of myopia evaluation trial (COMET). Investigative ophthalmology & visual science. 2002;43(2):314-21.
60. Schor C. The influence of interactions between accommodation and convergence on the lag of accommodation. Ophthalmic and Physiological Optics. 1999;19(2):134-50.
61. Marran L, Schor CM. Lens induced aniso-accommodation. Vision Res. 1998 Nov;38(22):3601-19. PubMed PMID: 9893793. Epub 1999/01/20. eng.
62. Troilo D. Experimental studies of emmetropization in the chick. Myopia and the control of eye growth. 1990; 155:89-101.
63. Smith EL, 3rd, Hung LF, Huang J. Relative peripheral hyperopic defocus alters central refractive development in infant monkeys. Vision research. 2009 Sep;49(19):2386-92. PubMed PMID:

19632261. Pubmed Central PMCID: 2745495.
64. Smith III EL. The Charles F. Prentice Award Lecture 2010: A Case for Peripheral Optical Treatment Strategies for Myopia. Optometry and Vision Science. 2011;88(9):1029.
65. Smith EL, Hung L-F, Huang J, et al. Effects of optical defocus on refractive development in monkeys: evidence for local, regionally selective mechanisms. Investigative ophthalmology & visual science. 2010;51(8):3864-73.
66. Tabernero J, Schaeffel F. More irregular eye shape in low myopia than in emmetropia. Investigative ophthalmology & visual science. 2009; 50(9):4516-22.
67. Lin Z, Martinez A, Chen X, et al. Peripheral defocus with single-vision spectacle lenses in myopic children. Optometry & Vision Science. 2010; 87(1):4-9.
68. Backhouse S, Fox S, Ibrahim B, et al. Peripheral refraction in myopia corrected with spectacles versus contact lenses. Ophthalmic and Physiological Optics. 2012;32(4):294-303.
69. Smith G, Millodot M, McBrien N. The effect of accommodation on oblique astigmatism and field curvature of the human eye Clinical and Experimental Optometry 1988;71(4):119-25.
70. Kee C-S, L.-F. H, Y. Q-G, et al. Effects of optically imposed astigmatism on emmetropization in infant monkeys. Investigative ophthalmology & visual science. 2004;45(6): 1647-59.
71. Whatham A, F. Z, A. M, et al. Influence of accommodation on off-axis refractive errors in myopic eyes. Journal of vision. 2009;9(3 ):14.

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