AN OVERVIEW OF FACTORS RELATED TO MYOPIC PROGRESSION AND THE USE OF PLUS LENSES TO RETARD MYOPIC PROGRESSION

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INTRODUCTION

The role of heredity is commonly accepted as an important factor in myopic development. In addition, near work has been implicated in many studies as contributing to the progression of myopia. The summary of five such studies are listed below.

1.) Young's study on three generations of Eskimo families found little myopia among the parents and grandparents but found a very high incidence (about 65%) of myopia among the younger generation(1). This dramatic difference was attributed to the introduction of compulsory education.

2.) In a study at the U.S. Naval Academy, it was revealed that 18% of students entering with 20/20 acuity became myopic between the ages of 17 and 21, during their years at the Academy(2).

3.) A 1992 study on the prevalence of myopia among clinical microscopists showed a 71% prevalence of myopia. In this population of 251 subjects, 49% of reported an onset or progression of myopia <u>after</u> entry into clinical microscopy(3).

4.) Parssinen et al. found that boys who spent a greater amount of time outdoors had a lower rate of myopic progression and lower myopia at the end of the 3 year follow up(4). Similarly, time spent on reading and close work was associated with a faster rate of myopic progression and a higher degree of myopia at the end of the study.

5.) In another population of 870 teenagers, a statistically significant higher prevalence and degree of myopia was found in a group of 193 Orthodox Jewish male students who differed from the rest in their study habits. The characteristic swaying motion during study creates frequent changes in accommodation and vergence(5).

The mechanism by which extensive near work can lead to myopia is highly controversial. Several factors come into play while reading and other similar near tasks. Is it accommodation, convergence, or retinal image blur that possibly contribute to myopic progression? Some feel that the myopic shift is due to the cognitive aspect of near work and is independent of the accommodative or the vergence demand of the task. Still others believe that reading requires information processing through symbols in a flat 2-dimensional plane and myopia is an adaptation mechanism to this stress(6).

The purpose of this paper is to review evidence supporting different theories for the progression of myopia. Both environmental and non-environmental factors are discussed. This paper will also review the therapeutic use of bifocal lenses in attempts to control myopic progression.

I.) ACCOMMODATION, CONVERGENCE, AND COGNITIVE DEMAND

A.) THE INFLUENCE OF THE NERVOUS SYSTEM ON ACCOMMODATION

In the absence of visual stimuli the eye has a resting position or a level of tonic accommodation(T.A.). T.A. is described as an equilibrium between the inhibitory sympathetic and stimulatory parasympathetic nervous actions to the ciliary muscle. Several studies have been done comparing T.A. of myopes to T.A. of non-myopes. McBrien and Millodot(7) studied the T.A. of 62 subjects ages 19-25. They found that late onset myopes (onset 15 years of age or later) had the lowest T.A.(20). It was also found that there was a significant difference in T.A. levels between late onset myopes and early onset myopes (onset 13 years of age or earlier).

Strang et al. did a study comparing the regression of accommodation after near work for both emmetropes and late onset myopes(8). After a near task is performed, it was shown that the late onset myope has a slower release of accommodation compared to the emmetrope. According to Strang et al., this difference in accommodative regression is due to deficit in sympathetic innervation to the ciliary muscle.

In a follow up to their previous study, McBrien and Millodot compared shifts in T.A. following a near task for different refractive groups(9). As a group, only late onset myopes demonstrated significant myopic shifts in T.A. after near viewing. A weak sympathetic innervation and strong parasympathetic innervation would leave a subject myopic. It is possible that when the myopic eye is then corrected with lenses, the tonic position of accommodation would be shifted to a lower dioptric value than that of an emmetropic eye with normal autonomic balance(7). This theory would explain the low T.A. of adult onset myopes and their myopic shift in T.A. following a near task. Another theory maintains that the low T.A. levels for myopes are due to overactive sympathetic innervation because the myope is constantly trying to clear distant image(7). However, this doesn't explain the myopic shift in T.A.

after a near task.

B.) THE ROLE OF ACCOMMODATION IN MYOPIA

Post task myopic shifts in T.A. were also measured by Rosenfield et al.(10). The tests were done monocularly through different plus lenses to maximize the effect of blur driven accommodation and minimize other variables such as convergence. At a 25cm viewing distance, equivalent myopic shifts were observed with a pin hole, distance Rx, and a +2.00 add. No myopic shift was recorded for a +4.00 add. This supports the idea that the induced myopic shift is related to the accommodative response.

In an effort to study the role of accommodation in myopia progression, many studies have observed the effects of cycloplegics such as atropine on myopic progression. Young (11) suggested that an inability to relax accommodation is a precursor of myopia which leads to an increase in axial length of the globe. Both Greenspan and Birnbaum agree that poor accommodative performance may be associated with greater likelihood of myopia progression (12).

Young (13) indicated that animals maintained under cycloplegia in a restricted nearpoint environment did not develop myopia. In a different study involving 253 human subjects, 1% atropine was instilled once a day with an average patient follow up of 4.5 years (14). The results revealed a marked reduction in rate of myopia progression during atropine treatment.

Though cycloplegics have been demonstrated to be effective in retarding myopic progression, their side effects render them impractical for therapeutic use. As many a 2/3 of the subject sample had to be dropped from one study (15) due to non-compliance with the regimen. One study using atropine therapeutically has also shown myopia to resume its progression at a faster rate when the atropine treatment is discontinued(14).

C.) THE ROLE OF CONVERGENCE IN MYOPIA

Since the actions of accommodation and vergence are physiologically linked, it is difficult to determine whether any environmentally induced myopic changes are due to accommodation or vergence. Rosenfield (16) looked at the myopic drift during a 60 second period following a near point task. Vergence demand was varied while accommodative stimulus was maintained. No significant difference was found in the myopic drift for the 3 different vergence demands measured.

However, in 1980 Greene (25) did extensive work supporting the idea that the mechanical actions of the extra ocular muscles (EOMs) during convergence are key in myopic progression. He stressed that the peak force capabilities of the EOMs were 250 times greater than that of the ciliary muscle, therefore suggesting that vergence must mechanically dominate accommodation. He concluded that during near work, the EOMs create a sizable increase in vitreous pressure which may contribute to an extension of the posterior sclera and subsequent myopia.

Parssinen et al.(4) conducted a 3 year study involving the progression of myopia among 238 school children. They found that the fastest progressing quartile had an accommodative stimulus that was smaller than that of the slowest progressing quartile. Time spent in reading and short reading distance were both related to myopic progression but high accommodative stimulus was not. Their work supports the idea that convergence plays a more important role in myopia progression than accommodation.

The dimensions of the globe for 8 hyperopic eyes, 6 emmetropic eyes and 7 myopic eyes were analyzed extensively using MRI (26). According to Cheng et. al., the myopic eyes were not elongated, instead they were larger in all three dimensions of the eye. Unlike the hyperopic and emmetropic eyes, the sclera and the choroid of the myopic eyes were uniform in thickness. The myopic eyes also showed the thinnest choroid and sclera among all eyes. They concluded that myopic progression is associated with an overall enlargement or a radial volume expansion of the globe. It is yet unknown if the thinning of the choroid and sclera is due to mechanical stresses on the globe.

The fact that nearpoint esophoria is a common finding among rapidly progressing myopes(17,18) is also interesting when considering the role of convergence in myopia development. The role of esophoria in myopia is discussed in more detail later in the paper, but some have theorized that poor accommodation leads to excessive effort at near, rendering an esophoric posture (12).

D.) COGNITIVE DEMAND AND MYOPIA

Others believe that environmental myopic shifts are not the result of the proximity of work, but are related to cognitive function. One study compared T.A. before and after a cognitive task was performed(19). A group of myopes (onset after 15 years of age) were matched by age and sex to a group of emmetropes. It was found that the change in T.A. during a cognitive task was significantly greater for the group of myopes (mean +.35D) than the emmetropes (mean +.07D).

In addition to the containment associated with reading, Skeffington's use/abuse theory(6) suggests that reading demands information processing though symbols that may also contribute stresses that lead to myopia.

In 1968 Goldschmidt(20) compared prevalence of myopia between 3 occupations that were near work intensive but differed in cognitive demand. He reported that myopia prevalence was 30% among university students, 12% among clerical workers and 9% in fine craftsmen. In 1980 Kruger(21) observed a significant mean increase of .28D in accommodation when subjects changed from simply reading a series of two digit numbers to adding the same numbers.

The National Examination Survey of 1971(22,23) showed that myopia prevalence increased markedly for all age groups as the number of years of school completed rose from less than 5 years to greater than 12 years (statistically significant at the $p<.01$ level). It is important to note that this result may be due to near work but be completely unrelated to cognitive demand.

Some studies opposed the theory relating cognitive demand and myopia. For example, Rosenfield and Ciuffreda(24) measured T.A. changes after 3 different levels of cognitive demand. The myopic shifts between the 3 different conditions did not vary significantly.

II.) SUGGESTED CULPRITS OF AXIAL ELONGATION

A.) INTRA-OCULAR PRESSURE

Myopes tend to have higher intra-ocular pressure (IOP) than emmetropes or hyperopes (27,28). Young has demonstrated an increase in vitreous chamber pressure during ciliary muscle stimulation in primates (29). His work found that the vitreous chamber pressure of a pig tail monkey doubled when fixation changed from 6 meters to 20 centimeters. Young concluded that this increase in vitriol pressure may be key in the expansion of the posterior pole in myopes.

Jenson (30) followed the myopic progression of 49 children over a 2 year period. He found that the rate of progression for kids whose IOP was below 16 mmHg was .86D/2yrs. The rate for kids whose IOP was 16mmHg or greater was a significantly higher 1.32D/2yrs. In a separate study (31), Jenson observed the effects of using timolol to reduce IOP and control myopic progression. In spite of a 2 to 3 mmhg decrease in IOP, there was no significant difference in myopia progression for the experimental and control groups.

B.) THE RELATION OF GROWTH FACTORS AND MYOPIA

Grosvenor and Scott analyzed the differences in the refractive components for emmetropes, youth onset myopes (age of onset before 16 years) and early adult onset myopes (age of onset 16 years or later)(32,33). It was found that both types of myopes had a deeper vitreous chamber depth, slightly steeper corneas and slightly deeper anterior chambers than that of the emmetrope group(32).

There was very little difference in lens power and thickness between the myopes and emmetropes. After 3 years of follow up, a significant increase in axial length was observed for both myopia groups but corneal power was not found to change significantly in any of the 3 groups (33). They suggested that any corneal steepening in a myopic eye occurs very early in the development of myopia or even before "clinical myopia" presents itself.

The Orinda Longitudinal Study of Myopia analyzed the refractive components for 530 children whose ages ranged from 6-14 years(34). Between the ages of 6 and 12 years, the vitreous chamber elongated and the crystalline lens power decreased. The decrease in lens power was associated with an overall thinning of the lens and an increase in both anterior and posterior lens radius of curvature. No trend in corneal power was noted for the population studied. It was suggested that the lens thinning which is associated with an increase in vitreous chamber depth is responsible for the "emmetropization" process in the human eye. Myopia results when the genetic or environmental signal that calls for vitreous chamber elongation exceeds the ability of the crystalline lens to thin.

It has been suggested that a release of biochemical growth factors is responsible for the axial length increase in childhood myopia development (35). In a control group for a study involving the effects of atropine(14), the fastest rate of myopic progression was noted between the ages of 8-12 years. In addition, the data from Goss et.al. showed that axial elongation in childhood myopia continues to about the same time as cessation of general body growth. The fact that myopia progression usually slows or stops when the growth spurt stops supports the idea that any biochemical growth factors for axial elongation may act synergistically with human growth hormone.

C.) RETINAL BLUR AND AXIAL ELONGATION

Several studies have shown that animals demonstrate myopia (particularly increased axial length) as a result of a restricted visual environment. Raviola and Wiesel showed that the myopia develops in animals raised in the light but not in those raised in the dark, indicating that visual stimulation is necessary for the development of myopia (36).

Wallman et al.(38) observed the effects of retinal blur on the eyes of chicks. They demonstrated that when visual deprivation is limited to specific retinal regions, axial elongation occurs only in that region suggesting that the elongation is due to image degradation.

Rosenfield et al. hypothesized that a defocussed retinal image caused the release of biochemical factors that may lead to an increased vitriol chamber depth (24). It is therefore possible that the myopic shift following a near work task can lead to an increased vitreous chamber depth.

McBrien and Millodot (39) showed that the ultimate cause of <u>late onset</u> myopia is vitreous chamber elongation. Since late onset myopia typically occurs after one's growth spurt, this finding suggests that growth factors for axial elongation may be triggered by retinal blur as well as human growth hormone.

III.) OTHER FACTORS RELATED TO MYOPIA

A.) RACE AND ETHNIC ORIGIN

The prevalence of myopia varies greatly among various countries and ethnic groups(12). In 1983, Sperduto et.al. re-analyzed data from the Health and Nutrition Survey and found that about 25% of the U.S. population between the ages of 12 and 54 years is myopic(23). They also found that the prevalence was about 26% for whites and 13% for blacks. Prevalence is greater in China, Japan, and Germany and less in Scandinavian countries(12). Crawford's screening of 50,000 schoolchildren in Hawaii showed a myopia prevalence of 3% for Polynesian kids, 12% for Caucasian kids and 17% for Chinese kids(40).

B.) THE ROLE OF GENETICS IN MYOPIA

According to Goss (37), it is likely that myopia development results from a complex interplay of genetics and environment. There is widespread belief that genetics definitely has a role in the development of myopia. However, the genetic influence in myopia has been difficult to study using pedigree analysis. This is because refractive error, like height and weight, is a continuous variable. Discrete variables such as blood type are analyzed much easier using pedigrees(37). In his review of several studies, Goss found no consistent mode of inheritance for myopia and concluded that myopia is polygenic (derived from more than one gene).

However, Goss did observe that the modes of inheritance were more clearly established in high myopia than in low myopia(37). Hirsch and Ditmars also concluded that patients with higher degrees of myopia showed hereditary influences, while those with lower degrees of myopia showed little or no hereditary influence(41).

Many studies have compared the refractive states in identical twins, fraternal twins, siblings and unrelated individuals(12). Baldwin(42) concluded from these studies that the incidence of myopia is influenced by heredity but there are also other factors involved in its development.

C.) AGE OF ONSET AND MAGNITUDE OF MYOPIA

Grosvenor(43) believes that a classification system for myopia based upon the age of onset may help us to understand the etiology of myopia. The four categories that he proposes are congenital, youth onset, early adult onset, and adult onset myopia. Youth onset myopia begins between the ages of 6 years though the teens. Early adult onset myopes have an onset between the ages of 20-40 years. In many studies, the assumption has been made that early adult onset myopia is induced by environmental factors such as excessive close work, rather than being due to hereditary influences(32).

McBrien and Millodot found a significant difference in T.A. between myopes whose onset was 13 years of age or younger and myopes whose onset was 15 years of age or older(7). This difference between early and late onset myopes may support a theory that late onset myopia is environmental in origin and early onset myopia is essentially genetic in origin.

In the 3 year study by Parssinen et al. myopic progression and final myopia was found to be significantly related to age of receiving first spectacles(4). In a study by Mantyjarvi myopic progression was .93D/year in 8 year old children and .52 D/year in 13 year old children.

A greater amount of myopia when receiving the first spectacle correction is associated with a greater rate of myopic progression(44,4).

D.) GENDER DIFFERENCES IN MYOPIA

A statistically significant difference in myopic progression was found between males and females in the study by Parssinen et. al.(4). Myopia progressed faster in girls than in boys. In contrast, Goss did not find that gender had a great effect on the progression of myopia(44).

It has also been shown that myopia tends to occur earlier in girls than in boys(12). In a separate study by Goss, he found that myopia stops increasing earlier in females than in males but there is a great deal of individual variability in age of cessation(45). It is possible that the differences in myopic development are related to the differences in the growth spurt and time of puberty between males and females.

The data from the Health and Nutrition Survey of 1971 showed that for all ages combined, prevalence rates were significantly less for men than for women(22,23). This difference in rates was not present after the age of 35 years.

IV.) 4 PREVIOUS STUDIES ON BIFOCALS IN MYOPIC PROGRESSION

If the environmental influence of myopia is due to excessive accommodative demand, it stands to reason that the use of plus lenses for near work (or bifocals) should decrease any environmentally induced myopia. The use of bifocal lenses to retard the progression of myopia has produced mixed results(6). One of the difficulties in these studies is that there are several different variables that are related to myopia development. If control subjects aren't matched by age, sex, and amount of myopia, we have no way of knowing whether the bifocals or some other factor is influencing myopic progression.

In 1959, Mandell(46) conducted a study of 175 patient files from a private practice in Southern California. The upper age limit for the study was 30 years. Of the 175 subjects, 59 of them wore bifocals. The results showed that bifocals made no significant difference in myopia progression. But Mandell's study was met with much criticism(47). The bifocal groups differed greatly in age and amount of myopia. The average age of the bifocal wearers was 14.3 years as opposed to the single vision group's average age of 17.1 years. The average initial refraction of the bifocal group was -2.75D versus the -1.48D of the single vision group. Since earlier onset and higher amount of myopia at a given age are associated with greater rates of progression (47), Mandell's results may be misleading.

Parssinen et al.(4) recently studied myopic progression of 240 children between the ages of 8.8 and 12.8. One treatment group wore a full correction continuously, the second group wore a correction for distance only and the third group wore bifocals with an add of +1.75D. After 3 years of follow up, no significant difference in myopic progression was found between the treatment groups. Parssinen suggested that convergence may be more responsible than accommodation in myopic progression.

In a 1967 study by Roberts and Banford(18), data from a private practice was obtained for subjects under the age of 17. After a statistical correlation technique was used to correct for age and sex differences between the control group and the bifocal wearers, a 22% decrease in myopic progression was found for the bifocal group. The mean rate for the bifocal group was -.31D/year while that of the single vision group was -.41D/year. This difference was significant at the p=.02 level.

In a 1975 study by Oakley and Young(17) a group of American Indians were studied (N=126) and a group of Caucasian subjects were studied (N=418). In each group the bifocal wearers and single vision wearers were matched by age, sex, and magnitude of refractive error. After 3 to 4 years of follow up, the American Indians who wore bifocals progressed at a rate of -.12D/year versus -.37D/year of the single vision wearers. This difference was significant at the p=.05 level. The Caucasians who wore bifocals progressed at a rate of .02D/year versus -.52D/year of the single vision group. This difference was significant at the p=.001 level.

Oakley and Young fit the bifocal such that the top of the segment was at the center of the pupil when the eyes were in their primary position. This forced the children to look through the bifocal during near work. Another factor that may have contributed to Young's dramatic results was the fact that an unusually high percentage of the subject population demonstrated a near point esophoria(47). An inadvertent investigator bias may have contributed to the large number of esophores(47).

V.) THE ROLE OF ESOPHORIA

Several studies have indicated that myopes with esophoria progress faster than patients with orthophoria or exophoria(17,18,44). A 1990 study by Goss(44) found that the mean rate of myopic progression for a population of esophores was -.50D/year while the orthophore and exophore group progressed at a rate of -.41D/year. A separate study by Goss(48) showed that the mean near phoria for a population of children who became myopic was 2 prism diopters eso and the mean for those who remained emmetropic was 1 prism diopter exo. Roberts and Banford(18) also found that patients with nearpoint esophoria had the highest rates of progression while orthophores and exophores had the lowest.

There is evidence that the use of bifocal correction in controlling myopia progression is more effective for esophores than for orthophores and exophores(17,18,47,49,51).

Grosvenor found no statistical difference in myopic progression between single vision and bifocal wearers(50). Goss(51) re-analyzed the data from this study and used linear regression to determine the amount of myopic progression. After adjusting the data for age and amount of myopia, it was apparent that bifocals were more effective in the esophoric group, though the difference was not significant at the P=.05 level.

For ortho and exophores, Roberts and Banford(18,51) found no statistically significant difference between the progression rates of single vision wearers and bifocal wearers. However, the esophores showed a rate of -.48D/year with single vision lenses and a rate of -.28D/year using bifocals. This difference is significant at the p=.02 level.

In 1986, Goss (49) found no statistical difference in myopic progression between 52 single vision wearers and 60 bifocal wearers. When the esophores were analyzed separately, it was shown that the bifocals significantly lowered myopic progression at the p=.05 level(51).

In contrast, Jensen(52) found that for esophores, the reduction in myopic progression was not much different than for orthophores and exophores. Goss(47) suggested that this may be due to the fact that the phoria was measured using prism neutralization at 30cm as opposed to the VonGraefe method at 40cm.

CONCLUSION

According to Zadnik et al. discovering why a child becomes myopic is not as important as the ultimate goal of being able to predict which subjects from a population are most likely to become myopic(34). It is possible that the inconsistencies of bifocal treatment in controlling myopic progression are due to the fact that bifocals are used on eyes that are already myopic and have already undergone axial elongation and scleral stretching(53). If predictions can be made, preventative treatment such as modification of environmental risk factors could be employed for kids at a high risk for myopia development.

According to Birnbaum, poor accommodative performance may be associated with a greater likelihood of myopia progression(12). When accommodative skills are poor, excessive effort may generate a nearpoint esophoria which is common in rapidly progressing myopes. Findings suggestive of accommodative insufficiency typically include low PRA and/or amplitude of accommodation. The patient may also struggle with NRA and accommodative facility test due to difficulty in relaxing accommodation.

Goss(47) found that the use of bifocals was more effective in patients with a binocular cross cylinder finding greater than +.50D. A higher binocular cross cylinder finding implies that the patient may have a higher lag of accommodation(47).

Birnbaum believes that since virtually all incipient myopes will show significant signs of accommodative insufficiency, preventative care should be initiated as soon as signs of accommodative dysfunctions are noted(6). This preventative care includes the use of: 1) plus lenses for near work, 2) good visual hygiene including proper working distance and frequent visual rests, and 3) vision therapy to create a more efficient visual system which can more easily withstand stress.

However, in 1944 the Baltimore Myopia Control Project used vision therapy on 111 subjects ranging from .50 to 9D myopia. The optometric report on the study showed no data concerning the reduction of myopia(54).

Patients least likely to benefit from bifocals are patients who develop myopia at early ages(6,55), patients with a higher amount of myopia(55) and patients demonstrating a nearpoint orthophoria or exophoria(17,18,47,49,51). Patients most likely to benefit from bifocals develop myopia later, have a lower magnitude of myopia, are esophoric at near and have minimal family history of myopia(4,6,17,18,47,49,51,55)

The studies on the use of bifocals to slow myopic progression are inconsistent. But, since several of the studies have shown that certain types of myopes may benefit from bifocals, it is the responsibility of the eye care provider to identify and inform patients that bifocals can be beneficial to certain individuals. Greenspan(55) concluded that "bifocals may be a very valuable approach in the treatment of myopia when discriminately prescribed for selected patients..."

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