Myopia, Near Work, Atropine and Bifocals: Critical Reflections of the Key Literature Examining the Influence of Several Factors on the Progression of Myopia.

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ABSTRACT

In the last century there have been many studies into the factors that influence the progression of myopia. Genetics, exposure to light, intra ocular pressure, near work, stress, presence of esophoria, level of education and living environment are described as possible factors influencing myopia. Some studies[1-3] indicate that there is a possible connection between near work and myopia progression and other studies suggest that methods to delay myopia progression are negligible[4,5]. The literature shows that it is impossible to measure the amount of influence each factor has on the progression of myopia as it is not possible to separate one individual factor from another. The exact mechanism that causes myopia progression is not known and there are no evidence based studies that document what the causes may be. Whilst it is known that genetics have an influence, it is also possible that reading and near work have influence on myopia. Thus, could the progression of myopia be delayed with treatment such as atropine and bifocals?

The purpose of this paper is to investigate the factors that may contribute to myopia progression as outlined in the literature and to consider, by comparing two key papers, whether the use of atropine and bifocals is effective treatment. In addition, important considerations from an orthoptic perspective are also described.

Keywords: myopia, progression, atropine, bifocals

INTRODUCTION

Myopia is a common public health problem throughout the world and there are many adverse eye health care problems that can be associated with it[6]. Through the last few decades there have been many researchers who have investigated which factors have influence on myopia progression and whether it is possible to stop or delay this progression. Reading is documented as one of the most significant factors influencing the progression of myopia[7-9].

A patient with myopia has an eye where the refractive index is unrelated to its axial length[10]. Young children are normally hypermetropic and if a child younger than 3 years is emmetropic there is a greater chance that he or she will develop myopia. The cause of myopia can be related to the lens or to the axial length of the eye. With lenticular myopia the lens is too thick and in turn the refractive index is too high, or the eye is of normal size but the corneal curvature is too high. In pure axial myopia the axial length of the eye is too long but the optical components are normal. There are 3 different types of myopia: physiological or low myopia (up to -2.00 dioptres); intermediate or moderate myopia (from -2.00 to -4.00 dioptres) and pathological or high myopia (greater than -6.00 dioptres). Myopia can also be categorised by age according to Grosvenor's classification system[11] with congenital or early onset myopia occurring from ages 5 to 12 years or late onset myopia from adulthood[12].

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FACTORS THAT HAVE AN INFLUENCE ON MYOPIA

Myopia is a common public health issue mainly in Asian countries where it has a larger impact compared with Australian or European countries and it has been reported that 75% to 80% of the Asian population has myopia[7,13-17]. Many studies have investigated effective treatment or prevention of myopia but to compare these studies it is important to investigate the factors that have influence on myopia progression. All ocular activities have an influence upon refractive error and inevitably undertaking near work and reading at a further focal distance reduces myopia

progression[8]. The progression of axial myopia in monkeys as a result of form and light deprivation has been reported[8,18] and other researchers suggest that accommodation, convergence, performance of daily living tasks, level of education, intra-ocular pressure, exposure to light and esophoria also have an influence[1,19-22]. Genetics however, are probably one of the largest factors causing myopia and one paper suggests that the children of myopic parents have longer eyes even before they have myopia[8,23]. Genetic factors cannot be denied in the refractive status of the patient and the specific genes for myopia have been identified[24,25]. However, the genetic factor is not the only issue as there has been an increase in the incidence of myopia in the last decade that cannot be explained solely by genetic factors and researchers suggest that near work is the other reason for the increase in myopia[2]. Wu and Edwards[9] conducted a study on familial myopia over three generations and conclude that the chance of myopia in children is five times greater if the parents and grandparents are also myopic. The chance of developing myopia in children was greater in the last three generations which concludes that probably it is not only genetic factors which influence the progression and that environmental factors may also play a part. Wu and Edwards[9] describe that the chance of a child from the third generation developing myopia is 22% when there is no parent with myopia and the chance is 30% if there is one parent with myopia and 46% if both parents are myopic. Mutti et al[1] suggest that the chance of a child with two myopic parents developing myopia is 30 to 40%, 20 to 25% with one myopic parent and smaller than 10% without myopic parents.

There are three possible hypotheses that explain the relationship between near work and myopia and are presented in Table 1.

Table 1. Hypothesis about the influence of near work on myopia

Researchers	Hypotheses
Coleman[26]	• Accommodation causes permanent change in the convexity of the lens. • The ciliary muscle holds the lens in the accommodative position contributing to new lens vessels growth. • If this persists, it can result in permanent change.
Smith et al[27]	• Biochemical processes cause the eye to grow. • These biochemical processes exist when there is a blurred image on the rertina
Young[28]	• A relationship exists between accommodation and intra ocular pressure. • During accommodation the volume of the posterior chamber is compressed and the pressure increases • This causes pressure on the sclera and may lead to an increase in the axial length, mainly in patients (especially in children) where the sclera is more flexible

Three significant studies, those by Mutti et al[1], Saw & Nieto[22] and Zylbermann and Landau[3] specifically address the influence of near work on myopia.

Mutti et al[1] suggest that children with myopia are more likely to have parents with myopia. Myopic children are also more likely to spend significantly more time reading and studying and less hours playing sport compared with emmetropic children. In addition, myopic children performed better on measures of reading and language compared to their emmetropic counterparts, although the interviews used to determine this were subjective and required parental response. One particular problem with the study by Mutti et al is that 'watching television' had been classified by the researchers as near work and all refractions performed used 1% tropicamide and autorefraction without the use of cycloplegia. However, a positive relationship was found between family history, increased near work and the development of myopia.

Unlike Mutti et al , Saw & Nieto did not specifically investigate family history and the number of myopic parents prior to commencement of the study. Instead they used a questionnaire to compare myopic children residing in Chinese cities and those in rural areas and retrospectively discovered that children from urban areas were more likely to have a family history of myopia. The researchers also found that parents of the city children had higher levels of education. The children from urban areas spent less time on school activities compared with those in rural areas and those with myopia spent 2.3 hours a day on near work compared with non-myopic children who performed near work for 1.9 hours a week. The conclusion of Saw & Nieto is consistent with Mutti et al in that there is a positive association between near work, genetic factors and myopia.

Zylbermann and Landau[3] undertook a much larger study compared with Saw & Nieto and Mutti et al and investigated the prevalence and degree of myopia in 870 Jewish students and compared students attending single sex public schools and single sex religious orthodox schools. It is important to note that the authors describe a difference in the amount of near work undertaken by boys in the orthodox school, who are required to read for three hours per day from age 4 to age 13 after which they study for 16 hours a day. In addition, the sustained near vision is affected by changes in print size of the text and swaying of the upper torso which results in frequent changes in accommodation. The female students attending the orthodox schools and the students attending public schools have a similar education without the high volume of near work. Figure 1 shows the prevalence of myopia in students from the different schools, with the highest prevalence in boys attending religious schools.

Zylbermann and Landau suggest that the amount of near work is a contributing factor to the progression of myopia but does not completely rule out the influence of family history. The authors suggest that the student's ethnicities

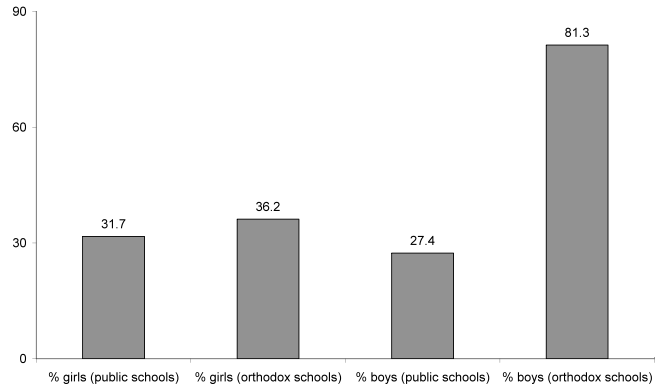

Figure 1. Prevalance of myopia in children, by sex and school. Adapted from Zylbermann and Landau[3]

are comparable, but did not research ethnicity or family history as part of the study. The researchers also compare the findings to animal studies, however, it has been suggested that it is not possible to relate human studies to animal ones as the eyes are not comparable. Also, the studies used for comparison were conducted on infantile animals, however main myopia progression in humans occurs in the juvenile period (the primate infant period being up to 2 years and the juvenile period after the age of 2 years until puberty)[8,29].

THE USE OF ATROPINE IN COMBINATION WITH BIFOCALS TO DELAY MYOPIA PROGRESSION

If the suggestion is true that accommodation has any influence on myopic progression, then this progression might be delayed or even halted with the use of atropine and bifocals. Chiang et al[4] and Syniuta and Isenberg[5] conducted a study to investigate the treatment of atropine and bifocals and whether this had an influence on the progression of myopia and these studies are compared. Whilst both studies investigated the combined use of atropine and bifocals, they were conducted in different parts of the world with participants of different ethnicities. A comparison of the characteristics of both studies is shown in Table 2a and 2b with critical reflections of the features of both studies emphasised by the grey highlighted areas.

The study by Syniuta and Isenberg[5] was a small pilot study compared with Chiang et al's large study which included 706 participants. There were a greater proportion of females to males in both studies and a slight difference in their average age. Both studies did not include investigation of family history of myopia. There was also a difference in the average treatment time given to participants in both studies. The study by Chiang et al did not incorporate a control group, but compared results with a previous

Table 2a. A comparison of the studies by Chiang et al[4] and Syniuta and IIsenberg[5]

Study Features	Chiang et al[4]	Syniuta and Isenberg[5]
Participants randomly chosen	No	No
Number of participants	706	30
Male	296 (42%)	12 (40%)
Female	410 (58%)	18 (60%)
Age	6 - 16 years	4 - 13 years
Average Age	Unkown	8 years
Ethnicity	Caucasian race	Not investigated
Investigation of family history of myopia	No	No
Time of study	12 years	Unknown
Average treatment time	3.62 years (range: 21 days - 10.1 years)	2.4 years (29.3 months) (range: 3 months - 96 months)
Control group	None Comparison made with a differrent longitudinal study	Yes
Compliance measured	Using questionnaire to parents	No
Vision chart used	Unknown	Snellen-chart
Review time	Once per year	Once per 6 months
Investigator	Unknown	Technical Nurse
Method of refraction	With cyclopentolate (Objective, subjective and auto-refraction included)	With cyclopentolate (Objective and subjective included
Glasses prescription given to participants	Yes	Yes
Use of photochromatic glasses	Yes	Yes
Size of addition prescribed	2.25 dioptres	2.50 dioptres
Ocular pathology such as strabismus and amblyopia excluded?	Yes	Yes
Refraction transcribed into the spherical equivalent?	Yes	Unknown
Was atropine used, how often?	For 1st two years every other day then for 5 years once per week (1% atropine)	Daily (1% atropine)
Number of patients with low myopia (0.00 - 2.00 dioptres)	472 (69%)	11 (73%)
Number of patients with moderate myopia (2.00 - 6.00)	215 (31%)	4 (26%)
Total number of patients	687 (100%)	15 (100%)

Table 2b. Average yearly myopia progression:

Study Features	Chiang et al[4]	Syniuta and Isenberg[5]
Low myopes with use of atropine	0.11 (+/-0.2) dioptres each year	0.038 (+/-0.71) dioptres each year
Low myopes without use of atropine	No matching control group	0.76 (+/-0.26) dioptres each year Control group from own study
Moderate myopes with use of atropine and bifocals	0.16 (+/-0.05) dioptres each year	0.19 (+/-0.38) dioptres each year
Moderate myopes without use of atropine	No matching control group	1.05 (+/-0.11) dioptres each year Control group from own study
All myopes with use of atropine and bifocals	0.05 (-0.14 dioptres each year)*	0.05 (+/-0.26) dioptres each year
All myopes without use of atropine	0.24 (-0.91 dioptres each year)**	0.84 (+/-0.26) dioptres each year Control group from own study

* Average variation of 4 longitudinal studies ** Average variation of 8 longitudinal studies

longitudinal study which was conducted in a different part of the world using participants with different ethnicities. As suggested by Fulk et al[30], different outcomes may arise with different ethnic groups and the degree of myopia can also differ between ethnic groups.

Chiang et al investigated participant compliance with treatment with the use of a questionnaire given to the parents and a comparison was made between participants that had complete compliance to those with moderate compliance. Syniuta and Isenberg on the other hand did not test for compliance and the exact amount of hours that the patients wore their glasses was not reported in either study. Whilst all participants in Chiang et al's study had an examination yearly, the researchers do not indicate what type of chart was used to measure vision and whether this was consistent for all participants. Annual review of patients receiving treatment with atropine and bifocals is considered too infrequent and as some authors suggest, the chance of bilateral amblyopia or hypo accommodation is present and would not be identified with such a long duration between visits. Also, an increased risk of adverse side effects including dryness of the mouth and skin, fever, delirium, tachycardia and a chance of allergic reaction or hyper toxicity can occur[31,32].

Whilst both research teams performed refraction using cyclopentolate, it is not clear whether objective refraction was performed with retinoscopy or by autorefraction. Some similarities in study design included the prescription of photochromatic glasses to patients to minimize light sensitivity and photophobia and the exclusion of ocular pathology including strabismus and amblyopia. Moreover, the near addition prescribed to patients in both studies was almost identical.

The use of atropine (1%) however, differed between the two studies. One study[4] prescribed it for use every two days for the first two years and thereafter to be used weekly. The other study prescribed the use of atropine on a daily basis[5].

In both studies, participants were divided into two groups for monitoring the yearly progression of myopia. It was found that low myopes using atropine in Chiang et al's study progressed more than those in Syniuta and Isenberg's study whilst the opposite was true for moderate myopes. Overall, myopes using atropine had similar progression patterns in both studies which were very small, whilst those not using atropine had greater progression of myopia. However the variation is very high as can be seen in Table 2, so it is still unclear exactly what level of effect atropine and bifocal treatment have. Whilst these authors conclude that myopia is delayed by giving atropine and bifocal treatment, the question that then arises is what happens to these patients after atropine and the use of bifocals is ceased?

A possible answer to this question can be found in a paper by Fulk et al[30] who conducted a similar study to Syniuta and Isenberg's and to Chiang et al's but only used bifocals as a treatment option. The conclusion was that the myopia will increase again soon after wearing bifocals has ceased. The level of myopia after the use of bifocals is stopped was found to be the same as that in participants who were not prescribed bifocals. Another important factor not considered in these papers is that of the influence of ethnicity upon myopic development and the differences in degree of myopia in various ethnic groups has been documented and underwrites the importance of family history and genetic factors. This is especially pertinent for Chiang et al's study as the researcher compares findings to the results of eight different studies using participants of various ethnicities. The opinion that pharmaceutical and lens therapies for myopia mostly have small treatment benefits, last for a short period of time and have significant side effects, is further supported by a more recent review conducted by Gwiazda[33].

IMPORTANT INVESTIGATIONS AND CONSIDERATIONS FROM AN ORTHOPTIC PERSPECTIVE

The influence of hereditary factors upon myopia development are well known[1,2,8,14,15,23]. Therefore history taking and accurate documentation of family history is one of the most important tasks conducted by the orthoptist. In addition, a patient at onset of myopia often presents with asthenopic symptoms and this can lead to de-compensation of a latent deviation. Therefore, careful investigation of binocular function, including near and distance cover testing is imperative. If a latent deviation is present, prism cover testing to measure the size of the phoria also provides important information.

In the presence significant asthenopic symptoms, assessment of fusion to determine whether it is within normal limits can assist with excluding decompensation of the phoria as a contributing factor to the asthenopia. Accommodation and convergence tested on the RAF gauge or testing of accommodation using dynamic retinoscopy is especially useful in children with speech problems or handicap.

Assessment of ocular motility is also an important investigation. High myopes often present with mechanical motility problems due to the size of the eye in the orbit. Motility problems in this instance need to be carefully differentiated from VIth nerve palsies, divergence insufficiency, Graves Ophthalmopathy and accommodative-convergence spasm[34,35]. One must also carefully investigate visual acuity prior to cycloplegic refraction and exclude pseudo myopia caused by accommodation. The ocular media and fundus also require examination as high myopes have increased prevalence of retinopathy.

If the presence of exophoria or exotropia is found on examination, this needs to be fully corrected in myopic patients as better vision leads to better control of the exo deviation.

In the presence of an esophoria or esotropia, a small under correction of the myopic prescription might control a latent or manifest deviation, especially when there is an accommodative factor involved. However, under correction is only advocated if it is certain that this will improve the eso deviation, binocular vision, provide adequate visual acuity and relieve asthenopic complaints[35]. Young children, however, should always be fully corrected to ensure full development of the visual system.

CONCLUSION

Can we conclude that reading or near tasks have an influence on the progression of myopia? All the studies examined in this paper conclude that there is a possible relationship between near work in addition to genetic factors in the development and progression of myopia. However it is still not clear which factor has which effect and the studies illustrate the difficulty of answering this question. Some studies did not directly address family history, the number of myopic parents and their degree of myopia, whilst others did not differentiate between participants of different ethnicities and it has been suggested that the degree and prevalence of myopia will differ between ethnic groups[7]. In addition, several researchers used each others flawed findings to compare results and to suggest limited conclusions to the question.

According to the literature, it can be suggested that if near tasks have any influence on myopia, then the use of atropine and bifocals might stop or delay this myopia progression. Chiang et al[4] and Syniuta and Isenberg's[5] studies suggest that myopia can almost be completely delayed using atropine and bifocals. As shown in table 2, the effect, if any, is minor and the variation is large. In addition, family history, number of myopic parents and their degree of myopia and ethnicity have not been investigated and these factors can greatly influence final results. There are also some issues related to the review time of participants and the increased chances of amblyopia and hypo accommodation. In addition, atropine is a very strong medication to give a child for such a long period of time, adverse reactions may occur and there may be psychological effects upon the child when they are given bifocals[31,36]. Quality of life and psychological factors have not been addressed in any of these studies. Therefore, considering all of these issues, it is unlikely that the use of atropine and bifocals should be given consideration as a treatment option.

It is difficult to compare the direct relationship between near tasks and myopia progression as there are so many factors that can influence and skew the results. In addition, little work has been conducted that considers factors such as accommodation, fusion and latent deviations. For example, a patient with a large latent exophoria who uses accommodative effort to control the latent squint could decompensate with the use of atropine and as mentioned previously, young children can loose binocularity and there is an increased chance of amblyopia. In addition, the reality of what happens once atropine and bifocal therapy is ceased is impossible to gauge.

Whilst there has been a documented increase in the prevalence of myopia in Asian countries and this seems to be as a result of increased near tasks, the degree of influence of near vision upon the progression of myopia is still in contention. Objective prospective research over three generations would offer more answers about the influence of near vision upon myopia progression.

REFERENCES

1. Mutti D, Mitchell G, Moeschberger M, Jones L, Zadnik K. Parental myopia, near work, school achievement and children's refractive error. Investigative Ophthalmology and Visual Science. 2002;43:3633-40.
2. Saw S, Hong R, Zhang M, Fu Z, Ye M, Tan D, et al. Near work activity and myopia in rural and urban schoolchildren in China. Journal of Paediatric and Ophthalmology Strabismus. 2001 May-June;38:149-55.
3. Zylbermann R, Landau D. The influence of study habits on myopia in Jewish teenagers. Journal of Paediatric Ophthalmology and Strabismus. 1993;30:319-22.
4. Chiang M, Kouzis A, Pointer R, Repka M. Treatment of childhood myopia with atropine eyedrops and bifocal spectacles. Binocular Vision and Strabismus Quarterly. 2001;16:209-15.
5. Syniuta L, Isenberg S. Atropine and bifocals can slow the progression of myopia in children. Binocular Vision and Strabismus Quarterly. 2001;38:149-55.
6. Taylor D, Hoyt C. Practical Pediatric ophthalmology. 1st ed. Sydney: Blackwell Scientific; 1997.

7. Frederick D. Myopia: was mother right about reading in the dark? British Journal of Ophthalmology. 2001;85:509-12.
8. Wildsoet C, Norton T. Toward controlling myopia progression. Optometry and Vision Science. 1999;76:341-2.
9. Wu M, Edwards M. The effect of having myopic parents: an analysis of myopia in three generations. Optometry and Vision Science. 1999 June;76:387-92.
10. Lith G. Inzicht in zien. 1st ed. Rotterdam: Lioness Mediaforce BV; 1995.
11. Grosvenor T. A review and suggested classification of myopia on the basis of age-related prevalence and age of onset. American Journal of Optometry and Physiological Optics. 1987;64:545-54.
12. Pastor D. Oogmeetkunde in de Praktijk. Houten/Diemen: Bohn Stafleu van Loghum; 1995.
13. Edwards M. The development of myopia in Hong Kong children between the ages of 7 and 12 years: a five-year longitudinal study. Ophthalmic and Physiological Optics. 1999;19:286-94.
14. Lam C, Goh W. The incidence of refractive errors among school children in Hong Kong and its relationship with the optical components. Clinical and Experimental Optometry. 1991;74:97-103.
15. Lin L, Shih Y, Hsiao C, Chen C, Lee L, Hung P. Epidemiologic study of the prevalence and severity of myopia among school children in Taiwan in 2000. J Formos Med Assoc. 2001;100:684-91.
16. Saw S, Shankar A, Tan S, Taylor H, Tan D, Stone R, et al. A cohort study of incident myopia in Singaporean children. Investigative Ophthalmology and Visual Science. 2006;47:1839-44.
17. Yap M, Wu M, Wang S, Lee F, Liu Z. Environmental factors and refractive error in Chinese children. Clinical and Experimental Optometry. 1994;77:8-14.
18. Raviola E, Wiesel T. An animal model of myopia. New England Journal of Medicine. 1985 October;62(10):680-8.
19. Goss D, Rainey B. Relationship of accommodative response and nearpoint phoria in a sample of myopic children. Optometry and Vision Science. 1999;73:292-4.
20. Jensen H. Myopia in teenagers. Acta Opthalmologica Scandinavica. 1995;73:389-62.
21. Rose K, Ip J, Robaei D, Huynh S, Kifley A, Smith W, et al. Near-work and outdoor activities and the prevalence of myopia in Australian school students aged 12-13 years: the Sydney Myopia Study. Investigative Ophthalmology and Visual Science. 2006;47:E-abstract 5453.
22. Saw S, Nieto F. Distance, lighting and parental beliefs: Understanding near work in epidemiologic studies of myopia. Optometry and Vision Science. 1999;76:355-62.
23. Zadnik K, Mutti D, Friedman N. Ocular predictors of the onset of juvenile myopia. Investigative Ophthalmology and Visual Science. 1999;40:1936-43.
24. Naiglin L, Gazagne C, Dallongeville F. A genome wide scan for familial high myopia suggests a novel locus on chromosome 7q36. Journal of Medical Genetics. 2002;39:118-24.
25. Young T, Ronan S, Alvear A. A second locus for familial high myopia maps to chromosome 12q. American Journal of Human Genetics. 1998;63:1419-24.
26. Coleman D. On the hydraulic suspension theory of accommodation. Transactions of the American Ophthalmological Society. 1986;84 846–68.
27. Smith E, Hung L, Kee C, Qiao Y. Effects of brief periods of unrestricted vision on the development of form-deprivation myopia in monkeys. Investigative Ophthalmology and Visual Science. 2002;43:291-9.
28. Young T. On the mechanism of the eye. Philadelphia Trans. 1801;1:23-88.
29. Zadnik K, Jones L, Irvin B. Myopia and night-time vision. Nature. 2000;404:43-4.
30. Fulk G, Cyert L, Parker D. A randomized clinical trial of bifocal glasses for myopic children with esophoria results after 54 months. Optometry 2002 August;73:470-6.
31. Luiten M, Trap N. Geneesmiddelen en het oog. Barendrecht: Derde druk; 1999.
32. Young F. The nature and control of myopia. Journal of the American Optometric Association. 1977;48:451-7.
33. Gwiazda J. Treatment options for myopia. Optometry and Vision Science. 2009;86:624-8.
34. Gutter M, Jellema H, Wijnen-Segeren I. Orthoptische diagnostiek. Ridderkerk: Luiten; 2001.
35. Von Noorden G. Binocular vision and ocular motility. 5th ed. Houston: Mosby; 1996.
36. Myers T, Wallace D, Johnson S. Ophthalmic medications in pediatric patients. Comp Ophthalmological Update. 2005;6:85-101.