PERGAMON

Vision Research 41 (2001) 2511–2520

Vision Research

www.elsevier.com/locate/visres

The effect of reading and near-work on the development of myopia in emmetropic boys: a prospective, controlled, three-year follow-up study

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Received 2 February 1999; received in revised form 4 August 2000

Abstract

This study aimed to investigate the effect of reading and near work on myopic development in emmetropic boys in school age. It involved totally 114 children in two groups. Right eyes of 67 randomly selected students (mean age = 12.93) with mean 6 h of reading and near work (Group 1) were compared with the right eyes of 47 apprentices (mean age = 12.96) working as skilled laborers (Group 2). Cycloplegic refraction, keratometric readings and biometric measurements including anterior chamber depth (ACD), lens thickness (LT), vitreous chamber depth (VCD) and axial length (AL) were performed for 3 years at 18 month intervals. Two analyses were conducted: (1) for subjects in both groups with baseline refractive error from +0.50 to −0.50 D; (2) for all subjects in both groups with baseline refractive error from +1.00 to −1.00 D. For subjects with baseline refractive error of ±0.50 D, myopic shift was present in 20 of 41 (48.8%) in group 1 and in seven of 37 (18.9%) in group 2 at the end of the study. The magnitude of the myopic shift was 0.56 and 0.07 D in group 1 and 2, respectively. For subjects with a baseline refractive error of ±1.00 D, myopic progression was present in 40 of 67 (59.7%) in group 1 and in 10 of 47 (21.3%) in group 2 at the last readings. In this larger refractive range, the magnitude of the myopic shift was 0.61 and 0.12 D in group 1 and 2, respectively. The mean ACD, VCD and AL were significantly higher in the last readings after 36 months than in the first readings (for each, $P = 0.0001$) in group 1. There was no statistically significant difference between two measurements of these parameters in group 2. The final keratometric dioptric readings were lower than the first values (for each, $P = 0.0001$) in both groups at the end of the study. This prospective and controlled study suggested that reading and near work, important environmental factors, might cause refractive myopic shifts in emmetropic students. The myopic shift was primarily related to significant increases in ACD, VCD and AL in this young age group.

Keywords: Axial length; Myopia; Near work; Reading

1. Introduction

The etiology and progression of myopia have been investigated for many decades. At present, myopia is considered to be a multifactorial disease related to both genetic and environmental factors (Mohan, Sudipto, & Garg, 1988; Phillips, 1990). It is known that myopia is more prevalent among school-aged children and educated people and less prevalent among the illiterate population (Taylor, 1981). Accommodative effort during near work is thought to be a causative factor in the development of myopia (Greene, 1980; Goss, 1991; Shum, Ko, Mg, & Lin, 1993). Although it has been proposed that myopia may be related to time spent on reading and close work with reading distance (Parssinen, Hemminki, & Klemetti, 1989; Parssinen & Lyyra, 1993), there is no substantial evidence that increased reading time and prolonged near work from early teens to mid-20s can result in myopia (Young, 1977; Angle & Wissman, 1980; Mohan et al., 1988; Phillips, 1990). The connection between myopia and excessive accommodation was also not supported by other recent studies that showed reduced accommodation and enhanced accommodative convergence as reasons for the development of myopia (Bayramlar, Cekic, & Hepsen, 1999;

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0042-6989/01/$ - see front matter
PII: S0042-6989(01)00135-3

Gwiazda, Grice, & Thorn, 1999). In spite of this indirect evidence, there are no controlled studies investigating the effect of reading and near work on myopic development.

Therefore, in this study, we investigated the influence of reading and near work on the development of myopia. We compared two distinctive groups: the emmetropic students attending school with regular daily basis reading and close work compared with the emmetropic children not attending school and working as skilled laborers. We prospectively followed up these two different populations for 3 years at 18 month intervals, and the data presented here are the final results.

2. Subjects and methods

In total, 177 male subjects from the same racial and ethnic origin were examined in both groups. Group 1 ($n = 94$) comprised students from a private school (study group), and group 2 ($n = 83$) comprised apprentices from a skilled laborer group (control group).

The students in group 1 were chosen randomly from the preparatory and first year classes of a private boarding secondary school. The educational system of this secondary school was the preparatory class followed by first, second and third year classes. Their schooldays were about 7 h with lessons of 45 min and a 15 min break each hour. In addition, their lecturers were giving another 3 h of research requiring near vision on both schooldays and weekends. The total number of daily study hours was high, and most of this time was spent for reading and discussing the text. The students were invited to our clinic with their parents with no pre-selection.

The apprentices in group 2 were randomly chosen from skilled laborers (apprentices of hairdresser, shoemakers and furniture makers) as a control group. Like in group 1, we visited the chairman of the association of industry and commerce and requested him to bring or send us any children (with their families) working as apprentices or helpers in various registered occupations. They attended primary school for 5 years, then dropped out and did not attend secondary school or receive any kind of higher education. The apprentices were not doing any prolonged reading or near work on a daily basis. The main activities of the apprentices engaged in were to assist the master, to clean the environment, to arrange the equipment, and to go outside for payments. Apprentices having study habits or attending apprenticeship schools were not invited and excluded from the study.

We obtained an informed consent from the principals of school and association and the families to examine the students contingent on our agreement to follow emmetropic students for 3 years at 18 month intervals in both groups. We also obtained permission from the ethical committee of the university for the study.

Since it is clearly known that the current refractive error is predictive of progression of myopia, we aimed to hold the mean refractive status of the pupils around emmetropia as much as possible. Many studies have accepted the baseline refractive error for emmetropia as ± 0.50 D. According to Angle and Wissman (1980), myopia is divided into four subgroups; > -0.50 to -1.75 D; -2.00 to -3.75 D; -4.00 to -5.75 D and more than -6.00 D. Some other authors have also used ± 0.50 D as a baseline refractive status around emmetropia (Hosaka, 1988). Rabie, Steele, and Davies (1986) accepted myopia as refractive error over -0.75 D. In his recent study, Fong (1997) also defined the myopia as those with a refractive error of -0.75 D or more. For this reason, we accepted the emmetropia as ± 0.50 D. In this way, we also aimed to obtain a baseline refractive error with a smaller standard deviation (S.D.) as much as possible, since the lower S.D. is also another indicator of the stability and reliability of the values to begin with. But still, we not only measured the eyes with refractive status of ± 0.50 D, but also obtained and followed the other subjects if their refractive levels were within ± 1.00 D to observe if the higher baseline refractive status at the beginning of the study would affect the final refractive level at the end of the study in both groups. Considering this distinction, we conducted the statistical analysis in two different categories at the end of the study: (1) for subjects in both groups with baseline refractive error from $+0.50$ to -0.50 D; (2) for all subjects in both groups with baseline refractive error from $+1.00$ to -1.00 D.

In both groups, we examined the eyes of the parents and obtained their socio-economic and educational status in order to provide as much consistency as possible. Detailed ocular and systemic examinations were done in all children. Subjects who had amblyopia, ametropia exceeding ± 1.00 D, anisometropia exceeding ± 0.50 D, strabismus, convergence insufficiency and ocular or systemic disease affecting vision were all excluded. The best visual acuity before cycloplegia was obtained with a standard Snellen chart at a distance of 6 m. Keratometric readings in two different axis were measured manually with Javal type (Haag-Streit AG, Switzerland) keratometer. The astigmatism was converted to spherical equivalent. Then, tropicamide 1% (Tropamid, Bilim, Istanbul, Turkey) and cyclopentolate hydrochloride 1% (Sikloplejin, Abdi Ibrahim, Istanbul, Turkey) were instilled two times to both eyes at 5 min intervals. Fifty minutes later, retinoscopic cycloplegic refraction was taken with a manual retinoscope (Heine EN90) at a distance of 66 cm, and the final spherical equivalent value was recorded after a working power of 1.50 D was subtracted.

After the instillation of proparacaine hydrochloride 0.5% (Alcaine, Alcon, Couvreur, Belgium) in the supine position, a total of five cycloplegic biometric measurements with a standard deviation less than 0.05 mm were taken for each eye in automatic biometric mode of A-scan Ophtasonic A/P-III ultrasonic biometer (Teknar Corporation of St Louis, MO). The lowest reading among them was not taken into account because of the possibility of an involuntary depression effect on the eye, and the mean value of the other four measurements was recorded. The anterior chamber depth, lens thickness, vitreous chamber depth, and axial length were all recorded. The frequency of the transducer was 7.5 MHz. The lens, vitreous, and average tissue velocities were 1641, 1532, and 1550 m/s, respectively. Biomicroscopic and fundus examinations of the children were done. In the next tests of the children after 18 and 36 months, the same ocular examinations and measurements were repeated. The same physician (C.E.) conducted all examinations and performed the measurements. The physician was unmasked to subject group, but masked to the previous findings from a particular subject. In addition, students' reading habits were authenticated. The students in group 1 were visited at their school premises, and their reading distances were measured with a ruler by the same examiner while they were reading a book at their desks in normal sitting positions. Examinations were scheduled in the morning when all students were available. The questionnaire at the beginning and at the end of the study was asked for the average amount of time spent daily on reading and other types of close work in and outside school, separately for both schooldays and weekends. Then, the mean hours of daily close work were calculated. These measurements were not taken on subjects in group 2, and mean hours of daily close work could not be obtained, since their reading and near working time were negligible and not on a regular hourly and daily basis.

The subjects were given suitable glasses to hold them in emmetropic range if their refraction exceeded the baseline emmetropic levels by 0.50 D or more in the second visit. The subjects who were given a prescription during the course of the study were marked on Table 1. A refractive error change of 0.50 D or more according to the baseline refractive status was considered as evidence of a change and progression in refractive level at the end of the study.

A paired t-test was used in the comparison of first, second and third measurements in each group, and an unpaired t-test was used in the comparison of both groups (Daniel, 1987).

3. Results

In group 1, 15 of 94 examined students were excluded from the study at the beginning of the study for the following reasons; three had anizometropia exceeding ± 0.50 D, one had ambliyopia, two had strabismus, five had convergence insufficiency, and four had a parental refractive error exceeding ± 0.50 D. In group 2, 20 of 83 examined apprentices were not included in the study for the following reasons: three had anizometropia exceeding ± 0.50 D, one had ambliyopia, three had strabismus, four had convergence insufficiency, three had parental refractive error exceeding ± 0.50 D, and six were attending to apprenticeship school (Table 2).

Consistently, the parents of children included in this study had a similar refractive and educational status, in which most of them graduated primary school in both groups. Visual acuity was 20/20 without glasses at the first visit in all subjects with a refraction of ± 0.50 D.

The subjects who did not participate in the following visits or left the city (a total of 12 subjects in group 1 and 16 in group 2) were excluded from the study in both groups. Therefore, we started with 79 students in group 1, 67 of which completed the longitudinal aspect of the present study on three occasions during the 3 year period. In group 2, we started with 63 apprentices, 47 of which completed the study.

In group 1, the daily mean time spent on reading and close-work both at the beginning and at the end of the study was 6 h on the average (range from 4.15 to 8.02). The average reading distance at the beginning was 36.36 ± 5.01 cm (range from 20 to 49). The apprentices who were involved in furniture making and shoemaking spent an average of 8 h daily for their distance and near work.

The mean age between two groups was comparable. Not only was the obtained mean value for the eyes in group 1 with baseline refractive error of ± 0.50 D ($n = 41$) at nearly zero level to begin with (mean, 0.04 D), but also, the S.D. was smaller ($\pm$ 0.38) when compared with the levels of all the eyes ($n = 67$) with baseline refractive error of ± 1.00 D (mean $\pm$ S.D., -0.24 ± 0.57). Similar findings for baseline refractive levels were obtained in group 2. The mean starting refractions for group 2 were 0.20 ± 0.35 D and 0.09 ± 0.54 D with baseline refractive error of ± 0.50 D and ± 1.00 D, respectively.

Of eyes emmetropic (± 0.50) at the start of our study in group 1, 20 of 41 (48.8%) underwent a myopic change in refraction with the greatest change of -2.25 D (Patient 36 in Table 1), eight of which (19.5%) were beyond > -1.00 D (Table 3). In group 2, myopic progression was seen in seven of 37 apprentices (18.9%), and no subject was beyond > -1.00 D. We also noted that there was a decrease in hyperopia less than 0.50 diopter in 10 students in group 1, and three

Table 1
Average regular close work time, education and economic status of the parents, and the refractive status of the subjects in first and last readings in group 1 and group 2

Group 1 $n = 67$[a]

Case	R-1	R-3	E-f/m		Ec	AL-1	AL-3	SECR1	SECR3
1[b]	5.15	5.20	2	1	2	23.74	23.97	−0.25	−0.75
2	4.15	5.00	1	1	1	23.30	23.48	0.00	0.25
3	6.15	6.00	1	1	2	24.50	24.52	0.00	−0.13
4	6.15	6.00	1	1	1	23.64	23.89	0.50	0.38
5	5.15	5.00	1	1	1	23.43	23.70	−0.50	−0.25
6[b,c]	6.15	6.50	1	1	2	23.72	23.71	−0.50	−0.75
7	6.15	6.00	2	2	2	23.91	24.17	0.25	0.00
8	6.15	6.00	1	1	1	23.68	23.94	0.00	−0.25
9[b,c]	6.15	6.30	1	1	3	23.11	23.90	−0.50	−1.13
10	6.15	6.50	1	1	2	22.97	23.58	0.50	0.00
11	5.15	5.30	1	1	1	22.14	22.69	0.00	0.00
12[b]	6.15	6.00	1	1	1	23.01	23.50	0.00	−0.63
13	5.15	5.00	1	1	1	23.98	24.18	0.50	0.13
14[b]	5.15	5.00	1	1	3	21.95	22.30	0.00	−0.75
15	6.15	6.00	2	1	1	24.14	24.51	0.00	0.00
16	5.02	6.00	1	2	2	22.73	23.11	0.25	0.13
17	5.02	5.00	1	1	1	24.57	24.90	0.50	0.00
18	5.02	5.15	3	1	2	23.25	23.41	0.50	0.25
19[b,c]	5.02	5.00	1	1	1	21.89	22.39	−0.25	−1.13
20	6.02	6.00	2	1	3	23.39	23.69	0.50	0.25
21	4.52	5.00	1	1	1	23.33	23.64	0.50	−0.38
22[b,c]	7.20	7.00	1	1	1	23.52	24.13	−0.50	−2.13
23[b,c]	7.02	7.00	1	1	1	23.72	24.46	−0.50	−1.50
24[b]	7.02	7.00	1	1	1	23.36	23.58	0.00	−0.75
25	6.02	6.00	1	1	1	23.76	24.07	0.50	0.13
26[b,c]	8.02	8.00	2	1	1	24.05	24.64	−0.50	−0.75
27	7.02	6.00	1	1	1	23.65	24.07	0.50	0.25
28[b]	6.02	7.00	2	1	1	22.80	23.00	0.00	−0.75
29[b]	7.02	7.00	1	1	1	23.03	23.83	−0.25	−0.75
30[b,c]	5.02	5.00	3	3	3	22.14	22.77	0.25	−0.75
31	6.02	6.00	1	1	1	22.92	23.28	0.00	−0.25
32[b,c]	6.02	6.00	3	2	1	21.88	22.33	−0.50	−0.63
33[b,c]	6.02	6.00	1	1	1	23.04	23.56	−0.50	−1.13
34	6.02	6.00	2	2	1	23.92	24.43	0.50	0.25
35[b,c]	7.02	6.00	1	1	1	22.98	23.43	0.00	−1.13
36[b,c]	6.52	7.00	1	1	1	22.97	23.76	−0.50	−2.75
37[b,c]	7.02	8.00	1	1	2	23.51	24.17	−0.25	−2.25
38	6.02	6.00	2	1	3	22.90	23.48	0.25	−0.13
39[b]	5.52	5.00	1	1	1	22.31	22.78	0.00	−0.75
40[b]	7.00	6.00	1	1	1	22.46	23.46	0.50	−0.63
41	6.52	7.00	1	1	1	22.13	23.56	0.50	−0.25
–	–	–	–	–	–	–	–	–	–
42[b]	6.52	6.00	1	1	1	24.01	24.33	−1.00	−1.25
43	7.00	6.00	1	1	1	23.56	23.88	−0.75	−1.00
44[b]	5.15	7.00	3	2	2	23.80	24.20	−1.00	−1.50
45[b]	7.00	5.00	1	1	1	23.59	23.80	−0.75	−1.25
46[b,c]	5.02	6.50	2	1	1	23.22	24.33	−1.00	−2.25
47[b,c]	7.00	7.00	1	2	1	23.25	23.98	−1.00	−2.00
48[b,c]	6.02	5.00	2	1	2	23.08	23.75	−0.75	−1.75
49[b,c]	6.02	5.00	1	1	1	23.00	23.50	−1.00	−1.50
50	7.00	7.00	1	1	1	22.24	22.84	0.75	0.00
51	5.15	6.00	2	2	1	22.11	22.45	0.75	−0.25
52[b,c]	7.00	6.50	1	1	2	23.15	23.99	−0.75	−1.50
53[b,c]	6.15	6.50	2	1	3	23.45	23.91	−0.75	−1.50
54[b,c]	5.02	6.00	1	1	1	24.10	24.33	−1.00	−1.50
55	6.15	6.00	1	1	1	23.80	24.08	1.00	0.25
56[b]	5.02	7.00	2	2	2	23.84	24.11	−1.00	−1.25
57[b,c]	6.15	5.00	2	1	3	23.70	24.50	−0.75	−2.25
58[b]	7.00	6.30	1	1	1	23.50	23.89	−0.75	−1.25
59[b,c]	6.15	6.30	1	1	1	23.25	23.35	−0.75	−1.50
60	6.15	6.30	1	1	2	24.60	24.70	−1.00	−1.00
61[b,c]	6.15	6.50	2	2	1	24.31	24.61	−1.00	−1.50
62[b,c]	6.15	7.00	1	1	2	23.75	23.99	−1.00	−1.75
63	5.15	5.30	1	1	2	23.60	23.75	−0.75	−0.75

Table 1 (Continued)

Group 1 $n = 67$[a]

Case	R-1	R-3	E-f/m		Ec	AL-1	AL-3	SECR1	SECR3
64[b,c]	5.15	7.00	1	1	1	23.55	24.33	−0.75	−1.25
65[b,c]	6.15	6.00	1	1	2	23.45	24.60	−0.75	−3.25
66[b,c]	5.15	7.00	2	1	1	23.88	24.00	−1.00	−1.25
67[b,c]	5.15	5.00	1	1	1	23.15	23.45	−0.75	−1.50

Group 2 $n = 47$[d]

Case	E-f/m		Ec	AL-1	AL-3	SECR1	SECR3
1	2	1	1	23.07	23.15	0.50	−0.38
2	2	1	3	21.17	21.20	0.50	−0.38
3	1	1	1	24.43	24.45	0.50	0.38
4	1	1	1	22.72	22.73	−0.25	0.00
5	1	1	1	22.96	22.97	0.50	0.00
6	1	1	1	22.65	22.66	0.50	0.00
7	1	1	1	23.62	23.40	0.50	0.50
8	1	1	2	22.88	22.85	0.50	0.00
9	1	1	2	22.77	22.86	0.25	0.50
10	1	1	1	23.20	23.23	0.13	0.13
11	1	1	1	23.35	23.36	0.50	0.50
12	1	1	2	23.80	23.90	−0.25	0.50
13	1	1	1	23.41	23.30	−0.25	0.13
14	1	1	1	22.74	22.85	0.25	0.75
15[b,c]	3	2	2	23.81	23.87	−0.50	−0.75
16	1	1	1	22.15	22.07	0.50	0.50
17[b]	1	1	1	21.90	22.01	0.50	0.75
18	1	1	1	22.08	22.20	0.00	0.00
19[b]	2	1	2	22.47	22.53	0.13	−0.63
20	1	1	1	22.74	22.50	−0.25	0.38
21	1	1	1	23.40	23.46	0.50	0.63
22	1	1	1	21.82	21.75	0.00	0.50
23	1	1	1	23.33	23.35	0.50	0.50
24	2	1	1	22.53	22.64	0.50	0.50
25	2	1	1	22.90	22.95	0.25	0.25
26	1	1	1	22.06	22.17	0.50	0.50
27	1	1	1	23.65	23.69	0.50	0.50
28	1	1	1	23.28	23.19	0.25	0.50
29	1	1	1	23.10	23.19	0.50	0.25
30	2	2	2	22.94	22.89	0.50	0.50
31	1	1	1	21.95	22.05	0.50	0.50
32	1	1	1	22.79	22.95	0.25	0.25
33[b]	3	3	3	24.09	24.17	−0.25	−0.75
34[b]	1	1	1	24.10	24.17	−0.25	−0.63
35[b]	1	1	1	23.93	23.95	−0.50	−0.75
36[b]	2	2	2	24.01	23.95	−0.50	−0.75
37[b]	2	2	3	24.11	24.08	−0.25	−0.75
–	–	–	–	–	–	–	–
38[b]	1	1	1	23.69	23.72	−1.00	−1.25
39	1	1	2	23.33	23.55	−0.75	−0.75
40	2	1	3	22.25	22.30	1.00	0.75
41	1	2	1	21.51	21.59	0.75	0.00
42	3	2	1	24.32	24.40	−0.75	−1.00
43	1	1	1	24.00	24.09	−0.75	−0.75
44[b]	2	1	1	22.95	23.00	−1.00	−1.25
45[b]	1	1	2	24.68	24.70	−1.00	−1.25
46	1	1	1	23.15	23.20	−0.75	−0.75
47	1	1	3	22.85	22.88	1.00	0.25

R: the average regular close work time (first [1] and last [3] questionnaire); E: education (1 = primary or secondary school, 2 = high school, 3 = college/university); Ec: economic status of the parents (1 = average, 2 = high, 3 = very high); f: father; m: mother; AL: axial length (first and last readings in mm); SECR: spherical equivalent cycloplegic refraction (first [1] and last [3] readings in diopters).

[a] Students in group 1 with baseline refractive error of ±0.50 D (Cases 1–41) and of ±1.00 D (Cases 42–67).

[b] Myopic shift or progression (by means of spherical equivalent cycloplegic refraction). Hyperopic shift or progression (by means of spherical equivalent cycloplegic refraction).

[c] Subjects given glasses after retinoscopy in the second visit.

[d] Apprentices in group 2 with baseline refractive error of ±0.50 D (Cases 1–37) and of ±1.00 D (Cases 38–47).

Table 2
Exclusion criteria of the subjects at the beginning of the study in both groups[a]

Exclusionary criteria	Group 1		Group 2	
	No.	%	No.	%
Anisometropia exceeding ±0.50 D	3	3.1	3	3.6
Parents' refraction exceeding ±0.50 D	4	4.2	3	3.6
Amblyopia	1	1.0	1	1.2
Strabismus	2	2.1	3	3.6
Convergence insufficiency	5	5.3	4	4.8
Attending to apprenticeship school	0	0.0	6	7.2
Total	15	15.6	20	24.0

[a] D: diopter.

children in group 2. Hyperopic progression was seen in three subjects in group 2, whereas no subject had hyperopic progression in group 1 (Table 1).

However, when we made the statistical analysis in all the eyes with a baseline refractive error of ±1.00 D, 40 of 67 students (59.7%) in group 1 underwent a myopic progression with the greatest change of −2.50 D (Patient 65 in Table 1). In group 2, myopic progression was seen in 10 of 47 eyes (21.3%). Clearly, the myopic progression was again significantly higher in the students with close work than the other group.

In group 1 with the baseline refractive status of ±0.50 D, the differences between the first and last measurements for spherical equivalent cycloplegic refraction, anterior chamber depth, vitreous chamber depth, axial length and keratometric readings were statistically significant (for each, $P = 0.0001$) (Table 4). Similar findings were observed for all the eyes with baseline refractive level of ±1.00 D. In group 2, the difference of these values was not significant except for keratometric readings ($P = 0.0001$). Corneal flattening was not statistically significant between two groups by means of unpaired t-test ($P = 0.723$). The interim statistical analyses on both groups were done after 18 months. The same statistics were also significant for anterior chamber depth, vitreous chamber depth, axial length and refractive values in group 1 (for each, $P = 0.0001$). Fig. 1 presents the trends of study components in each group and shows that most of the changes in the refraction and ocular components occurred in the first 18 months.

4. Discussion

We observed a significant myopic shift in emmetropic students reading and doing intensive near work. Fig. 1 shows that most of the changes in the refraction and ocular components occurred in the first 18 month interval in group 1. We, however, do not know what the exact cause is. The reasonable explanation may be that this period was the fist year for these students in their private secondary school life. The total mean progression after 3 years was only 0.56 D, which is less than in other parts of the world for children in this age range (Parssinen & Lyyra 1993).

According to Angle and Wissman (1980), myopia is divided into four subgroups: > −0.50 to −1.75 D; −2.00 to −3.75 D; −4.00 to −5.75 D and more

Table 3
Incidence of myopic or hyperopic progression at the end of the 3 year follow-up in both groups[a]

	Baseline refractive error within ±0.50 D ($n = 78$)					
	Group 1 $n = 41$ (12.90 years)			Group 2 $n = 37$ (12.97 years)		
	Myopic progression No. (%)	No change No. (%)	Hyperopic progression No. (%)	Myopic progression No. (%)	No change No. (%)	Hyperopic progression No. (%)
> −0.50 to −0.75 D	12 (29.3)	–	–	7 (18.9)	–	–
Beyond ≥ −1.00 D	8 (19.5)	–	–	0 (0)	–	–
Total	20 (48.8)	21 (51.2)	0 (0)	7 (18.9)	27 (73.0)	3 (8.1)
	Baseline refractive error within ±1.00 D ($n = 114$)					
	Group 1 $n = 67$ (12.93 years)			Group 2 $n = 47$ (12.96 years)		
	Myopic progression No. (%)	No change No. (%)	Hyperopic progression No. (%)	Myopic progression No. (%)	No change No. (%)	Hyperopic progression No. (%)
> −0.50 to −0.75 D	12 (17.9)	–	–	7 (14.9)	–	–
Beyond ≥ −1.00 D	28 (37.3)	–	–	3 (6.4)	–	–
Total	40 (59.7)	27 (40.3)	0 (0)	10 (21.3)	34 (72.3)	3 (6.4)

[a] A myopic change over the baseline emmetropic refractive status of the first readings. D: diopter.

Table 4
First and last readings for each parameter in both groups with baseline refractive error of ±0.50 D or ±1.00 D with the statistical analysis[a]

	Baseline refractive error within ±0.50 D ($n=78$)					
	Group 1 $n=41$ (12.90 years)			Group 2 $n=37$ (12.97 years)		
Variable	First readings Mean ± S.E.	Last readings Mean ± S.E.	$P=$	First readings Mean ± S.E.	Last readings Mean ± S.E.	$P=$
ACD (mm)	3.70 ± 0.04	3.92 ± 0.04	.0001	3.66 ± 0.04	3.65 ± 0.04	0.392
LT (mm)	3.43 ± 0.02	3.42 ± 0.02	.727	3.40 ± 0.03	3.41 ± 0.03	0.267
VCD (mm)	16.11 ± 0.10	16.35 ± 0.11	.0001	16.05 ± 0.14	16.07 ± 0.13	0.186
AL (mm)	23.21 ± 0.11	23.66 ± 0.10	.0001	23.02 ± 0.12	23.05 ± 0.12	0.161
SECR (D)	0.04 ± 0.06	−0.52 ± 0.11	.0001	0.20 ± 0.06	0.13 ± 0.07	0.318
K (D)	42.23 ± 0.23	41.64 ± 0.24	.0001	42.27 ± 0.29	41.71 ± 0.29	0.0001

	Baseline refractive error within ±1.00 D ($n=114$)					
	Group 1 $n=67$ (12.93 years)			Group 2 $n=47$ (12.96 years)		
Variable	First readings Mean ± S.E.	Last readings Mean ± S.E.	$P=$	First readings Mean ± S.E.	Last readings Mean ± S.E.	$P=$
ACD (mm)	3.75 ± 0.05	3.95 ± 0.05	0.0001	3.68 ± 0.05	3.67 ± 0.05	0.423
LT (mm)	3.42 ± 0.02	3.41 ± 0.02	0.689	3.41 ± 0.03	3.42 ± 0.03	0.288
VCD (mm)	16.17 ± 0.11	16.41 ± 0.12	0.0001	16.10 ± 0.15	16.12 ± 0.14	0.195
AL (mm)	23.32 ± 0.11	23.77 ± 0.07	0.0001	23.08 ± 0.12	23.11 ± 0.12	0.150
SECR (D)	−0.24 ± 0.06	–0.85 ± 0.11	0.0001	0.09 ± 0.08	–0.03 ± 0.09	0.109
K (D)	42.31 ± 0.25	41.72 ± 0.26	0.0001	42.36 ± 0.28	41.80 ± 0.27	0.0001

[a] ACD, anterior chamber depth; LT, lens thickness; VCD, vitreous chamber depth; AL, axial length; SECR, spherical equivalent cycloplegic refraction; K, keratometric readings; D, diopters; S.D., standard deviation; S.E., standard error of mean.

than −6.00 D. Some other authors have also used ±0.50 D as a baseline refractive status around emmetropia (Ramsdale, 1985; Hosaka, 1988; Gwiazda, Thorm, Bauer, & Held, 1993). Rabie, Steele, and Davies (1986) accepted myopia as a refractive error over −0.75. In his recent study, Fong (1997) also defined the myopia as those with a refractive error of −0.75 D or more.

Actually, in the beginning of the study for about 4 years ago, we aimed to hold the mean refractive status of the children in both groups around emmetropia as much as possible, since it is clearly known that the current refractive error is predictive of progression of myopia. The fact that starting levels of refraction and axial length are different in the two groups using the narrow range (shown in Fig. 1), and are even more disparate with the larger refractive range, should be taken into consideration. We do not know whether the different starting values may have contributed to the outcome of our study.

If we had originally designed the study to include all subjects only as one group with refractive error of ±1.00 D, some of these eyes would have been myopic to begin with. In addition, we thought that if more eyes of −1.00 D were in group 1 than group 2, that would skew all our data. Furthermore, we also aimed to obtain a baseline refractive error with a smaller standard deviation as much as possible, since the lower standard deviation (S.D.) is also another indicator of the stability and reliability of the values to begin with. But still, we measured not only the eyes with baseline refractive status of ±0.50 D, but also measured and followed the other subjects with baseline refractive error of ±1.00 D in the course of this 3 year study to observe if the higher baseline refractive status at the beginning of the study would affect the final refractive level at the end of the study in both groups. Considering this distinction, we made the statistical analysis in two different categories at the end of the study: (1) the results of the subjects with a baseline refractive error of ±0.50 D ($n=41$ in group 1 and $n=37$ in group 2); (2) the results of all the subjects with baseline refractive error of ±1.00 D ($n=67$ in group 1 and $n=47$ in group 2). In this way, for example in group 1, the mean baseline refractive error of students with ±0.50 D ($n=41$) was at nearly zero level to begin with (mean, 0.04 D), and the S.D. was also smaller (±0.38) when compared with the levels of all the students ($n=67$) with a baseline refractive error of ±1.00 D (mean ± S.D., −0.24 ± 0.57) (Table 4). Clearly, the myopic progression was again significantly higher in the students with close-work than the other group when the baseline refractive error of ±0.50 D has been extended to ±1.00 D. Of eyes emmetropic (±0.50) at the beginning of our study, 20 of 41 (48.8%) in group 1 underwent a myopic change in refraction with the greatest change of −2.25 D (Patient 36 in Table 1). However, of eyes with baseline refractive error of ± 1.00 D, 40 of 67 (59.7%) in group 1 underwent a myopic progression with the greatest change of −2.50 D (Patient 65 in Table 1).

Zylbermann, Landau, and Berson (1993) also observed a statistically significant higher prevalence and degree of myopia among Orthodox Jewish males when compared with the students of general schools. Orthodox schoolboys differ from the other groups by their uncommon study habit characterized by sustained near vision, frequent changes in accommodation due to the swaying habit during study, the variety of print size, and the need for accurate accommodation when reading tiny print, i.e. heavy accommodative eye use. It has been shown that the amount of time spent on reading and near work and the reading distance were positively correlated to myopic progression (Angle & Wissman, 1980). Sustained near vision is known to enhance myopia in animals (Rose, Yinon, & Belkin, 1974) and humans (Sveinsson, 1982).

Despite the previous studies, our study has an important advantage of maintaining consistency in the age and sex of its subjects. We realize that it is very difficult to obtain an exactly consistent control group because the apprentices working as the helper staff of hairdressers, shoemakers, and furniture makers would probably be expected to be performing some near work. However, it is evident that there is a significant difference between the groups based upon the time spent on reading and/or the daily basis of regular near work. However, Parssinen and Lyyra (1993) suggested that the use of eyes in near work like sewing, watch repairing, and assembling electronic equipment is different

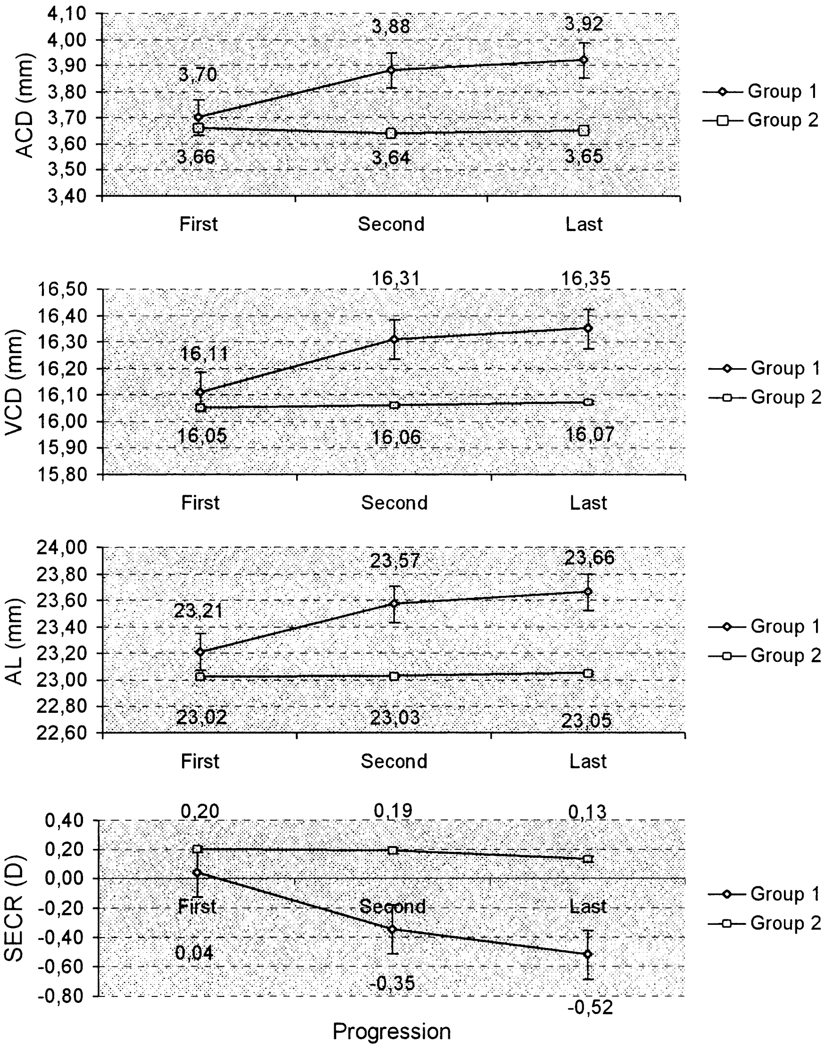

Fig. 1. Results of the first, second and third measurements of the children with baseline refractive error of ±0.50 D in both groups and the progression of the eye components with age. It is noted that most of the changes in the refraction and ocular components occurred in the first 18 month interval, and total mean progression after 3 years was only 0.56 D in group 1. ACD: anterior chamber depth; VCD: vitreous chamber depth; AL: axial length; SECR: spherical equivalent cycloplegic refraction; D: diopters.

from that of reading. They proposed that there are constant saccadic back-and-fourth movements of the eye during reading, and these eye movements clearly cause repeated pressure and pulses of stretch on the eye. It is obvious that there are fewer eye movements, although the working distance is the same, during many other kinds of near work. We know that it is impossible to find two identical parental groups for cultural and socio-economic status. However, we tried to make each group as similar as possible by excluding the subjects with parents giving the anamnesis of high cultural and socio-economic status.

In our study, the subsistence of the families was mostly trading in both groups. Their occupations did not depend upon the education so much. Some of these families chose the education and let their children go to secondary and high school after primary school. Some other families that were used in our study chose to be small traders or craftsmen for a profession. Therefore, we observed that these two groups were similar.

The myopic shift in this study was associated with a statistically significant increase in average anterior chamber depth, vitreous chamber depth, and consequently in axial length. There is some controversy about the effect of accommodation on axial length. Although some authors suggest that accommodation might be responsible for the myopic progression (Sato, 1981; Shum et al., 1993), some evidence runs counter to this view. Parssinen et al. (1989) found a positive correlation between short reading distance and rapid myopic progression, but not between myopic progression and accommodation. In their 3 year follow-up, neither the use of bifocals nor avoiding the use of spectacles in reading has slowed down the myopic progression. In another study, Parssinen and Lyyra (1993) found more myopic progression in subjects needing less accommodation stimulus than the subjects needing more accommodation. They concluded that if accommodation played a significant role in myopic progression, the feedback mechanism would probably halt the process when reading with undercorrected glasses or without glasses. The theory that convergence is one reason for myopic progression was also supported by a recent study. In our different study (Bayramlar et al., 1999), we observed a significant axial length elongation during near fixation both with and without cycloplegia. Based upon this result, one can conclude that convergence, a component of near reflex, rather than accommodation, may cause axial length elongation during near fixation. Gwiazda et al. (1999) also found that both lens-induced and distance-induced types of AC/A ratios are elevated in myopic children, who showed reduced accommodation and enhanced accommodative convergence.

Coleman (1970) remarked upon the pressure gradient of the lens on vitreous and anterior chamber during accommodation, and the stress effect on sclera. Fontana and Brubaker (1980) stated that the anterior chamber depth is related to the degree of ametropia, namely that it is 0.06 mm deeper per diopter in myopia and shallower in hyperopia. This represents a further relationship between anterior chamber depth and accommodation where the greater depth demands more accommodation. Obsfeld (1989) mentioned that the cornea flattens with age, and this process occurs to a greater extent in younger than in older eyes. Our results on significant corneal flattening were consistent with this literature in both groups.

Anatomically, most myopia is caused by an increased axial length (Adams, 1987; McBrien & Millodot, 1987). According to Hosaka (1988), the length of vitreous chamber is the component showing the strongest correlation with refractive value. He suggested that the myopic change of teenagers was mainly due to axial elongation of the vitreous chamber depth from the age of 10 or so. In previous studies, it has also been demonstrated that the posterior segment (vitreous chamber depth) and axial length of the eye elongate, while anterior chamber depth, lens thickness and corneal curvature remain stable in late onset of myopia and its progression (Bullimore, Gilmartin, & Royston, 1992; McBrien & Adams, 1997). In our study, we found an increase in both anterior chamber depth and vitreous chamber depth that were the responsible components of ocular elongation. These results were consistent with previous studies (Fontana & Brubaker, 1980; Hosaka, 1988; Shum et al., 1993). Vitreous chamber depth and axial length were higher in group 1 than group 2 in first readings. Consequently, relatively lower hyperopic readings were also present in the study group than the control group in the beginning of the study (Fig. 1).

A number of investigations have been carried out so far on this topic, but according to our best knowledge, this study is the first controlled study performed on secondary school-aged children. Based upon these results, it seems reasonable to postulate that reading and near work, environmental factors, can cause myopic shift in early teenagers, which is attributable to their sustained near vision. This myopic shift is primarily associated with an increase in anterior chamber depth, vitreous chamber depth, and consequently in axial length.

Acknowledgements

We thank Saim Yologlu, Ph.D., from the Department of Biostatistics, for carrying out the statistical analysis, the principals of the school and association, and the families for their patience and assistance.

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