Refractive errors and binocular dysfunctions in a population of university students

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PURPOSE. *This clinical study was performed to determine the presence of refractive errors and binocular dysfunctions in a population of university students.*
METHODS. *Refraction and binocular function were evaluated in a young patient population (230 students and 234 nonstudent subjects, aged 18-27 years). Distance visual acuity (DVA) and near visual acuity (NVA), refraction, cover test (CT), ocular motility, near-point of convergence, horizontal phoria measurement by Maddox wing, negative and positive vergence amplitude in prism diopters, fusion amplitude in synoptophore, as well as stereoacuity (Titmus test) were tested.*
RESULTS. *Emmetropia was the most frequent refractive status in our student and nonstudent groups (78.7%). Myopia was the most frequent refractive disorder in the whole population (13.1%). Myopia and hypermetropia were significantly more frequent in the students than in nonstudents (χ2emp 47.55). Exophoria is significantly more frequent in myopic subjects. Vergence amplitude (t test 0.000) and fusion amplitude (t test 0.005) show significantly lower values in student population. Results of Titmus test in the student group is significantly worse than in the nonstudent group (t test 0.000). Maddox wing resulted in significantly higher degree of heterophoria in the student population (t test 0.000). Myopic subjects, in the student group (t test 0.002) as well as in the nonstudent group (t test 0.001), show significantly better results in Titmus test.*
CONCLUSIONS. *High near visual demand could be the most important factor for higher incidence of myopia, worse convergence and fusion amplitude, higher degree of exophoria, and worse results in Titmus test in the student population. (Eur J Ophthalmol 2008; 18: 1-6)*

KEY WORDS. *Binocular function, Refraction, Students*

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INTRODUCTION

Although some authors report on the prevalence of general binocular dysfunction (nonstrabismic) for the nonpresbyopic population, limited research is available to support this statement (1). Some studies have researched the prevalence of refractive and binocular disorders in the student population (2). There have been very few reports on prevalence of refractive disorders among medical students (3).

We presumed that the incidence of refractive and binocular disorders increases with prolonged near work and additional academic achievements.

This clinical study aimed to determine the presence of refractive errors and binocular dysfunction in a population of university students with heavy near visual demands.

MATERIALS AND METHODS

A range of visual parameters used to evaluate binocular function were evaluated in a young patient population (230 students and 234 nonstudent subjects, aged 18 to 27 years). The criteria for selection were the absence of

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significant uncorrected refractive error, healthy eyes, and no strabismus or amblyopia. All ophthalmic examinations followed the guidelines of the Declaration of Helsinki.
Orthoptic assessment included distance (DVA) and near visual acuity (NVA), refraction, cover test (CT), ocular motility, near-point of convergence (penlight push-up technique, PPC in cm), horizontal phoria measurement by Maddox wing, negative and positive vergence amplitude in prism diopters (PD) for near and far vision, fusion amplitude in synoptophore, as well as stereoacuity (Titmus test, in sec arc).
The best VA before cycloplegia was obtained with a standard Snellen and Jaeger chart, at a distance of 6 m and 30 cm. Retinoscopic cycloplegic refraction was taken with a manual retinoscope (Kueller) after the tropicamide 1% drops were instilled two times to both eyes at 5-min intervals.
Orthoptic assessment was done by two orthoptists.
A statistical comparison of these values between the student and nonstudent population was performed (descriptive statistic, Student *t* test, chi quadrant test, and Spearman correlation test).

RESULTS

The mean age in the student group was 22.01±2.52 and in the nonstudent group 21.97±2.43 years (Tab. I).
DVA and NVA in the student and nonstudent groups were not significantly different (*t* test >0.05).
Among all subjects, the most common refractive status was emmetropia and the most common binocular status was ortophoria (Tab. II). Among 62 subjects with myopia, 24 had exophoria and 6 esophoria. Among 28 subjects with hypermetropia, 10 had exophoria and 2 esophoria. Exophoria associated with myopia, compared with exophoria associated with hypermetropia, shows a highly significant difference (Pearson chi-square 28.00, p=0.000). Exophoria is significantly more frequent in myopic subjects.
Esophoria associated with hypermetropia, compared with esophoria associated with myopia, shows a highly significant difference (Pearson chi-square 62.00, p 0.000). Esophoria is significantly more frequent in hypermetropic subjects.
No significant difference was found in vergence amplitude for near and far fixation, fusion amplitude, measurement of heterophoria in Maddox wing, and PPC, compared in myopia and hypermetropia (*t* test >0.05) (Tab. III).
Titmus test shows statistically significantly better results in myopic subjects compared with hypermetropic subjects (*t* test 0.000, t -3.456, *df* 88).
Positive correlation was confirmed between convergence response and Titmus test (Pearson 0.125), between convergence response and Maddox wing (Pearson 0.260), and between Maddox wing and Titmus test (Pearson 0.171).

TABLE I - DISTANCE (DVA) AND NEAR (NVA) VISUAL ACUITY IN STUDENT AND NONSTUDENT POPULATION

	Student	Nonstudent
R DVA	0.993 ± 0.02	0.987 ± 0.05
L DVA	0.991 ± 0.04	0.996 ± 0.02
R NVA	1.00 ± 0.00	0.998 ± 0.01
L NVA	1.00 ± 0.00	1.00 ± 0.00

TABLE II - REFRACTIVE AND ORTHOPTIC STATUS IN ALL SUBJECTS

Status	All 464 subjects
Refractive status	
Emmetropia (<−0.50 D and <+2.00 D)	R 365 (78.6%)/L 363 (78.2%)
Hypermetropia (≥+2.00 D)	R 28 (6.0%)/L 24 (5.2%)
Myopia (≥−0.50 D)	R 61 (13.1%)/L 61 (13.1%)
Astigmatism (≥1.00 cylinder)	R 10 (2.3%)/L 16 (3.5%)
Orthoptic status	
CT ortophoria	283 (61.0%)
CT exophoria	173 (37.3%)
CT esophoria	8 (1.7%)
Insufficient convergence	25 (5.4%)

TABLE III - BINOCULAR STATUS IN ALL SUBJECTS WITH MYOPIA OR HYPERMETROPIA

	Myopia (mean)	Hypermetropia (mean)
DC	13.05	13.29
D1C1	16.00	14.54
Fusion amplitude	4.44	4.18
Madox wing	1.39	0.89
PPC	7.02	6.93
Titmus	41.9355	45.3571

When we compared refractive status between student and nonstudent population chi-square test showed that myopia and hypermetropia are significantly more frequent in the student than in the nonstudent group (p 0.000) (Tab. IV).
No significant difference in frequency of astigmatism among groups was confirmed.
Vergence amplitude for near and distance in PD (DC and D1C1) shows significantly lower values in the student population (*t* test 0.000, t -2.448) (Tab. V).
Fusion amplitude in synoptophore is significantly worse in the student group (*t* test 0.005, t -4.82).
Convergence response (PPC in cm) is not significantly better in nonstudent population (*t* test 0.154, t 4.295).
Insufficient convergence response is more frequent in student (16 subjects, 7.8%) compared with nonstudent population (9 subjects, 3.9%).
Results of Titmus test in the student group is significantly worse than in the nonstudent group (*t* test 0.000, t 3.49).
Maddox wing resulted in significantly higher degree of heterophoria in student population (*t* test 0.000, t 6.35).
Myopic subjects, in the student group (*t* test 0.002) as well as in the nonstudent group (*t* test 0.001), show significantly better results in Titmus test (student group 42.14, nonstudent group 40.00) compared with the results of emmetropic or hypermetropic subjects (student group 44.43, nonstudent group 42.02) (Fig. 1). Correlation of my-

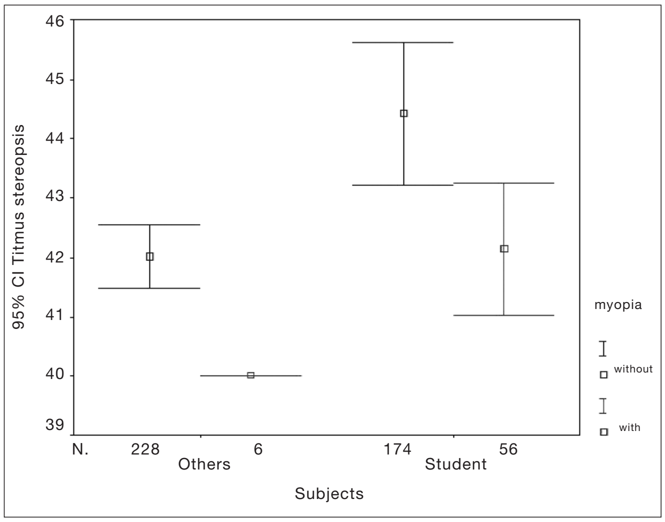

Fig. 1 - *Steropsis in myopic subjects compared with subjects with hypermetropia or emetropia*

TABLE IV - REFRACTIVE STATUS COMPARED IN STUDENT AND NONSTUDENT POPULATION

Refractive status	Student (n=230)	Nonstudent (n=234)	Chi-squared test
Emmetropia (<–0.50 D and <+2.00 D)	144 (62.6%)	219 (93.6%)	χ^2_{emp} 163.20 (p 0.000)
Hyperopia (≥+2.00 D)	22 (9.6%)	6 (2.5%)	χ^2_{emp} 10.03 (p 0.002)
Myopia (≥–0.50 D)	56 (24.3%)	6 (2.5%)	χ^2_{emp} 47.55 (p 0.000)
Astigmatism (≥1.00 cylinder)	8 (3.5%)	3 (1.4%)	χ^2_{emp} 2.42 (p 0.120)

TABLE V - BINOCULAR STATUS COMPARED IN STUDENT AND NONSTUDENT POPULATION

	Subject	Mean	Standard deviation	t Test
DC	Student	12.90	6.41	p 0.000
DC	Nonstudent	14.92	10.80	p 0.000
D1C1	Student	16.69	8.67	p 0.000
D1C1	Nonstudent	19.44	9.99	p 0.000
Fusion amplitude	Student	4.47	2.93	p 0.005
	Nonstudent	5.87	3.30	p 0.005
PPC	Student	7.20	0.94	p 0.154
	Nonstudent	6.83	0.92	p 0.154
Titmus	Student	43.87	7.32	p 0.000
	Nonstudent	41.97	3.98	p 0.000
Maddox	Student	1.94	2.36	p 0.000
	Nonstudent	0.77	1.51	p 0.000

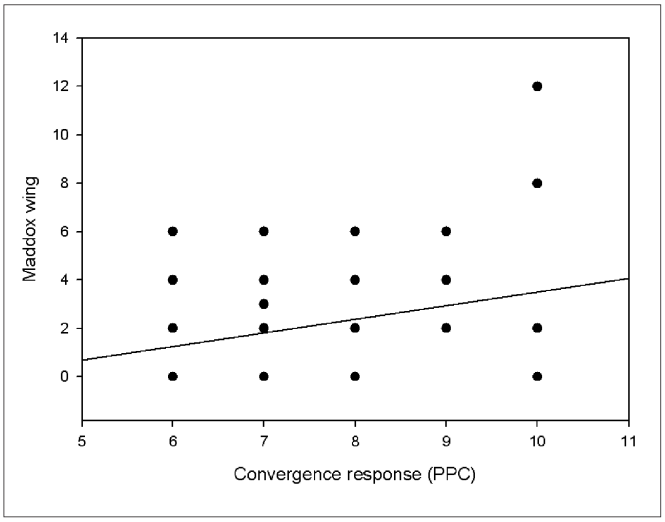

Fig. 2 - *Correlation between exophoria by Maddox wing and convergence response in student group*

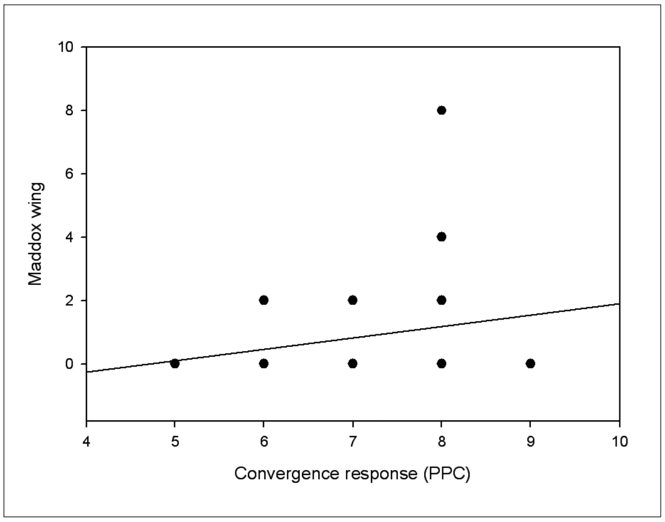

Fig. 3 - *Correlation between exophoria by Maddox wing and convergence response in non student group*

opia with Titmus values is significant at the 0.001 level.

Correlation of Maddox wing results with convergence response (PPC) is significant at the 0.001 level for both groups (students: Maddox wing = –2.1+0.57 PPC [Fig. 2]; nonstudents: Maddox wing = –1.66+0.36 PPC [Fig. 3]).

Significant correlation is confirmed for Titmus values with PPC (students: Titmus = 31.2+1.76 PPC; nonstudents: Titmus = 45.9–0.58 PPC).

DISCUSSION

Emmetropia was the most frequent refractive status in our students as well in the nonstudent group. Myopia was the most often frequent disorder in the whole population. Our study also showed that myopia as well as hypermetropia are significantly more frequent in the student than in the nonstudent group.

Myopia is a leading cause of loss of vision throughout the world, and its prevalence is increasing. The prevalence of myopia varies by country and by ethnic group, reaching as high as 70–90% in some Asian populations (3-5).

The prevalence of myopia in Asia is as high as 70–90%, in Europe and America 30–40%, and in Africa 10–20% (6,7). Although most researchers agree that people's refractive status is in large part genetically determined, a growing body of evidence shows that visual experiences may affect ocular growth and eventual refractive status (1, 8-13). The prevalence of myopia (73.9%) in Singapore teenagers is high. The prevalence of refractive conditions was found to be myopia 73.9%, hypermetropia 1.5%, astigmatism 58.7% (5). Current reading and writing habits, reading at close distances, and a better educational stream are possible risk factors for myopia.

The correlation between level of academic achievement and the prevalence and progress of myopic refractive errors is strong; people whose professions entail much reading during either training or performance of the occupation (lawyers, physicians, microscopists, and editors) have higher degrees of myopia, and the myopia may progress not just in people's teenage years but throughout their 20s and 30s (1).

Many studies have been performed to determine whether near work plays a role in the etiology of myopia. The idea that the way in which we use our eyes early in life can affect ocular growth and refractive error is gaining scientific credence. It has been hypothesized that prolonged reading or the retinal blur of prolonged near work leads to the development of myopia.

Prolonged near work was thought to lead to progressive myopia through the direct physical effect of prolonged accommodation (8, 5, 12,14), but according to current theory prolonged near work leads to myopia via the blurred retinal image that occurs during near focus (15).

It may be that a great deal of myopia can be explained by a person's cumulative exposure to use of the eye at a short focal distance but until a better measure of such exposure is produced, it will not be possible to demonstrate how important this variable is in making an eye myopic (1). Ting et al have confirmed that the microscopy task may slightly exacerbate myopia development in Chinese people (16).

Many contemporary theories of myopia etiology implicate that accommodation and convergence are important factors in myopia development (17, 18). One factor that has been related to myopia development is the phoria status (18-20).

In our myopic subjects 24 had exophoria and 6 esophoria. Among subjects with hypermetropia, 10 had exophoria and 2 esophoria. In most studies the number of esophoric subjects is small (19).

Chung and Chong's results support the hypothesis that near esophoria is associated with high myopia (21). That study suggests that near phoria might be an important factor in myopia development. We did not consider myopia progression in our study.

Myopic subjects in our study had significantly better stereopsis.

Among our students significantly more subjects have some refractive disorder, either myopia or hypermetropia. Amplitude of vergence and fusion are significantly lower in the student than in the nonstudent group. Convergence response is weaker in students. Convergence insufficiency is more frequent in students. Stereopsis is worse in the student group.

The prevalence of nonstrabismic accommodative and binocular dysfunction in a clinic population according to study of Lara et al was 22.3% in some form of accommodative or binocular dysfunction and required not just the correction of the refractive error but a specific treatment for each of the problems diagnosed (1). The remaining subjects were classed as having refractive anomalies. The frequency of binocular dysfunctions was 12.9%. Convergence excess (4.5%) was more prevalent than convergence insufficiency (0.8%).

In the study of Hokoda, the prevalence of symptomatic general binocular dysfunction among non-presbyopic urban workers and students was 21.0% (22). Symptomatic near esophoria was found in 5.9% of patients and convergence insufficiency in 4.2%. Both vergence dysfunctions overlapped with accommodative dysfunctions.

In the United States, the prevalence of convergence insufficiency has been reported in approximately 3–5% of the population (23). Our study pointed out that 5.4% of the young student and nonstudent population has insufficient convergence. Incidence increases with additional near work demand. The disorder is rare in children younger than 10 years; however, the increased visual demands of schoolwork and prolonged periods of reading exacerbate symptoms in older children. The most common presentation encountered by a clinician is that of a high school or college student who develops symptoms when excessive demands are placed on the visual system during extended periods of studying. Lack of sleep, illness, and anxiety are known to aggravate the problem. Convergence insufficiency is frequent (13%) among fifth and sixth grade children (23). The causes of convergence insufficiency are not completely clear. A connection has been made between accommodative insufficiency and convergence insufficiency. A significant exophoria at near with inadequate fusional convergence appears to be the primary underlying problem.

In our study the positive correlation is confirmed between the degree of heterophoria measured by Maddox wing and convergence response.

Some of our results could be explained by the influence of prolonged near work. High near visual demand could be the most important factor for higher incidence of myopia, worse convergence, and exophoria in the student population.

Proprietary interest: None.

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REFERENCES

1. Lara F, Cacho P, Garcia A, Megias R. General binocular disorders: prevalence in a clinic population. Ophthalmic Physiol Opt 2001; 21: 70-4.
2. Porcar E, Martinez-Palomera A. Prevalence of general binocular dysfunctions in a population of university students. Optom Vis Sci 1997; 74: 111-3.
3. Chow YC, Dhillon B, Chew PT, Chew SJ. Refractive errors in Singapore medical students. Singapore Med J 1990; 31: 472-3.
4. Wong TY, Foster PJ, Hee J, et al. Prevalence and risk factors for refractive errors in an adult Chinese population in Singapore. Invest Ophthalmol Vis Sci 2000; 41: 2486-94.
5. Quek TPL, Chua CG, Chong CS, et al. Prevalence of refractive errors in teenage high school students in Singapore. Ophthalmic Physiol Opt 2004; 24: 47-55.
6. Negrel AD, Maul E, Pkharel GP, Zhao J, Ellwein LB. Refractive error study in children: sampling and measurement methods for a multi-country survey. Am J Ophthalmol 2000; 129: 421-6.
7. Saw SM, Katz J, Schein OD, Chew SJ, Chan TK. Epidemiology of myopia. Epidemiol Rev 1996; 18: 175-87.
8. Diether S, Gekeler F, Schaeffel F. Changes in contrast sensitivity induced by defocus and their possible relations to emmetropization in the chicken. Invest Ophthalmol Vis Sci 2001; 42: 3072-9.
9. Hyman L, et al. Relationship of age, sex, and ethnicity with myopia progression and axial elongation in the Correction of Myopia Evaluation Trial. Arch Ophthalmol 2005; 123: 977-87.
10. Wojciechowski R, Congdon N, Bowie H, Munoz B, Gilbert D, West SK. Heritability of refractive error and familial aggregation of myopia in an elderly American population. Invest Ophthalmol Vis Sci 2005; 46: 1588-92.
11. Khandekar R, Kurup P, Mohammed AJ. Determinants of the progress of myopia among Omani school children: a historical cohort study. Eur J Ophthalmol 2007; 17: 110-6.
12. Gwiazda JE, Hyman L, Norton TT, et al. Accommodation and related risk factors associated with myopia progression and their interaction with treatment in COMET children. Invest Ophthalmol Vis Sci 2004; 45: 2143-51.
13. Guggenheim JA, Hill C, Yam TF. Myopia, genetics, and ambient lighting at night in a UK sample. Br J Ophthalmol 2003; 87: 580-2.
14. Zylbermann R, Landau D, Berson D. The influence of study habits on myopia in Jewish teenagers. J Pediatr Ophthalmol Strabismus 1993; 30: 319-22.
15. Fredrick DR. Myopia. BMJ 2002; 324: 1195-9.
16. Ting PW, Lam CS, Edwards MH, Schmid KL. Prevalence of myopia in a group of Hong Kong microscopists. Optom Vis Sci 2004; 81: 88-93.
17. Goss DA, Zhai H. Clinical and laboratory investigations of the relationship of accommodation and convergence function with refractive error: a literature review. Doc Ophthalmol 1994; 86: 349-80.
18. Goss DA. Clinical accommodation and heterophoria findings preceding juvenile onset of myopia. Optom Vis Sci 1991; 68: 110-6.
19. Goss DA, Grosvenor T. Rates of childhood myopia progression with bifocals as a function of near-point phoria: consistency of three studies. Optom Vis Sci 1990; 67: 637-40.
20. Goss DA, Rainey BB. The relationship of accommodative response and near-point phoria in a sample of myopic children. Optom Vis Sci 1999; 76: 292-4.
21. Chung KM, Chong E. Near esophoria is associated with high myopia. Clin Exp Ophthalmol 2000; 83: 71-5.
22. Hokoda SC. General binocular dysfunctions in an urban optometry clinic. J Am Optom Assoc 1985; 56: 560-2.
23. Rouse MW, Borsting E, Hyman L, et al. Frequency of convergence insufficiency among fifth and sixth graders. The Convergence Insufficiency and Reading Study (CIRS) group. Optom Vis Sci 1999; 76: 643-9.