

Impact of Carpet Weaving on Refractive Errors

AbbasAli Yekta, PhD¹ • Hassan Hashemi, MD^{2,3} • Hadi Ostadimoghaddam, PhD¹
Javad Heravian, PhD¹ • Samira Heydarian, MSc⁴ • Shiva Mehravaran, MD²
Tahereh Abdolahi-nia, MSc^{2,5} • Farhad Rezvani, MD² • Abbas Azimi, PhD⁴
Akbar Derakhshan, MD⁶ • Mehdi Khabazkhoob, MSc² • Hormoz Chams, MD³

Abstract

Purpose: To determine the effect of carpet weaving on refractive errors

Methods: In this cross sectional study, carpet weavers and non-weavers in the normal population of Mashhad were regarded as exposed and non-exposed groups, respectively. A carpet weaver was a person who wove carpets 7 hours a day for at least 2 years. The non-weavers group was selected from the population of Mashhad through stratified cluster sampling. The variables of age, gender, education, with respect to their frequency, were matched between the two groups.

Results: In this study, 266 carpet weavers (exposed individuals) and 549 non-weavers group (non-exposed individuals) were evaluated. The prevalence of myopia was 78.9% in carpet weavers and 19.0% in non-weavers [Odds ratio (OR)=16.03, 95% confidence interval (CI)=11.13-23.09]. The prevalence of hyperopia was 6.02% in carpet weavers, and 56.75% in non-weaver group (OR=0.05, P<0.001). The prevalence of astigmatism was 39.47% in carpet weavers and 21.46% in non-weavers. The odds of against-the-rule (ATR) astigmatism was 1.72 times more in carpet weavers as compared to non-weavers (P<0.001).

Conclusion: The results of this study showed that carpet weaving had a strong correlation with myopia. In addition to myopia, the prevalence of astigmatism, specially ATR astigmatism, was higher in carpet weavers.

Keywords: Myopia, Hyperopia, Astigmatism, Carpet Weaving

Iranian Journal of Ophthalmology 2011;23(4):29-36 © 2011 by the Iranian Society of Ophthalmology

1. Associate Professor of Optometry, Department of Optometry, Mashhad University of Medical Sciences, Mashhad, Iran
2. Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, Iran
3. Professor of Ophthalmology, Eye Research Center, Farabi Eye Hospital, Tehran University of Medical Sciences, Tehran, Iran
4. Department of Optometry, Mashhad University of Medical Sciences, Mashhad, Iran
5. Department of Optometry, Tehran University of Medical Sciences, Tehran, Iran
6. Associate Professor of Ophthalmology, Khatam-al-Anbia Hospital, Mashhad University of Medical Sciences, Mashhad, Iran

Received: July 23, 2011

Accepted: November 1, 2011

Correspondence to: Hadi Ostadimoghaddam, PhD
Associate Professor of Optometry, Department of Optometry, Mashhad University of Medical Sciences, Mashhad, Iran,
Tel:+98 511 7610111, Email: ostadih@mums.ac.ir

Competing interests: None

Introduction

According to available studies, uncorrected refractive errors are the second cause of blindness based on the presenting vision.¹ Although these errors can be easily corrected with glasses, they are still considered as a serious defect in many countries and many reports indicate that 50% of the children and adults are affected by this defect in different parts of the world.²⁻⁹ Different studies in the world have investigated the prevalence and risk factors of refractive errors.⁴⁻¹¹

In addition to demographic factors such as age, gender, and education, factors such as ocular biometry, profession, near work, and environmental and genetic factors have been assessed.⁴⁻¹³ Based on available reports, myopia is correlated with variables such as genetics,¹⁴ male gender,^{6,15,16} high education,^{8,17} near work and environmental factors.¹⁸ These studies have identified age,^{6,19} female gender, genetics, structural changes of the lens, and low education as the determinants of hyperopia. The relationship between near work and myopia has been investigated in laboratory, epidemiologic, and experimental studies and has been confirmed by most of them.^{10,20,21} Some studies have shown that prolonged near work may cause transient myopia.^{22,23} Important studies conducted by McBrien, Saw and Morgan have assessed the relationship between myopia and near work.^{10,24,25} Since near work is considered a risk factor for myopia, controlling the exposure to near work can be regarded as an effective way of preventing the development or progression of myopia. Identifying professions and activities that include near work can be helpful in this regard. McBrien demonstrated this relationship in microscopists;²⁶ Ip et al²⁰ also showed that a close distance during studying can cause myopia. Carpet weaving is a traditional occupation in Iran. In most parts of Iran, many people have taken up carpet weaving as their occupation and learn this skill in childhood. In carpet weaving, the person is always involved in near work and therefore might cause myopia. Evaluation of refractive errors in this occupation has received little attention. In a previous report,²⁷ we presented findings in a sample population of carpet weavers in which ocular biometrics were significantly associated with myopia. This has

been demonstrated by Akbarzadeh et al²⁸ as well. However it was not a comparative study and it was difficult to judge the relationship between refractive errors and carpet weaving.²⁷ The purpose of this study was to compare refractive errors between carpet weavers and a non-weavers group unexposed to near work.

Methods

The study population

In this cross-sectional study, two groups of carpet weaving and non-weaving were evaluated. Among carpet weaving workshops of the city of Mashhad, 6 were chosen for this study. After explaining the aim and protocol of the study, the owners of all workshops but one consented to the participation of their workers in the study.

The inclusion criteria for carpet weavers were as the following:

- 1- Seven hours of daily work in the past 2 years or more
- 2- No history of ocular diseases, amblyopia, aphakia, strabismus, refractive error surgery, diabetes, or systemic disease affecting refractive errors. During the interview, they were asked about a history of using spectacles, refractive surgery, and systemic disease. All participants had a complete optometric and ophthalmic examination.

After selecting the carpet weaving group, the non-weaving group was selected among the normal population of Mashhad; using stratified cluster sampling, non-weavings were selected proportionate to the population of different districts of Mashhad (municipality districts were used as strata). In total, 34 clusters were randomly selected, and the first house number in each cluster was set as the head cluster; 710 individuals were selected. The inclusion criterion for this group was no history of ocular diseases, amblyopia, aphakia, strabismus, refractive error surgery, diabetes, or systemic disease affecting refractive errors.

The variables of near work, age, and education were matched between the carpet weavers and the non-weavers groups with respect to their frequency. Individuals in the non-weaver group whose jobs involved near work (barbers, laboratory technicians,

computer operators, tailors, painters or any other activity) were excluded from the study. All participants signed an informed written consent prior to the study. After acquiring their written consent, carpet weavers completed a questionnaire on personal information, family history, the age at which they started weaving, hours of weaving per day, and other near work. Then, ocular examinations including manifest refraction, retinoscopy, subjective refraction and visual acuity (VA) testing with a Snellen chart at 6 m were performed. Refractive errors of each eye were measured by autorefractometer (mean of six measurements by Topcon Autorefractometer, model KM 8000, Japan), the autorefraction results were checked using the HEINE BETA 200 retinoscope (HEINE Optotechnic, Germany). Results with the autorefractometer were recorded and used in the analysis. All the aforementioned examinations were also carried out on non-weavers. The methodology of the examinations has been thoroughly discussed in another report.²⁷

Definitions

In this study, refractive errors were defined based on the spherical equivalent (SE=half of negative cylinder + sphere). Myopia was defined as a minimum SE of -0.5 diopter (D) or less in at least one eye.^{4,17} Hyperopia was defined as a minimum SE of +0.5 D or more in at least one eye, provided the other eye is not myopic.^{4,17} Astigmatism was defined as a cylinder power of 1.0 D or more. Anisometropia was present when the SE of the left and right eyes differed by 1.0 D or more.^{4,19}

The following categorization was considered for refractive errors: mild myopia (-0.5 to -3.0 D), moderate myopia (-3.1 to -6.0 D), and severe myopia (more than -6.0 D); mild hyperopia (0.5 to 2.0 D), moderate hyperopia (2.0 to 4.0 D) and severe hyperopia (more than 4.0 D).

Based on astigmatism axis, an axis of 180±20 was classified as with-the-rule (WTR), an axis of 90±20 was considered against-the-rule (ATR), and others were considered oblique astigmatism.

Statistically analysis

In this study, all collected information was processed with STATA V 10 software. The

prevalence of the refractive errors in the two groups was reported with a 95% confidence interval (CI). Simple logistic regression was applied to assess the association between refractive errors and carpet weaving.

Results

In this study, 815 individuals were evaluated. Of these participants, 61.2% were male and the rest were female. The mean age of the participants was 41.3±8.9 years. In this study, 266 carpet weavers with a mean age of 41.4±6.4 (range, 21 to 60) years were evaluated. The mean duration of carpet weaving was 25.7 ±9.2 (range, 2 to 50) years.

After implementing other inclusion criteria to match the two groups, 549 individuals were finally chosen as the non-weavers group with a mean age of 41.2±9.9 years, which did not differ significantly with the carpet weavers group (P=0.706). Regarding education, 87.6% and 85.5% of the individuals in the carpet weavers and non-weavers groups had primary education, and 12.4% and 14.2% had junior high school education (Pearson $\chi^2=0.482$).

Mean SE was -1.55 ±1.79 (range, -10.25 to 2.38) D in carpet weavers and +0.26±1.37 (range, -6.75 to 6.75) D in the non-weaver group; independent samples test showed a statistically significant difference between these two groups (P<0.001).

Table 1 presents the prevalence of different types of refractive errors in the two groups. As this table shows, the prevalence of myopia in weavers and non-weavers was 78.95% and 18.96%, respectively. The association between carpet weaving and refractive errors is summarized in table 2. The odds of developing myopia in carpet weavers was 16.03 (95% CI: 3.46-5.01) times greater than non-weavers (P<0.001).

Table 1. The prevalence (%) of different types of refractive errors in the two groups of carpet weavers and non-weavers

	Carpet-weavers	Non-weavers
Myopia	78.95 (74.02 -83.88)	18.96 (15.64 -22.28)
Hyperopia	6.02 (3.14 -8.89)	56.75 (52.56 -60.93)
Astigmatism	39.47 (33.56 -45.39)	21.64 (18.14 -25.14)
Anisometropia	10.15 (6.50 -13.80)	8.08 (5.76 -10.41)

Table 2. The association of different types of refractive errors and near work activity

	Odds ratio (95%CI)	P
Myopia	16.03 (11.13-23.09)	<0.0001
Hyperopia	0.05 (0.03-0.08)	<0.0001
Anisometropia	1.28 (0.77-2.13)	0.331
Astigmatism	2.36 (1.71-3.25)	<0.0001

Carpet weavers: exposure group

The prevalence of hyperopia was 6.02% in carpet weavers, and 56.75% in non-weaver group; the prevalence of hyperopia was significantly less in carpet weavers (OR=0.05, P<0.001). Figure 1 compares the severity of myopia and hyperopia between the two groups; mild, moderate, and severe myopia was more prevalent among carper weavers while the non-weaver group showed a higher prevalence of moderate and severe hyperopia. The inter-group difference in the severity of refractive errors was statistically significant (P<0.0001).

Mean cylinder power was 0.75±0.66 D and 0.45±0.63 D in carpet weavers and non-weavers, respectively; T-test showed a significant difference between the two groups in this regard (P<0.001). According to table 1, the prevalence of astigmatism in weavers and non-weavers was 39.47% and 21.64%, respectively. The odds of developing astigmatism was 2.36 times higher in carpet weavers than non-weavers (Table 2).

Table 3 presents the prevalence of different types of astigmatism in exposure and non-exposure groups. As this table shows, ATR astigmatism was more frequent in carpet weavers than non-weavers, and the odds was 1.72 times greater (P<0.001).

Table 3. The prevalence (%) of different types of astigmatism in the two groups of carpet weavers and non-weavers

	With-the-rule	Oblique	Against-the-rule
Not carpet weavers	27.7	19.6	52.7
Carpet weavers	21.0	13.3	65.7
P	0.249	0.212	0.051

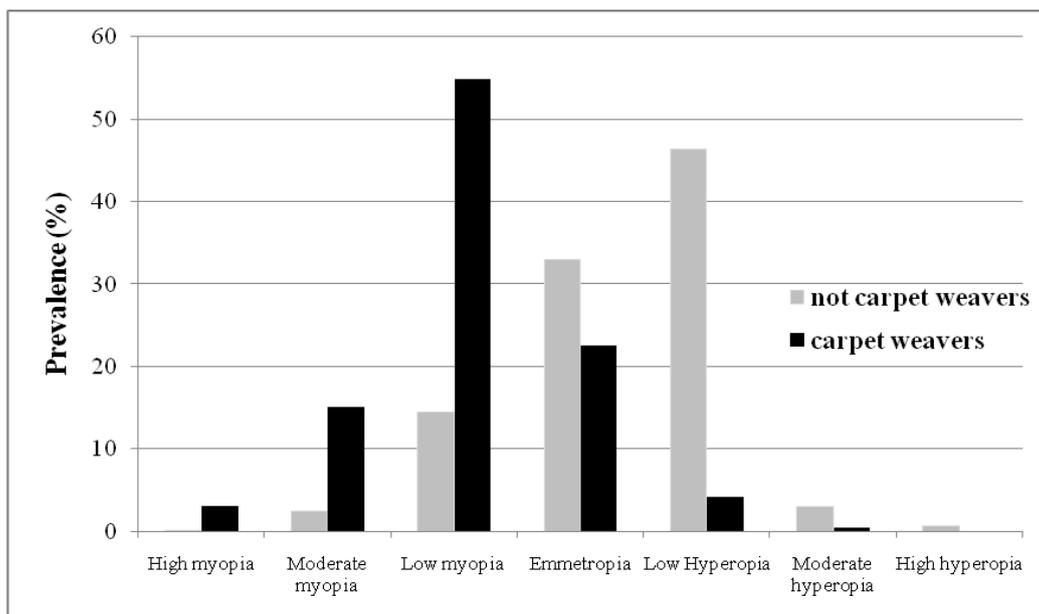


Figure 1. The prevalence of severity of myopia and hyperopia in the two groups of carpet weavers and non-weavers

Discussion

To date, many studies have been performed on the etiology of myopia.^{10,24,25} Although most studies have reported that near work is a risk factor of myopia, some recent studies have contradicted this finding.¹⁸

There are limited comparative studies on the relationship between myopia and near work. The current survey was a cross sectional study in which the exposure group was carpet weavers who had focused on near objects long. In this report, we matched the exposure and non-exposure groups through epidemiological methods to control the confounding effects of important variables like age and sex that affect refractive errors. Also, since the effect of education on refractive errors has been already reported,^{8,17} we matched the two groups in terms of education as well. A discussion about ocular biometric parameters in carpet weavers has been presented elsewhere.²⁷

As mentioned, the risk of myopia was 4.16 times greater in carpet weavers than non-weavers, and 76% of the myopia in carpet weavers was attributed to weaving; this finding was expected based on other studies in this regard.^{29,30} However, the difference between the two groups was notable.

Carpet weaving is a traditional Iranian profession; nonetheless, the relationship between refractive errors and this profession has received little attention in the literature, though many studies have documented the correlation between near work and myopia.^{26,29-31}

According to our findings, myopia was more severe in carpet weaver which was attributed to near work and its duration. However, Ip et al³² reported that the duration of near work did not affect myopia as the distance of the near work was more important.

The reason for more myopia in individuals whose jobs involve near work is the biometric changes of the eye. Some other studies have also identified ocular biometric changes, specially an increase in the vitreous chamber depth,^{33,34} as the main reason for myopia in near work.

Its seems that long-term chronic accommodation can result in increment of vitreous chamber depth and myopia due to scleral traction.^{35,36} Some studies have demonstrated the transient effect of

accommodation on myopia;³⁶⁻³⁸ transient myopia develops after a short period of near work. More information can be gained through long-term experimental and/or cohort studies. In our study, the average participant had 26 years of weaving experience, and one can assume that most of this process occurred during their adolescence when they had active accommodation. Thus, the onset age for myopia would be the 2nd or 3rd decade of their lives.

In addition to near work, environmental factors can be regarded as a confounding factor. For example, many carpet weavers work in low light conditions. Also, the profession runs in families for generations and therefore genetic factors may play a role in developing myopia. As our findings showed, hyperopia was significantly less common in carpet weavers. The higher prevalence of myopia in this group due to the increased axial length can justify the lower prevalence of hyperopia. Another hypothesis can be proposed regarding the low prevalence of hyperopia in carpet weavers; since hyperopic individuals have more visual problems and symptoms during near work as compared to myopic people, they might be less interested in taking up carpet weaving as their occupation.

A higher prevalence of astigmatism in carpet weavers was one of the findings of this study which has been less addressed in other reports.³⁹ One of the few studies in this regard was conducted by Tong et al³⁹ on the schoolchildren of Singapore which showed that the severity of astigmatism somehow correlated with near work like watching TV and playing computer games; however, they showed that astigmatism more than 1.0 D was not associated with any type of near work.

Although it is rather difficult to justify the relationship between near work and astigmatism, lid tension due to carpet weavers' near work can be proposed as a viable hypothesis. The relationship between near work and astigmatism might result from incyclotorsion during near work; with the contraction of the ciliary muscle during accommodation, the center of the cornea steepens and increases its power.⁴⁰ In a study by Buehren et al⁴¹ on the effect of microscopy and computer work on corneal aberrations,

corneal topography was examined before and after 60 minutes of near work; a change in corneal topography, specially corneal astigmatism was observed in some cases which were attributed to the effect of the eyelids. In another study by Buehren et al⁴² some of the corneal topographic changes during accommodation were attributed to cyclotorsion.

As mentioned earlier, ATR astigmatism was more frequent in carpet weavers and therefore, the hypothesis of more lid tension in carpet weavers seems rational. The effect of lid tension on developing ATR astigmatism has also been reported by some authors.⁴¹ Some hypotheses have been discussed in a review article by Read⁴³ who believes changes in topographical patterns are related to the position of the eyelids and the amount of horizontal eye movement.

Although our study had many strong points in its methodology, it had some weaknesses as well. Some risk factors like ethnicity, work conditions, or history of previous near work were some potential confounders which could have influenced our findings. However, we

minimized the effects of such confounders through matching in terms of age, gender, and education. As myopic weavers are more comfortable with this job than hyperopes, they probably last longer, and this could have been a source of selection bias for our samples. Since in cross-sectional studies, temporality and causation cannot be determined, we suggest that a cohort study be conducted for further assessment.

Conclusion

The results of this study showed that near work had a strong correlation with myopia. In addition to myopia, the prevalence of astigmatism, specially ATR astigmatism, was higher in carpet weavers who did more near work.

Acknowledgments

We thank the research vice chancellor of Mashhad University of Medical Sciences for supporting this study (grant code: 86200). The results described in this paper were part of a thesis for a masters degree in optometry.

References

1. Resnikoff S, Pascolini D, Mariotti SP, Pokharel GP. Global magnitude of visual impairment caused by uncorrected refractive errors in 2004. *Bull World Health Organ* 2008;86(1):63-70.
2. Fotouhi A, Hashemi H, Khabazkhoob M, Mohammad K. The prevalence of refractive errors among schoolchildren in Dezful, Iran. *Br J Ophthalmol* 2007;91(3):287-92.
3. Yekta A, Fotouhi A, Hashemi H, et al. Prevalence of refractive errors among schoolchildren in Shiraz, Iran. *Clin Experiment Ophthalmol* 2010;38(3):242-8.
4. Gupta A, Casson RJ, Newland HS, et al. Prevalence of refractive error in rural Myanmar: the Meiktila Eye Study. *Ophthalmology* 2008;115(1):26-32.
5. Sawada A, Tomidokoro A, Araie M, et al. Refractive errors in an elderly Japanese population: the Tajimi study. *Ophthalmology* 2008;115(2):363-70.
6. Yekta AA, Fotouhi A, Khabazkhoob M, et al. The prevalence of refractive errors and its determinants in the elderly population of Mashhad, Iran. *Ophthalmic Epidemiol* 2009;16(3):198-203.
7. Attebo K, Ivers RQ, Mitchell P. Refractive errors in an older population: the Blue Mountains Eye Study. *Ophthalmology* 1999;106(6):1066-72.
8. Cheng CY, Hsu WM, Liu JH, et al. Refractive errors in an elderly Chinese population in Taiwan: the Shihpai Eye Study. *Invest Ophthalmol Vis Sci* 2003;44(11):4630-8.
9. He M, Zeng J, Liu Y, et al. Refractive error and visual impairment in urban children in southern china. *Invest Ophthalmol Vis Sci* 2004;45(3):793-9.
10. McBrien NA, Young TL, Pang CP, et al. Myopia: Recent advances in molecular studies; prevalence, progression and risk factors; emmetropization; therapies; optical links; peripheral refraction; sclera and ocular growth; signalling cascades; and animal models. *Optom Vis Sci* 2008 Dec 19. [Epub ahead of print]

11. Ip JM, Huynh SC, Robaei D, et al. Ethnic differences in refraction and ocular biometry in a population-based sample of 11-15-year-old Australian children. *Eye (Lond)* 2008;22(5):649-56.
12. Mallen EA, Gammoh Y, Al-Bdour M, Sayegh FN. Refractive error and ocular biometry in Jordanian adults. *Ophthalmic Physiol Opt* 2005;25(4):302-9.
13. Wickremasinghe S, Foster PJ, Uranchimeg D, et al. Ocular biometry and refraction in Mongolian adults. *Invest Ophthalmol Vis Sci* 2004;45(3):776-83.
14. Dirani M, Chamberlain M, Couper TA, et al. Role of genetic factors in lower- and higher-order aberrations--the genes in myopia twin study. *Ophthalmic Res* 2009;41(3):142-7.
15. Krishnaiah S, Srinivas M, Khanna RC, Rao GN. Prevalence and risk factors for refractive errors in the South Indian adult population: The Andhra Pradesh Eye disease study. *Clin Ophthalmol* 2009;3:17-27.
16. Bourne RR, Dineen BP, Ali SM, et al. Prevalence of refractive error in Bangladeshi adults: results of the National Blindness and Low Vision Survey of Bangladesh. *Ophthalmology* 2004;111(6):1150-60.
17. Saw SM, Chan YH, Wong WL, et al. Prevalence and risk factors for refractive errors in the Singapore Malay Eye Survey. *Ophthalmology* 2008;115(10):1713-9.
18. Low W, Dirani M, Gazzard G, et al. Family history, near work, outdoor activity, and myopia in Singapore Chinese preschool children. *Br J Ophthalmol* 2010;94(8):1012-6.
19. Hashemi H, Fotouhi A, Mohammad K. The age- and gender-specific prevalences of refractive errors in Tehran: the Tehran Eye Study. *Ophthalmic Epidemiol* 2004;11(3):213-5.
20. Ip JM, Saw SM, Rose KA, et al. Role of near work in myopia: findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci* 2008;49(7):2903-10.
21. Konstantopoulos A, Yadegarfar G, Elgohary M. Near work, education, family history, and myopia in Greek conscripts. *Eye (Lond)* 2008;22(4):542-6.
22. Vasudevan B, Ciuffreda KJ. Additivity of near work-induced transient myopia and its decay characteristics in different refractive groups. *Invest Ophthalmol Vis Sci* 2008;49(2):836-41.
23. Vera-Díaz FA, Strang NC, Winn B. Nearwork induced transient myopia during myopia progression. *Curr Eye Res* 2002;24(4):289-95.
24. Saw SM, Hong RZ, Zhang MZ, et al. Near-work activity and myopia in rural and urban schoolchildren in China. *J Pediatr Ophthalmol Strabismus* 2001;38(3):149-55.
25. McBrien NA, Morgan IG, Mutti DO. What's hot in myopia research-The 12th International Myopia Conference, Australia, July 2008. *Optom Vis Sci* 2009;86(1):2-3.
26. McBrien NA, Adams DW. A longitudinal investigation of adult-onset and adult-progression of myopia in an occupational group. Refractive and biometric findings. *Invest Ophthalmol Vis Sci* 1997;38(2):321-33.
27. Yekta AA, Fotouhi A, Hashemi H, et al. Relationship between refractive errors and ocular biometry components in carpet weavers. *Iranian Journal of Ophthalmology* 2010;22(2):45-54.
28. Akbarzadeh S, Samavati M. The comparative study of refractive errors between carpet weavers and blue collar workers. *Saudi Med J* 2006;27(6):912-4.
29. Kinge B, Midelfart A, Jacobsen G, Rystad J. The influence of near-work on development of myopia among university students. A three-year longitudinal study among engineering students in Norway. *Acta Ophthalmol Scand* 2000;78(1):26-9.
30. Saw SM, Zhang MZ, Hong RZ, et al. Near-work activity, night-lights, and myopia in the Singapore-China study. *Arch Ophthalmol* 2002;120(5):620-7.
31. Simensen B, Thorud LO. Adult-onset myopia and occupation. *Acta Ophthalmol (Copenh)* 1994;72(4):469-71.
32. Ip JM, Saw SM, Rose KA, et al. Role of near work in myopia: findings in a sample of Australian school children. *Invest Ophthalmol Vis Sci* 2008;49(7):2903-10.
33. Jiang BC, Woessner WM. Vitreous chamber elongation is responsible for myopia development in a young adult. *Optom Vis Sci* 1996;73(4):231-4.
34. Xie R, Zhou XT, Lu F, et al. Correlation between myopia and major biometric parameters of the eye: a retrospective clinical study. *Optom Vis Sci* 2009;86(5):E503-8.
35. Read SA, Collins MJ, Woodman EC, Cheong SH. Axial length changes during accommodation in myopes and emmetropes. *Optom Vis Sci* 2010;87(9):656-62.

36. Young FA, Leary GA, Baldwin WR, et al. The transmission of refractive errors within eskimo families. *Am J Optom Arch Am Acad Optom* 1969;46(9):676-85.
37. Allen PM, O'Leary DJ. Accommodation functions: co-dependency and relationship to refractive error. *Vision Res* 2006;46(4):491-505.
38. Wolffsohn JS, Gilmartin B, Li RW, et al. Nearwork-induced transient myopia in preadolescent Hong Kong Chinese. *Invest Ophthalmol Vis Sci* 2003;44(5):2284-9.
39. Tong L, Saw SM, Carkeet A, et al. Prevalence rates and epidemiological risk factors for astigmatism in Singapore school children. *Optom Vis Sci* 2002;79(9):606-13.
40. Yasuda A, Yamaguchi T. Steepening of corneal curvature with contraction of the ciliary muscle. *J Cataract Refract Surg* 2005;31(6):1177-81.
41. Collins MJ, Buehren T, Bece A, Voetz SC. Corneal optics after reading, microscopy and computer work. *Acta Ophthalmol Scand* 2006;84(2):216-24.
42. Buehren T, Collins MJ, Loughridge J, et al. Corneal topography and accommodation. *Cornea* 2003;22(4):311-6.
43. Read SA, Collins MJ, Carney LG. A review of astigmatism and its possible genesis. *Clin Exp Optom* 2007;90(1):5-19.