Original Article

The Prevalence of Astigmatism and its Determinants in a Rural Population of Iran: The "Nooravaran Salamat" Mobile Eye Clinic Experience

Hassan Hashemi, Farhad Rezvan, Abbas Ali Yekta[1], Maryam Hashemi[2], Reza Norouzirad[3], Mehdi Khabazkhoob[4]

ABSTRACT

Purpose: The prevalence of astigmatism, and the astigmatic axis, and their determinants were evaluated in a rural population of Iran.

Materials and Methods: In a cross-sectional study conducted from May to August 2011, 13 villages in the vicinity of the city of Khaf in northeast Iran were investigated in this study. All the examinations including visual acuity, refraction, slit-lamp biomicroscopy and fundoscopy were performed in a Mobile Eye Clinic. Written informed consent was obtained from all participants. Only phakic eye that could be reliably refracted without a previous history of ocular surgery were included.

Results: Out of 2635 participants who were screened, 2124 were analysed for this study of whom 52% were female. The prevalence of astigmatism was 32.2% (95% confidence intervals (CI): 30.2-34.2). Astigmatism significantly increased from 14.3% in the under 15-year-old age group to 67.2% in the age group of over 65-years old ($P < 0.001$). The prevalence of With-The-Rule (WTR), Against-The-Rule (ATR), and oblique astigmatism was 11.7%, 18.1%, and 2.4 %, respectively. ATR significantly increased with age ($P < 0.001$). The mean corneal astigmatism was 0.73 D which linearly increased with age ($P < 0.001$).

Conclusion: Attention must be paid to astigmatism in rural areas due to the high prevalence. Further studies are suggested to discover the role of the environmental and genetic factors. It seems that environmental and occupational factors in the villages cause a significant increase in the prevalence of astigmatism with age. A high percentage of participants had ATR astigmatism, which was more common at older ages.

Key words: Astigmatism, Iran, Prevalence, Rural

Access this article online

Website: www.meajo.org

DOI: 10.4103/0974-9233.129772

Quick Response Code:

INTRODUCTION

Astigmatism is a refractive error. The prevalence of astigmatism, myopia, and hyperopia, has been reported in numerous studies worldwide.[1-5] Similar to myopia, astigmatism is influenced by genetic and ethnic actors and its prevalence has been reported from 30% among old people in Myanmar to 77% in Indonesia.[6-9] Astigmatism is the most common refractive error in certain countries such as Indonesia,[6] Taiwan,[8] and Japan,[9] and approximately half of the people in these areas suffer from astigmatism. Age, gender, genetics, and even environmental factors have been shown to affect astigmatism in different studies.[1,5,7,9-18] Astigmatism has some major differences compared to myopia and hyperopia. The prevalence of myopia and hyperopia is presented in amount and percentage, however, there are different types of astigmatism mainly related to cornea.

Noor Ophthalmology Research Center, Noor Eye Hospital, Tehran, [1]Department of Optometry, School of Paramedical Sciences, Mashhad University of Medical Sciences, Mashhad, [2]Department of Medicine, Tehran University of Medical Sciences, Tehran, [3]Department of Medicine, Dezful University of Medical Sciences, Dezful, [4]Department of Epidemiology, Faculty of Public Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Corresponding Author: Dr. Mehdi Khabazkhoob, Department of Epidemiology, Shahid Beheshti University of Medical Sciences, Tehran, Iran. E-mail: khabazkhoob@yahoo.com

Therefore, the prevalence of the different types of astigmatism need to be reported. Furthermore, the astigmatic axis is an important indicator of this refractive error which in some cases, is more important than the magnitude of astigmatic power.[12,19]

Few studies have focused solely on the details of astigmatism.[13,20] Although the prevalence of astigmatism has been reported in many studies, fewer studies have investigated the astigmatism axis and corneal astigmatism in addition to the prevalence of astigmatism in a normal population.[11,17,20,21]

In Iran, some studies have reported the prevalence of astigmatism along with myopia and hyperopia.[1,2,5,10,22] Only two studies have reported the prevalence of astigmatism without myopia and hyperopia in Tehran and Shahroud.[11,16] Previous studies[11,16] have reported a relatively high prevalence of astigmatism in Iran. Hence, greater details of astigmatism in an Iranian population can provide valuable information about this refractive error. Furthermore, previous studies have been mostly done in Iranian cities and no reports are available on astigmatism in rural areas of Iran. Therefore, this study investigates the total and corneal astigmatism in a normal rural population of Iran.

MATERIALS AND METHODS

In this cross-sectional study, participants were selected from rural areas of Khaf, Iran, from May to August 2011. The details of the methodology of this study have been previously published.[23]

Briefly, Khaf is located in the north-eastern Iran and has 83 villages. Thirteen villages were selected for this study and all of their residents were investigated. After selecting the villages and based on a predefined schedule, the residents of each village were transported to the central village to be visited by ophthalmologists and optometrists.

Examinations were performed in the Mobile Eye Clinic (Nooravaran salamat), which was equipped with ophthalmic equipment. After making the required arrangements with local authorities, the participants were interviewed and ophthalmic examinations were performed on a previously announced day.

Inclusion and exclusion criteria

Inclusion criteria were the person's consent to participate in the study and being the resident one of the selected villages. Only data from phakic eyes were included for analysis. Individuals with a history of eye surgery, and the persons whose refraction and keratometry were not measured or were measured erroneously were excluded from the study.

Examinations

Optometric examinations

The site for optometric examinations had standard illumination. The first step was auto-refraction and k-reading with the Topcon RM8800 (Topcon Corporation, Tokyo, Japan) for each individual. To verify the accuracy of auto-refraction, refraction (HEINE BETA 200 retinoscope; HEINE Optotechnic, Herrsching, Germany) with trial lenses (MSD, Italy) was performed. The right eye of each subject was tested first followed by the left eye. All study participants underwent a non-cycloplegic refraction. Visual acuity was measured at a distance of 4.5 m with a NIDEK LCD (NIDEK Co. Ltd., Gamagori, Japan). If uncorrected visual acuity of the individual was less than 20/20, subjective refraction was performed.

Ophthalmic examinations

These examinations were performed by two ophthalmologists after optometric examinations. All subjects were underwent an examination including direct and indirect ophthalmoscopy, slit-lamp biomicroscopy (Slit Lamp; Haag-Streit, Koeniz, Switzerland), measurement of intraocular pressure (IOP), and assessment of lens opacities. In this study, two ophthalmologists collaborated with us who were trained for the examination procedures specific to this study.

Definition

Astigmatism was defined as the cylinder power of more than 0.5 D. For investigating the severity of astigmatism, its prevalence was reported based on the cylinder power greater than 1, 2 and 3 D. To analyze the axis of astigmatism, those with astigmatism >0.5 D were included. The astigmatism axis was classified as With-The-Rule (WTR) if the axis was between 150° and 180° or between 0° and 30°, against-the-rule (ATR) if the axis was between 60° and 120° and oblique (OBL) if was at any other meridian. Keratometry results were used to determine corneal astigmatism. This index was the difference between maximum and minimum keratometry.

Statistical analysis

The prevalence of total and corneal astigmatism was reported as percentage with 95% confidence intervals (CI). A multiple logistic regression model was used for investigating the relationship of astigmatism with age, gender and cataract. In this model, astigmatism with cylinder power worse than 0.5 D was defined as the dependent variable. Multiple logistic regression was performed to investigate all variables. A *P* value less than 0.05 was considered statistically significant.

Ethics approval

A written informed consent was obtained from each participant. If the participant was under the legal age, consent was obtained from his/her guardian. The protocol of this study was approved by the review board of Noor Ophthalmology Research Center.

RESULTS

Of 3,475 selected individuals 2,635 participated in the study (response rate 75.8%). After implementing the inclusion

and exclusion criteria, the data of 2124 participants were analyzed of whom 52% were female. The mean (± standard deviation) age of the participants was 32.1(±19.5)-years old (range, 1-90 years).

The prevalence of astigmatism with cylinder power greater than 0.5 D was 32.2% (95% CI: 30.2-34.2). The prevalence of astigmatism was 33.3% and 31.1% in females and males, respectively. Logistic regression did not reveal any significant relationship between the gender and the prevalence of astigmatism ($P = 0.273$). The prevalence of astigmatism increased linearly with age [Table 1]. The prevalence of astigmatism was 14.3% in the participants younger than 15 years of age and showed a significant increase up to 67.2% in the participants over 65-years old; therefore, each 1-year increase in age increased the likelihood of astigmatism by 1.04 times ($P < 0.001$). According to the results of this study, the prevalence of astigmatism with cylinder power more than 1, 2 and 3 D was 15.6% (95% CI: 14.0-17.1), 4.2% (95% CI: 3.3-5.0), and 1.5% (95% CI: 1.3-2.1), respectively. As shown in Table 2, the prevalence of astigmatism with the cylinder power greater than 0.5 D was 14.1% in the participants aged 5-15 years and 53.3% in the participants who were 40 years of age or older.

Figure 1 shows the severity of astigmatism in males and females ($P = 0.278$, Chi-square test).

The prevalence of WTR, ATR, and oblique astigmatism was 11.7% (95% CI: 10.4-13.1), 18.1% (95% CI: 16.5-19.8), and 2.4% (95% CI: 1.7-3.0), respectively. As shown in Figure 2, the prevalence of different types of astigmatism showed significant changes with age. The greatest variation of astigmatism with age was seen in ATR. This type of astigmatism increased from 5.9% in participants under the age of 15 years to 48.2% in participants over 65 years of age ($P < 0.001$). The prevalence of WTR, ATR, and oblique astigmatism was 10.8%, 18% and 2.3% in males and 12.5%, 18.3% and 2.5% in females. There was no significant difference in astigmatism between males and females ($P = 0.612$, Chi-square test).

Table 2 presents the minimum, maximum and average k-readings. The mean k was 43.44 D (95% CI: 43.35-43.53) in all participants, 42.99 D (95% CI: 42.87-43.12) in males, and 43.86 D (95% CI: 43.74-43.98) in females. The mean k was significantly higher in females than males ($P < 0.001$). No significant difference in mean k was found among different age groups ($P = 0.558$). Based on the results of this study, the mean k was greater than

Table 1: Prevalence of astigmatism based on cylinder powers of 0.5, 1, 2, and 3 dioptre according to age and gender

Age	Cylinder power>0.5 D	Cylinder power>1 D	Cylinder power>2 D	Cylinder power>3 D
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)
<=15	14.3 (11.0-17.5)	4.2 (2.3-6.0)	1.3 (0.3-2.4)	0.4 (-0.2-1)
16-25	20.1 (16.5-23.8)	7.5 (5.1-9.9)	1.7 (0.5-2.9)	0.4 (-0.2-1)
26-35	28.9 (24.4-33.3)	11.9 (8.7-15.1)	2.3 (0.8-3.8)	0.8 (-0.1-1.6)
36-45	38.9 (33.1-44.7)	18.5 (13.9-23.2)	4.7 (2.2-7.3)	1.5 (0.0-2.9)
46-55	47.8 (41.4-54.3)	20.3 (15.0-25.5)	5.6 (2.6-8.6)	2.2 (0.3-4.0)
56-65	65.5 (57.6-73.4)	41.5 (33.3-49.8)	10.6 (5.4-15.7)	4.9 (1.3-8.5)
65+	67.2 (59.2-75.1)	48.2 (39.7-56.6)	16.1 (9.8-22.3)	7.3 (2.9-11.7)
5 to 15	14.1 (10.6-17.7)	4.1 (2.0-6.1)	1.4 (0.2-2.5)	0.5 (-0.2-1.3)
40+	53.5 (49.7-57.3)	30.2 (26.7-33.7)	8.8 (6.6-10.9)	3.6 (2.2-5.1)
Female	33.3 (30.5-36.1)	15.7 (13.6-17.9)	4.4 (3.2-5.6)	1.9 (1.1-2.7)
Male	31.1 (28.3-34.0)	15.5 (13.2-17.7)	4.0 (2.8-5.2)	1.2 (0.5-1.8)
Total	32.2 (30.2-34.2)	15.6 (14-17.1)	4.2 (3.3-5.0)	1.6 (1-2.1)

D:Dioptre, CI: Confidence intervals, 95%CI denotes 95% Confidence intervals

Table 2: Minimum, maximum and mean keratometry-readings and corneal astigmatism in different studies

Age	Minimum keratometry (diopter)	Maximum keratometry (diopter)	Mean keratometry (diopter)	Corneal astigmatism (diopter)
	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)	Mean (95% CI)
<=15	43.19 (43.01-43.37)	43.70 (43.51-43.89)	43.45 (43.27-43.63)	0.51 (0.45-0.57)
16-25	43.12 (42.93-43.31)	43.65 (43.46-43.84)	43.39 (43.20-43.58)	0.53 (0.49-0.58)
26-35	43.20 (42.99-43.41)	43.83 (43.59-44.06)	43.51 (43.30-43.73)	0.62 (0.53-0.72)
36-45	43.12 (42.87-43.37)	43.81 (43.54-44.09)	43.47 (43.21-43.73)	0.68 (0.60-0.76)
46-55	42.86 (42.60-43.12)	43.64 (43.39-43.89)	43.25 (43.00-43.49)	0.76 (0.66-0.87)
56-65	42.88 (42.51-43.24)	44.01 (43.64-44.37)	43.44 (43.09-43.79)	1.14 (0.92-1.36)
65+	42.81 (42.46-43.17)	44.51 (44.17-44.85)	43.66 (43.34-43.99)	1.68 (1.41-1.94)
Female	43.49 (43.37-43.61)	44.23 (44.11-44.36)	43.86 (43.74-43.98)	0.74 (0.68-0.80)
Male	42.63 (42.50-42.76)	43.36 (43.23-43.49)	42.99 (42.87-43.12)	0.72 (0.66-0.78)
Total	43.07 (42.98-43.16)	43.81 (43.72-43.90)	43.44 (43.35-43.53)	0.73 (0.69-0.77)

CI: Confidence intervals, 95%CI denotes 95% Confidence intervals

47 D in 1.3% of the participants. The mean corneal astigmatism was 0.73 D (95% CI: 0.69-0.77) with no significant difference between males and females ($P = 0.570$). Corneal astigmatism showed a significant linear increase, from 0.51 D in individuals aged below 15 years to 1.68 D in the participants above 65 years of age, with age ($P < 0.001$) [Table 2]. Figure 3 shows the prevalence of different types of corneal astigmatism in the participants with corneal astigmatism more than 0.5 D. According to this figure, WTR astigmatism decreased and ATR astigmatism increased with age ($P < 0.001$).

DISCUSSION

To our knowledge, this the first published study that investigated the prevalence of astigmatism in a rural Iranian population. Additionally, few studies worldwide have focused on the prevalence of astigmatism in an extended age group similar to our study. The prevalence of astigmatism with the cylinder power greater than 0.5 D was 32.2%. There was considerable variation in the different age groups and the lowest and highest prevalence of astigmatism was observed among the participants below 15 years of age and over 65 years of age, respectively. We have attempted to compare these results with those of other studies with similar equal age groups; however, there are very few studies on all the age groups.

The prevalence of astigmatism in the participants who were 5-15 years old was 14.1%. This age group is the most frequently investigated group in most studies. The results of other studies are summarized in Table 3. The lowest and highest prevalence of astigmatism were reported in Nepal[24] (3.5%) and China[25] (42.7%), respectively, using the same definition. According to the studies conducted in Iran, the prevalence of astigmatism varies from 11.3% in Shiraz[1] to 18.7% in Dezful.[12] Comparison of these results with the results of other studies conducted in Iran reveals that the mean prevalence of astigmatism in children aged 5-15 years who live in rural areas of Khaf was mid-range. Nonetheless, in comparison with the studies conducted in other parts of the world such as China and other East Asian countries [Table 3], the prevalence of astigmatism in children in this study was not high. Based on the previous studies, it has been proven that genetic and even ethnic factors affect astigmatism.[18] Therefore, the difference between the findings of the present study and other studies performed in this age group in Iran can be justified by ethnic and genetic differences. Nevertheless, our findings for the participants over 40 years of age were significant. In contrast to children, the prevalence of astigmatism was high among middle-aged and elderly participants. The prevalence of astigmatism among the participants over 40 years of age was 53.5% and increased up to 67% in the participants over 65-years old. This finding was not expectable when compared with other studies conducted in similar age groups. According to Figure 4, the prevalence of astigmatism with the same definition as our study varied from 30.6% in people over 40-years old in Myanmar[15] to 77%

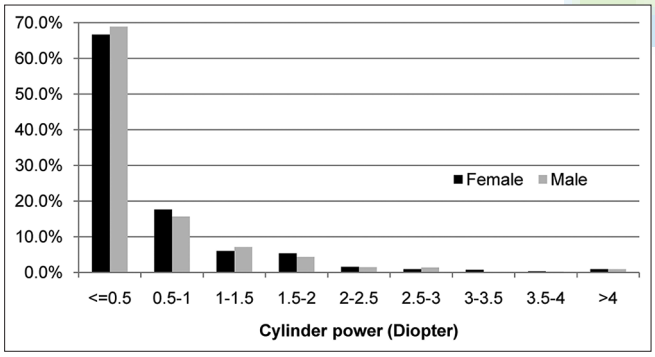

Figure 1: The severity of astigmatism in males and females

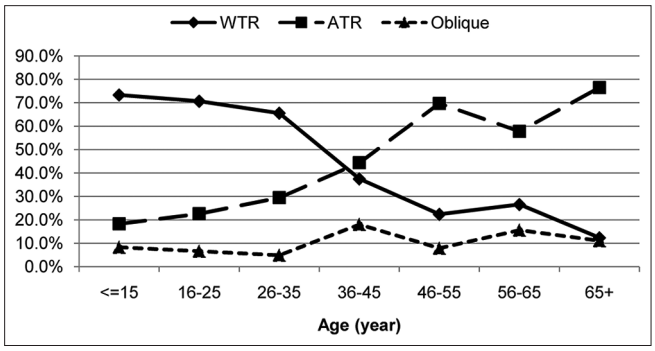

Figure 3: Types of corneal astigmatism in different age groups

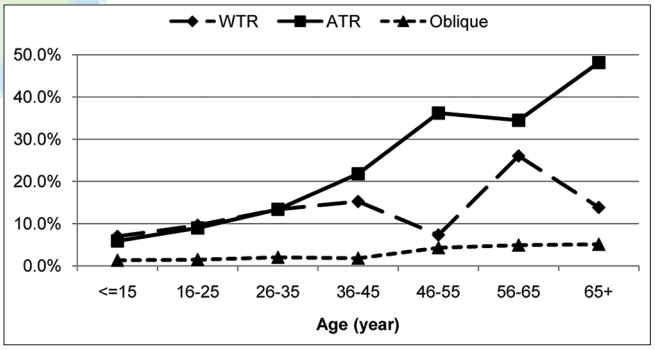

Figure 2: The prevalence of the different types of total astigmatism in different age groups

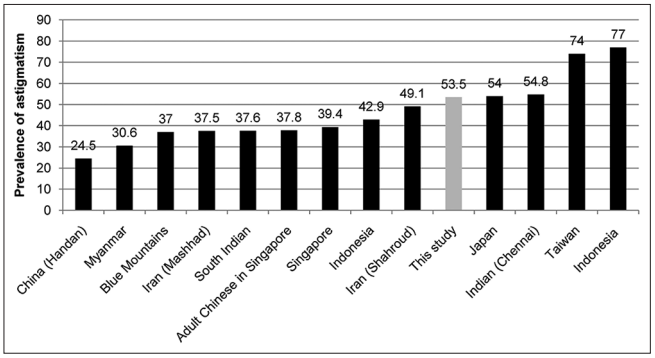

Figure 4: The prevalence of astigmatism with cylinder power more than 0.5 D in individuals over 40-years old in different studies

Table 3: The prevalence of astigmatism in children in different studies worldwide

Country	Age (years)	Astigmatism (%)
Nepal[24]	5-15	3.5
India (rural)[38]	7-15	9.7
China[39]	5-15	10.0
South Africa[40]	5-15	14.6
India (New Delhi)[41]	5-15	14.6
Malaysia (Gombak)[42]	7-15	21.3
Chile[43]	5-15	27.0
China (Guangzhou)[44]	5-15	33.6
Iran (Dezful)[45]	7-15	18.7
Iran (Shiraz)[1]	7-15	11.3
China (southern)[25]	5-15	42.7
Iran (northeast)[5]	6-17	11.5
Iran (Khafs rurals)	5-15	14.1

in people over 50-years old in Indonesia.[6] The prevalence of astigmatism in this study was even higher as compared to other studies in Iran; the prevalence of astigmatism was reported to be 49.1% and 37.5% in the middle-age and elderly residents of Shahroud[11] and Mashhad[2], respectively. Since the prevalence of astigmatism was low in children, the high prevalence of astigmatism in the middle-aged participants can be affected by factors other than ethnicity and genetics. Considering the fact that most of the participants in this study were farmers and ranchers, and environmental conditions such as dirt, dust, and sun cause more eye rubbing and also more squinting due to more sunlight, it seems that these factors have considerable effects on the prevalence of astigmatism in this rural age group. In this study, the prevalence of astigmatism did not show a significant difference between genders in different age groups. However, contradictory results have been reported in the literature.[4,8,9,15] For example, Sawada *et al*.,[9] in Japan, Wong *et al*.,[26] among the Chinese living in Singapore, Krishnaiah *et al*.,[27] in India, Gupta *et al*.,[15] in Myanmar, Cheng *et al*.,[8] in Taiwan and Saw *et al*.,[4] in Singapore did not find any differences in the prevalence of astigmatism between males and females. Also, some reports from Beijing[3] and Bangladesh[28] have shown the prevalence of astigmatism was higher among females than males. However, Nanjia *et al*.,[29] in India and Saw *et al*.,[6] in Indonesia reported the prevalence of astigmatism was higher in males when compared to females.

The prevalence of astigmatism increased considerably with age, which concurs with previous studies.[11,26] Some prospective studies[30,31] have reported that the cylinder power significantly increases with age over time. In the present study, most of the changes in astigmatism can be justified by environmental factors in the elderly and the greater exposure to these conditions as compared to children. However, corneal changes with age is another explanation for the increase in the prevalence of astigmatism the elderly, which has been confirmed by Asgari[32] and Asano.[33]

The current study found that ATR astigmatism was the most frequent among the participants and that the prevalence of this type of astigmatism significantly increased with age. Previous studies have also shown that ATR astigmatism increases with age.[4,11,19,33]

Variations of astigmatism with age show that immediately after birth, newborns have ATR astigmatism which shifts toward WTR astigmatism at the beginning of childhood up to almost 20 years old. Then, it remains almost unchanged up to the 4th decade of life and subsequently changes towards ATR.[18] The decrease in the eyelid pressure due to weakness of the eye muscles is one of the most important factors that change the type of astigmatism with age. This finding has been confirmed in previous studies.[34]

In the current study, the mean keratometry was 43.44 D, which concurs with results from previous studies.[35-37] Since the power of the cornea has been measured by different devices in different studies, comparison of the results is tenuous at best. However, the results were not considerably different for keratometry between the current study and previous studies. The mean corneal astigmatism was 0.73 D in this study, which was a little lower than the findings of other similar studies.[35,36]

Nevertheless, in age groups, the mean corneal astigmatism considerably increased in such a way that the difference in corneal astigmatism between participants under 15 and over 65-years old was 1 D. This finding supported the previous hypothesis concerning the effect of environmental factors on the cornea.[18] This finding was also in agreement with the findings of Asano *et al*.,[33] and Asgari,[32] who reported that changes in astigmatism at an older age are mostly due to corneal changes.

The axis of corneal astigmatism was similar to total astigmatism. In this type of astigmatism, the increase in ATR astigmatism and decrease in WTR astigmatism with age were even more significant than total astigmatism. This finding shows that major changes in the axis of refractive astigmatism follow the axis of corneal astigmatism. This finding confirms that with age, the effect of eyelid pressure on the cornea decreases.

The limitations of this study were sampling in a certain rural area of Iran, which limits generalizing the results to all Iranian villages, and the high non-response rate which may be accompanied by selection bias.

CONCLUSIONS

Attention must be paid to astigmatism in villages due to the high prevalence. Further studies to explore the roles of genetics and environment are suggested. It seems that environmental and occupational factors in the villages cause a significant increase in the prevalence of astigmatism with age. A high percentage of participants had ATR astigmatism, which was more common at older ages. Corneal astigmatism was rather similar to total astigmatism in all age groups.

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Cite this article as: Hashemi H, Rezvan F, Yekta AA, Hashemi M, Norouzirad R, Khabazkhoob M. The prevalence of astigmatism and its determinants in a rural population of Iran: The "Nooravaran Salamat" mobile eye clinic experience. Middle East Afr J Ophthalmol 2014;21:175-81.

Source of Support: Noor Ophthalmology Research Center, **Conflict of Interest:** None declared.