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Prevalence of Astigmatism in 4- to 6-Year-Old Population of Mashhad, Iran

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Background: Astigmatism is a correctable cause of visual impairment in childhood. It increases the incidence of amblyopia in children.
Objectives: In this report, we intended to describe the prevalence of the amount and axis of astigmatism, astigmatism components, and associations of astigmatism with age, gender and spherical equivalent in under six years old children through a population-based study.
Patients and Methods: This report was a part of the cross-sectional Mashhad Eye Study in which 3675 of 4-6 years old children in Mashhad kindergartens were selected through random cluster sampling, of which, 3701 participated in the study (response rate: 98.3%). Refractive astigmatism was determined using a retinoscope (HEINE BETA-200, Germany) and defined as a cylinder power of more than 0.5 diopter (D). Corneal astigmatism was measured using Pentacam (Oculus Optikgerate GmbH, Germany).
Results: The prevalence of refractive astigmatism of more than 0.5D in at least one eye was 51.4% (95% confidence interval (CI): 50.7-52.1); 52.1% in girls and 50.7% in boys (P = 0.412). Prevalence of astigmatism decreased with age, but not statistically significant (odds ratio: 0.97; 95% CI: 0.87-1.07). Mean corneal astigmatism was 1.01 D (95% CI: 0.99-1.03); 1.00 D (95% CI: 0.98-1.02) and 1.02 D (95% CI: 1.00-1.04) in girls and boys, respectively (P = 0.243). Mean corneal astigmatism was not significantly different between different age groups (P = 0.410).
Conclusions: The prevalence of astigmatism was high in children under six years old in this study, and to control amblyopia, it is necessary to consider astigmatism at younger ages.

Keywords: Prevalence; Astigmatism; Children; Population- Based Planning

1. Background

Astigmatism is a refractive error measured in the form of total and corneal astigmatism. The importance of astigmatism in children lies in the fact that it is a correctable cause of visual impairment in these ages, and whether it coexists with spherical error (1). In addition, astigmatism increases the incidence of amblyopia in children, and even treatment results are affected by the type of astigmatism (2-4). Amblyopia is defined as a reduction of best corrected visual acuity to 20/30 or less in one eye or 2-line interocular optotype acuity differences in the absence of pathological causes. To better understand the development and progression of astigmatism, it is important to have knowledge of distribution of astigmatism and associations among its components.

2. Objectives

In Iran, a high prevalence of astigmatism has been reported in different populations with average ages of about 51 years (5), 32 years (6, 7) and 12 years (8). To our knowledge, no population-based study has been conducted on children under six years old and data on the amount and axis of astigmatism is not available in this age group. In this report, we intended to describe the prevalence of the amount and axis of astigmatism, astigmatism components and associations of astigmatism with age, gender and spherical equivalent in children under six years old through a population-based study.

3. Patients and Methods

This report was a part of a cross-sectional study conducted in 2011 on 3765 four to six years old children in the city of Mashhad, which is the second most populous city in Iran and the capital of Khorasan Razavi province in the north east of the country. For sampling, we obtained a list of kindergartens and the number of 4-6 years old children from the Office of Education and Development. Kindergartens were selected as cluster heads and random cluster sampling was performed considering the number of children in each given kindergarten in proportion to all kindergartens. Randomization was performed using Microsoft Excel software. Inclusion criteria were not having any kind of eye disease or systemic disease affecting vision.

Children's demographics were extracted from their

records. Uncorrected (UCVA) and best corrected (BCVA) visual acuity were tested using the Snellen chart. Refraction was determined with a retinoscope (HEINE BETA-200, Germany). Astigmatism was defined as a cylinder power more than 0.5 diopter (D). Since refractive astigmatism is indicative of cylinder error of both the cornea and the lens, we assessed corneal astigmatism separately using Pentacam (Oculus Optikgerate GmbH, Germany). The Pentacam HR is a computerized corneal topographer, which displays simulated keratometry readings in flat and steep axes equivalent to the maximum keratometry (max-K) and minimum keratometry (min-K), respectively. By definition, keratometry is the measurement of the curvature of the cornea, which can be converted to the refractive power of the cornea. In the analysis, astigmatism was categorized in three groups by axis as with-the rule (WTR) (0 ± 30^{o}), against-the-rule (ATR) (90 ± 30^{o}) and oblique (other cases).

The prevalence of astigmatism, as a cylinder power of more than 0.5 D in at least one eye, was described in percentages and 95% confidence intervals (CI). In light of the high correlation between keratometry in the two eyes (r = 0.987), we used right eye data in studying corneal astigmatism. Corneal astigmatism was derived from the difference between max-K and min-K. We used chi-square test, one-way ANOVA and independent sample t test in the analyses. We considered 0.05 as the level of significance, and applied a correction coefficient of 1.25 for cluster sampling. In analyzing and calculating the 95% CI, which was performed using the STATA software version 11, adjustments for the design effect of cluster sampling were applied.

The study adhered to the tenets of the Declaration of Helsinki at all stages. Signed consents were obtained from children's parents and children with no parental consent were excluded from the study. The Ethics Committee of Mashhad University of Medical Sciences approved this study.

4. Results

Of 3765 selected children, 3701 participated in the study (response rate: 98.3%). One thousand and 900 of them were boys (51.3%). The mean age of study participants was 5.09 ± 0.63 years. Visual acuity was 8/10 or better bilaterally in 91.7% of the children (91.6% of boys and 91.8% of girls). Regarding parents' level of education, a high school diploma/associate degree was the most frequent (47.6% of mothers and 41.9% of fathers), followed by a bachelor's degree (41.1% of mothers and 40.9% of fathers).

The prevalence of astigmatism was 51.4% (95% CI: 50.7-52.1). Astigmatism decreased with age, but not statistically significant (odds ratio: 0.97; 95% CI: 0.87-1.07). The prevalence of astigmatism was 52.1% in girls and 50.7% in boys (P = 0.433). The prevalence rates of astigmatism more than 1.0, 2.0 and 3.0 D in at least one eye were 16.3% (95% CI: 15.7-16.9), 3.6% (95% CI: 3.3-3.9) and 1.1% (95% CI: 0.9-1.3), respectively. Table 1 demonstrates the prevalence of astigmatism by age and gender.

Based on the analysis, age-related axis changes were not statistically significant (P = 0.119). We used logistic regression to examine inter-sex differences in the prevalence of three general orientations of astigmatism, and the oblique axis was taken as baseline. WTR was more common in boys (OR = 1.26, P = 0.016), but ATR showed no significant inter-gender difference.

Overall, the prevalence rates of WTR, ATR and oblique astigmatism were 71.3% (95% CI: 70.6-72.0), 19.5% (95% CI: 18.8-20.2) and 9.3% (95% CI: 8.8-9.8), respectively. Table 2 shows the prevalence of astigmatism axes by age and gender.

Mean max-K, min-K and corneal astigmatism in the studied sample were 44.15 D (95% CI: 44.10-44.19), 43.13 D (95% CI: 44.08-44.18) and 1.01 D (95% CI: 0.99-1.03), respectively. Mean corneal astigmatism did not significantly differ between the age groups (P = 0.410). Mean corneal astigmatism was 1.00 D (95% CI: 0.98-1.02) in girls and 1.02 D (95% CI: 1.00-1.04) in boys (P = 0.243). In this sample, the prevalence of corneal astigmatism > 0.5 D, > 1.0 D and > 2.0 D was 86.0% (95% CI: 85.4-86.6), and the prevalence of corneal astigmatism > 3.0 D was 2.1% (95% CI: 1.8-2.4) (Table 3).

Table 1. Prevalence (Percentage and 95% Confidence Intervals) of Astigmatism by Age and Gender in 4- to 6-Year Old Children

Astigmatism	> 0.5 D	> 1.0 D	> 2.0 D	> 3.0 D
Age, yr				
4-4.5	52.1 (51.3-52.9)	17.0 (16.4-17.6)	4.4 (4.1-4.7)	0.8 (0.7-0.9)
4.5-5	51.4 (50.6-52.2)	17.4 (16.8-18.0)	4.6 (4.3-4.9)	1.3 (1.1-1.5)
5-5.5	53.7 (52.9-54.5)	14.4 (13.8-15.0)	2.2 (2.0-2.4)	1.2 (1.0-1.4)
5.5-6	48.9 (48.1-49.7)	15.7 (15.1-16.3)	2.9 (2.6-3.2)	1.0 (0.8-1.2)
P value [a]	0.237	0.301	0.106	0.640
Gender				
Female	52.0 (51.2-52.8)	16.4 (15.8-17.0)	3.8 (3.5-4.1)	0.8 (0.7-0.9)
Male	50.7 (49.9-51.5)	16.2 (15.6-16.8)	3.5 (3.2-3.8)	1.4 (1.2-1.6)
P value [b]	0.433	0.864	0.626	0.119

[a] Based on fisher's exact test.
[b] Based on Chi square test.

Table 2. Prevalence (Percentage and 95% Confidence Intervals) of Astigmatism Axes by Age and Gender in 4- to 6-Year Old Children [a]

Age, yr	WTR	ATR	Oblique
4-4.5			
Male	67.6 (66.8-68.4)	21.0 (20.3-21.7)	11.4 (10.9-11.9)
Female	62.4 (61.6-63.2)	23.1 (22.4-23.8)	14.6 (14.0-15.2)
4.5-5			
Male	65.1 (64.3-65.9)	19.4 (18.8-20.0)	15.5 (14.9-16.1)
Female	57.2 (56.4-58.0)	26.3 (25.6-27.0)	16.5 (15.9-17.1)
5-5.5			
Male	63.4 (62.6-64.2)	24.1 (23.4-24.8)	12.5 (12.0-13.0)
Female	57.5 (56.7-58.3)	27.3 (26.6-28.0)	15.2 (14.6-15.8)
5.5-6			
Male	63.8 (63.0-64.6)	23.0 (22.3-23.7)	13.3 (12.7-13.9)
Female	58.0 (57.2-58.8)	27.7 (27.0-28.4)	14.4 (13.8-15.0)

[a] Abbreviations: ATR: against the rule, WTR: with the rule.

Table 3. Prevalence (Mean and 95% Confidence Intervals) of Maximum Keratometry, Minimum Keratometry and Corneal Astigmatism by Age and Gender in 4- to 6-Year Old Children

Variables	Maximum Keratometry	Minimum Keratometry	Corneal Astigmatism
Age, yr			
4-4.5	44.30 (44.20-44.40)	43.24 (43.14-43.34)	1.06 (1.01-1.10)
4.5-5	44.16 (44.07-44.24)	43.13 (43.05-43.21)	1.02 (0.98-1.06)
5-5.5	44.05 (43.94-44.15)	43.09 (42.98-43.19)	0.96 (0.91-1.01)
5.5-6	44.08 (43.99-44.18)	43.09 (43.00-43.18)	0.99 (0.95-1.04)
P value [a]	44.30 (44.20-44.40)	43.24 (43.14-43.34)	1.06 (1.01-1.10)
Gender			
Female	44.33 (44.23-44.43)	43.34 (43.24-43.44)	1.00 (0.95-1.04)
Male	43.97 (43.87-44.07)	42.94 (42.85-43.04)	1.02 (0.98-1.07)
P value [b]	0.112	0.203	0.243

[a] Based on fisher's exact test.
[b] Based on Chi square test.

5. Discussion

Astigmatism is one of the most common refractive errors, which is highly prevalent in infancy (9-11) and quickly decreases with growth (12). Uncorrected astigmatism has been shown to be associated with myopia progression as the child grows (13-15). In addition, the blur caused by uncorrected astigmatism can lead to amblyopia, and despite optical correction or emmetropization, amblyopia continues to exist (16, 17). In a review study by Chou et al. (18), astigmatism more than 1.5 D was presented as a risk factor of amblyopia. This is while refractive errors, including astigmatism, can be simply corrected with eyeglasses to stop their progression or development into amblyopia. In our sample, 3.6% had refractive astigmatism more than 2.0 D and 9.2% had corneal astigmatism more than 2.0 D. Two population-based studies in Iran reported prevalence rates of 3.5% (19) and 4% (20) for amblyopia among seven year olds. These rates highlight the importance of considering astigmatism in children even more than before.

According to the present study, the prevalence rates of refractive astigmatism and corneal astigmatism more than 0.5 D were 51.4% and 86.0% in 4-6 years old children in Mashhad. As shown in Table 4, the prevalence of refractive astigmatism was higher than corneal astigmatism in this age group, and WTR astigmatism was the predominant type. In our study and two studies in China (21, 22), the prevalence of astigmatism was higher than Australian population (23). This is while inter-study differences in age were subtle. Race and population differences could be the causes of such difference. The effect of ethnicity on the incidence of refractive errors has been reported by Huynh et al. (23). Their study showed that

Table 4. Prevalence of Astigmatism and Its Types in Under Six Years Age Group in Selected Populations [a]

Author, yr	Country	Sample size	Sample age, yr	Astigmatism, D	Prevalence, %	Prevalence of type of astigmatism, %
Xiao, 2014 (22)	China	2304	3-6	RA ≥ 1.25	12.7	WTR 82.9%, ATR 12.6%, Oblique 4.5%
Harvey, 2011 (10)	US	1235	0.5-8	CA ≥ 1	78.3	WTR 91.4%, ATR 1.3%, Oblique 7.2%
Gwiazda, 1984 (30)	UK	1000	0-6	RA ≥ 1	39.0	NR
Fan, 2004 (21)	China	522	2.2-6.4	RA ≥ 1	21.1	WTR 53.0%, ATR 7.9%, Oblique 39.1%
Huynh, 2006 (23)	Australia	1765	6-7	RA ≥ 1	4.8	WTR 31.6%, ATR 28.7%, Oblique 39.1%
				RA ≥ 0.5	22.6	
				CA ≥ 1	27.7	
				CA ≥ 0.5	74.9	
Current study	Iran	3701	4-6	RA ≥ 1	16.3	WTR 71.3%, ATR 19.5%, Oblique 9.3%
				RA ≥ 0.5	51.4	
				CA ≥ 1	52.6	
				CA ≥ 0.5	86.0	

[a] Abbreviations: WTR: with the rule; ATR: against the rule; CA: corneal astigmatism; RA: refractive astigmatism.

mean refractive and corneal astigmatism was higher in East Asian and South Asian children compared to European children. (23) The prevalence of corneal astigmatism was lower than the US population (10) and higher than the Australian population (23). This type of astigmatism was measured with Pentacam in our study, with IK4 in the study by Harvey et al. (10), and with IOL Master in the study by Huynh et al. (23). As studies demonstrated, keratometry readings measured with these devices are not interchangeable (24-27) and this could be the reason for different results.

As shown in Table 4, WTR astigmatism was the most prevalent type in this age group in all populations. The second most prevalent type was ATR in some studies (the present study and the study by Xiao et al. (22)), and oblique in some other studies (10, 21, 23). Age-related astigmatism axis change has been reported in various populations; this has been attributed to decreased lid tension, corneal flattening and rotation of the horizontal axis to the vertical orientation (6, 28-30). Axis changes were not statistically significant in our study due to the limited age range (2 years), but could be observed if a wider age range was studied or maybe axis rotation in this age group is too subtle to be detected compared to other ages. Harvey et al. (10) demonstrated that the prevalence of WTR astigmatism increases up to the age of six years, and decreases thereafter up to the age of eight years, while the prevalence of oblique astigmatism increases. The prevalence of ATR, however, was very low and remained constant. Comparison of results raises the question whether axis rotation happens faster in our population and that WTR passes oblique at six years of age and reaches ATR. Further studies are needed to examine this issue.

Similar to the study by Huynh et al. (23), both the prevalence and average corneal astigmatism were higher than RA in our study. This could be because compensation between corneal astigmatism and internal astigmatism reduces the amount of refractive astigmatism. However, vector analysis would be necessary to confirm this.

In conclusion, the prevalence of astigmatism in our population was higher than other populations and astigmatism axis rotation probably occurs faster than some populations. In addition, it is necessary to consider astigmatism at younger ages to control amblyopia, especially considering the 1.9% prevalence of amblyopia in the seven-year-old population of the country (31).

Authors' Contributions

Study concept and design: Hassan Hashemi, Abbas Ali Yekta, Hadi Ostadimoghaddam; data collection: Batool Haghighi, Sara Soroush, Hava Shafiee, statistical analysis and interpretation of data: Soheila Asgari, Mehdi Khabazkhoob, drafting of the manuscript: Soheila Asgari, Mehdi Khabazkhoob, critical revision: Hassan Hashemi, Abbas Ali Yekta, Hadi Ostadimoghaddam, administrative, technical and material supports: Hassan Hashemi, Abbas Ali Yekta, Hadi Ostadimoghaddam, study supervision: Hassan Hashemi, Abbas Ali Yekta.

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