

## ORIGINAL ARTICLE

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# Refractive errors in Filipino eyes in a single-center study population

## ABSTRACT

### Objective

We determined the frequency of refractive errors among Filipino patients undergoing refractive or cataract screening at an ambulatory eye-care center, correlated them with demographic and ophthalmic variables, and compared refractive and keratometric astigmatism.

### Methods

Clinical records of 666 consecutive patients who had optical interferometry were reviewed and the demographic and clinical parameters obtained were subjected to statistical analyses.

### Results

The mean axial length (AL) was  $24.43 \pm 1.56$  mm, significantly shorter among females ( $p < 0.001$ ). Axial length (AL) was also inversely correlated with age ( $r = -0.50$ ). Mean sphere was  $-1.3 \pm 3.4D$ , and correlated with age ( $r = 0.57$ ); younger age groups had higher negative values. Myopia was the major refractive-error type (90 to 100%) in the 17- to 30-year-old age bracket. Hyperopia was the predominant refractive error (50 to 75%) among the elderly. The mean keratometry reading was  $44 \pm 1.5D$ . Females had steeper K readings than males ( $p = 0.000$ ). Refractive astigmatism was observed in 47.88% and keratometric astigmatism in 71.7%. Against-the-rule (ATR) was the prevalent type (46.1%) in refractive astigmatism and with-the-rule (WTR) (59.1%) in keratometric astigmatism.

### Conclusion

In the older population, AL was shorter and hyperopia was more prevalent; in the younger population, myopia was more prevalent. Astigmatism did not differ between gender groups but differed among age groups. WTR astigmatism was more prevalent in the younger age group and ATR in the elderly.

**Keywords:** *Refractive error, Astigmatism, Myopia, Hyperopia*

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ACCORDING to the World Health Organization's (WHO) "Global Initiative for the Elimination of Avoidable Blindness 2020" (Vision 2020), errors of refraction accounted for 18% of visual disability, next to cataract (39%), and that "reversing or treating these refractive errors greatly decreased the number of subjects with visual disability".<sup>1</sup> Awareness of the frequency of refractive errors is, therefore, a crucial step in the Vision 2020's goal of eliminating refractive-error-related visual disability.

Locally, there are few published reports on the prevalence of refractive errors. We, therefore, determined the frequency of refractive errors in an ambulatory-care center and assessed the refractive status of patients using axial length measurements by optical interferometry<sup>2</sup> and corneal power by automated keratometry. These were compared with the manifest refraction (retinoscopy) of the patients. We also correlated them with demographic and other ophthalmic variables, and compared refractive and keratometric astigmatism.

### METHODOLOGY

This is a retrospective study involving 1,332 eyes of 666 consecutive patients who underwent refractive or cataract screening and optical biometry (IOL Master, Carl Zeiss Meditec, Jena, Germany) measurements from March to October 2008. Patients who could not physically undergo optical biometry or manifest refraction were excluded. The manifest refraction of each patient using the retinoscopy technique for best-corrected visual acuity was retrieved from the clinical record.

The following data were obtained: age and gender, axial length, manifest refraction, type of refractive error, corneal power, refractive (by manifest refraction) and keratometric astigmatism (by IOL Master), and axis of astigmatism (refractive and keratometric).

Manifest refraction was measured using retinoscopy where sphere, cylinder (measured in negative cylinders), and axis were noted. Spherical equivalent (SE) was calculated as sphere plus half the cylinder power. Presence of anisometropia, defined as SE of >1D between the right and left eyes, was noted. The types of refractive errors were classified as follows: myopia with SE  $\geq -0.50$ D, hyperopia with SE  $\geq +0.50$ D, and emmetropia with SE  $\pm 0.25$ D.

Eyes with and without astigmatism were noted. Astigmatism was defined as >0.50D measured in two ways: (1) Refractive – by the cylinder obtained in the retinoscopic manifest refraction (MR-astigmatism), and (2) Keratometric – by calculating the difference between the steepest and flattest keratometric readings obtained by the IOL Master (IM-astigmatism). The axis of astigmatism was determined by manifest refraction (MR-axis) and by the axis of the flattest K as measured by the IOL Master (IM-axis). With-the-rule (WTR) astigmatism occurred when

the axis was at  $0 \pm 15^\circ$ , against-the-rule (ATR) when the axis was at  $90 \pm 15^\circ$ , oblique astigmatism (OA) when the axis was within  $20^\circ$  to  $70^\circ$  and  $110$  to  $160^\circ$ .

Data were stored in Excel (Microsoft Corp, Redmond WA, USA) and transferred to Statistical Package for the Social Sciences (SPSS) version 16 for statistical analyses. Descriptive statistics, bivariate correlation study (Spearman's), parametric and nonparametric tests for independent samples were used to compare values depending on whether the distribution was Gaussian (t-test) or non-Gaussian (Mann-Whitney). The statistical level of significance was  $p < 0.05$ .

### RESULTS

A total of 1,332 eyes of 666 patients (276 males and 390 females) were included in the study. The mean age was  $52 \pm 18$  years. Of the 666 pairs of eyes, 13% had anisometropia with a mean dioptric difference of 3.13D between each pair of anisometropic eyes (Table 1). Anisometropia was observed in 12% of males and 15% of females. However, this gender difference was not statistically significant.

#### Mean Axial Length

The mean axial length was  $24.43 \pm 1.56$  mm for the entire study population. The axial length between males (24.67 mm) and females (24.46 mm) was statistically different ( $p < 0.001$ ) (Table 2), with the male population

Table 1. Prevalence of anisometropia by gender.

	Male	Female	Total	p
Prevalence (%)	12	15	27	
Standard Deviation	1.86	1.86		
Confidence	0.63	0.82		
<b>Dioptric difference</b>				0.38 <sup>a</sup>
Mean	3.13 $\pm$ 1.86D	3.13 $\pm$ 3.16D		
Range	1.5 to 8.75	1.5 to 8.75	1.5 to 8.75	

<sup>a</sup>Mann-Whitney test for independent samples between men and women

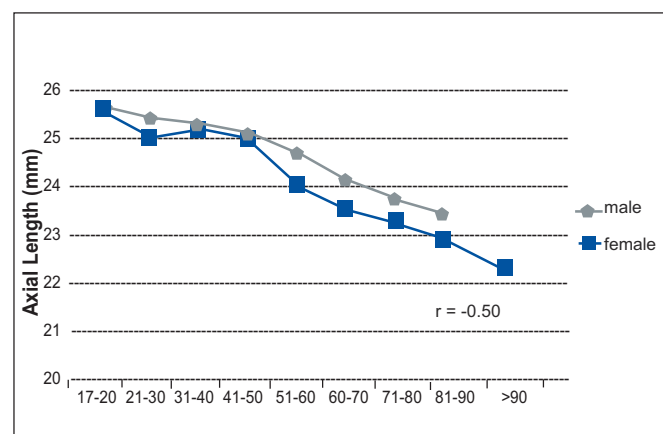


Figure 1. Axial-length measurements by gender and age groups.

having a longer axial length. A statistically significant negative correlation ( $r = -0.50$ ) between axial length and age was present; as the age increased, there was a decrease in measured axial length (Figure 1). This correlation was similar for each gender group.

### Manifest Refraction

#### Mean Sphere

The mean sphere was  $-1.3D$  for the entire population (Table 2). There was a positive correlation between spherical diopter and age ( $r = 0.57$ ,  $p < 0.001$ ); more plus spheres were frequent in the middle-aged and the elderly (Figure 2). A similar correlation when matched for gender and age was present.

Myopia was more frequent in the younger age group while hyperopia increased with age and became the predominant refractive error (50 to 75%) in the elderly group.

#### Mean Cylinder

The mean cylinder power was  $-0.81D$  for the entire population;  $-0.79D$  for males and  $-0.81D$  for females. The difference between the 2 groups was not significant ( $p = 0.56$ ). However, there was a negative correlation between cylindrical power and age ( $r = -0.17$ ;  $p < 0.001$ ; Table 2) in the entire population; the cylinder lessened among the middle aged group and then increased in the elderly group (Figure 3). This correlation remained when gender-specific-age match was done (Table 2).

### Corneal Power/Keratometry (K)

#### Flattest K

The mean flattest K was  $43.5D$  for the entire population,  $43.37D$  for males, and  $43.67D$  for females. The difference between the 2 groups was significant ( $p < 0.001$ ), with females having a flatter keratometry reading. Age also showed a positive correlation with K measurements higher with age ( $r = 0.10$ ,  $p < 0.001$ ) and significant

Table 2. Clinical parameters and correlation of age with different parameters by gender.

Parameter	Mean	Range	p	Correlation
<b>Axial Length (mm)</b>			0.000 <sup>a,c</sup>	
Male	24.67 ± 1.9	20.47 to 31.95		-0.45 <sup>b,d</sup>
Female	24.46 ± 7.2	20.81 to 31.33		-0.53 <sup>b,d</sup>
Total	24.43 ± 1.57	20.4 to 34.83		-0.50 <sup>b,d</sup>
<b>Manifest Refraction</b>				
<i>Sphere (diopters)</i>			0.56	
Male	-1.45 ± 3.36	-19.5 to 9.25		0.62 <sup>b,d</sup>
Female	-1.36 ± 3.5	-19.5 to 6.50		0.54 <sup>b,d</sup>
Total	-1.3 ± 3.4	-19.5 to 9.25		0.57 <sup>b,d</sup>
<i>Cylinder (diopters)</i>			0.56 <sup>a</sup>	
Male	-0.79 ± 0.75	-5.00 to 0		-0.22 <sup>b</sup>
Female	-0.81 ± 0.89	-6.75 to 0		-0.16 <sup>b,d</sup>
Total	-0.81 ± 0.83	-6.75 to 0		-0.17 <sup>b,d</sup>
<i>Axis (degrees)</i>			0.48 <sup>a</sup>	
Male	86.70 ± 63.5	0 to 180		-0.03 <sup>b</sup>
Female	79.89 ± 62.1	0 to 180		-0.04 <sup>b</sup>
Total	79.93 ± 60.1	0 to 180		-0.02 <sup>b</sup>
<i>Spherical Equivalent (diopters)</i>			0.52 <sup>a</sup>	
Male	-1.88 ± 3.41	-20.13 to 8.88		0.61 <sup>b,d</sup>
Female	-1.78 ± 3.62	-20.88 to 6.00		0.52 <sup>b,d</sup>
Total	-1.81 ± 3.49	-20.88 to 8.88		0.55 <sup>b,d</sup>
<b>Keratometry</b>				
<i>Flattest K (diopters)</i>			0.000 <sup>a,c</sup>	
Male	43.37 ± 1.5	34.83 to 47.67		0.08 <sup>b</sup>
Female	43.67 ± 1.5	36.41 to 51.53		0.12 <sup>b,d</sup>
Total	43.50 ± 1.5	34.83 to 51.53		0.10 <sup>b,d</sup>
<i>Steepest K (diopters)</i>			0.000 <sup>a,c</sup>	
Male	44.35 ± 1.6	38.01 to 51.84		0.03 <sup>b</sup>
Female	44.80 ± 1.6	37.84 to 51.84		0.01 <sup>b</sup>
Total	44.60 ± 1.6	37.84 to 51.84		0.01 <sup>b</sup>
<i>Mean K (diopters)</i>			0.000 <sup>a,c</sup>	
Male	43.84 ± 1.5	36.49 to 49.76		0.02 <sup>b</sup>
Female	44.20 ± 1.5	37.13 to 51.69		0.03 <sup>b</sup>
Total	44.00 ± 1.5	36.49 to 51.69		0.05 <sup>b</sup>
<i>Axis of flattest K (degrees)</i>			0.79 <sup>a</sup>	
Male	86.70 ± 63.5	0 to 179		0.04 <sup>b</sup>
Female	88.40 ± 67.5	0 to 179		0.04 <sup>b</sup>
Total	87.70 ± 65.0	0 to 179		0.04 <sup>b</sup>

<sup>a</sup>Mann-Whitney test for independent samples between men and women

<sup>b</sup>Spearman rho correlation between parameter and age

<sup>c</sup>Significant if  $p < 0.05$

<sup>d</sup> $p < 0.001$

only in the female group (Table 2).

#### Steepest K

The mean steepest K was  $44.6D$  for the entire population;  $44.35D$  for males and  $44.8D$  for females. Females had higher corneal curvature radii than the males ( $p = 0.001$ ) (Table 2).

#### Mean K

The mean K reading was  $44.0D$  for the entire population;  $43.84D$  for

males and  $44.2D$  for females. The female group showed higher mean keratometric readings ( $p < 0.001$ ). Correlation with age was not significant for the entire population ( $r = 0.05$ ,  $p = 0.10$ ) (Table 2; Figure 4).

#### Refractive Astigmatism (MR-Astigmatism)

Eyes with astigmatism ( $> -0.50D$ ) accounted for 47.88% of the total population with a mean cylinder of

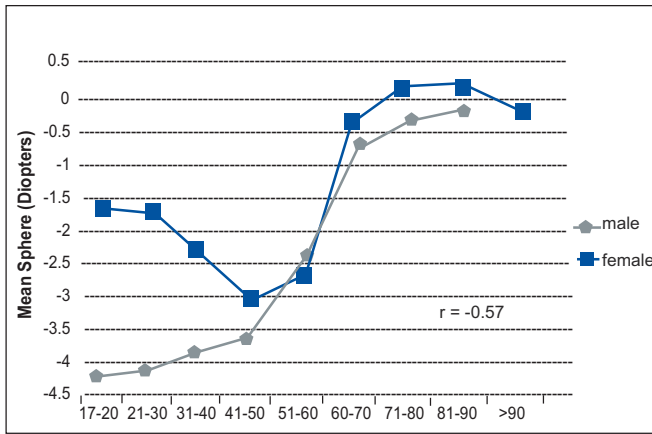


Figure 2. Mean sphere measurements by gender and age groups.

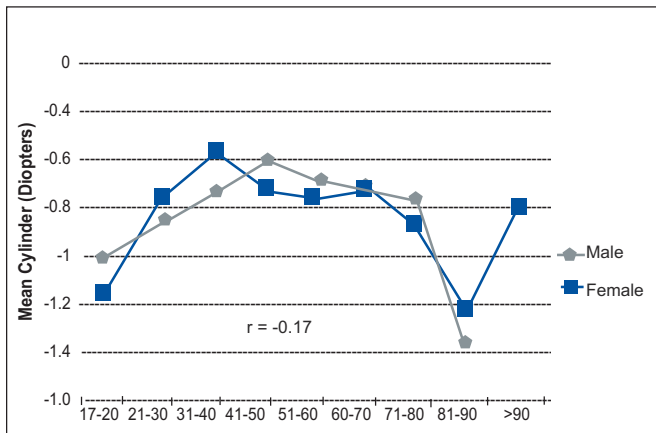


Figure 3. Mean cylindrical measurements by gender and age group.

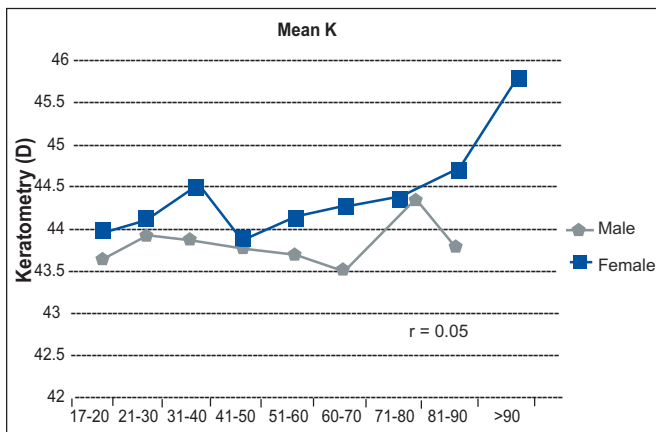


Figure 4. Mean keratometric measurements by gender and age groups.

$-1.35 \pm 81D$ . 48.55% of males and 47.44% of females had a mean cylinder of  $-1.27D$  and  $-1.40D$  respectively (Table 3).

#### Keratometric Astigmatism (IM-Astigmatism)

The mean difference between the steepest K and the

flattest K was  $1.10 \pm 0.80D$  for the entire population,  $1.02D$  for males and  $1.15D$  for females. The difference was significantly higher ( $p < 0.001$ ) in females. The keratometric difference was negatively correlated with age; this difference was less in the older population ( $r = -0.23$ ,  $p < 0.001$ ) and was observed in both males ( $r = -0.24$ ,  $p < 0.001$ ) and females ( $r = -0.23$ ,  $p < 0.001$ ; Table 3). 71.70% of the total population had astigmatism ( $K_{diff} > 0.05D$ ) with a mean of  $1.33 \pm 0.79D$ . 65.94% of males and 75.77% of females had mean of  $1.27D$  and  $1.37D$  respectively (Table 3).

#### Refractive (MR-Astigmatism) vs. Keratometric (IM-Astigmatism)

There was a significant difference between the astigmatism measured by manifest refraction and the IOL Master, where the keratometric astigmatism showed a higher astigmatism rate than the refractive astigmatism ( $p < 0.001$ ) (Table 3).

#### Axis of Astigmatism

##### Refractive Axis (MR-Axis)

The mean MR-Axis was  $97.97^\circ \pm 51.5^\circ$  for the entire population;  $94^\circ$  for males and  $101^\circ$  for females. No difference was noted between the two groups ( $p = 0.10$ ). There was a significant correlation with age in the entire population ( $r = -0.13$ ,  $p < 0.001$ ) (Table 3).

##### Keratometric Axis (IM-Axis)

The mean IM-axis was  $87.96^\circ \pm 68.6^\circ$  for the population,  $87^\circ$  for males,  $89^\circ$  for females. No difference between the male and female groups was seen ( $p = 0.89$ ). No correlation was obtained with age ( $r = 0.03$ ,  $p = 0.34$ ) (Table 3).

#### MR-Axis and IM-Axis

The refractive axis and the keratometric axis showed a significant difference between the two groups ( $p < 0.001$ ) (Table 3).

#### Types of Astigmatism

##### Refractive

Against-the-rule (ATR) (46.1%) was the prevalent type of astigmatism, followed by with-the-rule-astigmatism (WTR) (32.8%), and oblique astigmatism (OA) (21.1%). WTR was more prevalent in the younger age groups (20 to 40 years old), while ATR was more prevalent in the middle and elderly age groups (Figure 5).

##### Keratometric

The prevalent type of astigmatism measured by the IOL Master was WTR (59.1%), followed by ATR (20%), and OA (20%). WTR astigmatism was the predominant type in the younger and middle-aged groups (20 to 60 years old), while ATR was more prevalent in the older age group (Figure 6).

Table 3. Correlation of age with different astigmatic parameters by gender.

Parameter	Mean	Range	p	Correlation
Refractive astigmatism (MR-Astigmatism) <sup>e</sup> (diopter) (47.88% of total population)			0.26 <sup>a</sup>	
Male	-1.27 ± 0.69	-5.00 to 0		-0.16 <sup>c,d</sup>
Female	-1.40 ± 0.89	-6.75 to 0		-0.02 <sup>c</sup>
Total	-1.35 ± 0.81	-6.75 to 0		-0.09 <sup>c,d</sup>
Refractive axis (MR-Axis) (degrees) <sup>f</sup>			0.10 <sup>a</sup>	
Male	94.4 ± 49.8	0 to 180		-0.03 <sup>c</sup>
Female	100.5 ± 52.5	0 to 180		-0.20 <sup>c,d</sup>
Total	97.7 ± 51.4	0 to 180		-0.13 <sup>c,d</sup>
Keratometric (IM-Astigmatism) <sup>e</sup> (diopter) (71.70% of total population)			0.02 <sup>a,b</sup>	
Male	1.27 ± 0.82	0 to 5.83		-0.24 <sup>c,d</sup>
Female	1.37 ± 0.76	0 to 4.66		-0.23 <sup>c,d</sup>
Total	1.33 ± 0.79	0 to 5.83		-0.23 <sup>c,d</sup>
Keratometric axis (IM- Axis) (degrees) <sup>f</sup>			0.89 <sup>a</sup>	
Male	86.80 ± 66.73	0 to 179		0.01 <sup>c</sup>
Female	88.68 ± 69.80	0 to 179		0.05 <sup>c</sup>
Total	87.96 ± 68.63	0 to 179		0.04 <sup>c</sup>

<sup>a</sup>Mann-Whitney test for independent samples between men and women  
<sup>b</sup>Significant if  $p < 0.05$   
<sup>c</sup>Spearman rho correlation between parameter and age  
<sup>d</sup>Significant if  $p < 0.001$   
<sup>e</sup>Tested for significant difference  
(MR-measured vs IM-measured astigmatism t-test:  $p = 0.000$ ,  $SD = 0.89$ ,  $CI = 0.24$  to  $0.34$ )  
<sup>f</sup>Tested for significant difference  
(MR-measured vs IM-measured axis of astigmatism t-test:  $p = 0.000$ ,  $SD = 78.2$ ,  $CI = 4.4$  to  $13.2$ )

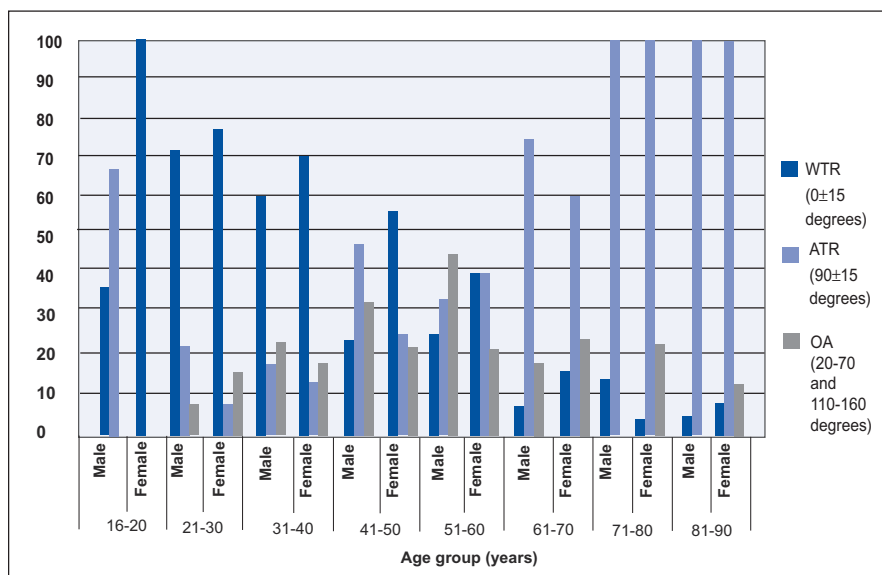


Figure 5. Prevalence (in percent) of refractive astigmatism (MR-measured) in 638 astigmatic eyes by age and gender groups.

## DISCUSSION

Anisometropia was observed in 13% of the patient population, 12% among males and 15% among females. This finding was similar to population-based reports done in Japan (15.1%)<sup>3</sup> and Australia (14%).<sup>4</sup>

Our rates were slightly lower than those reported in Singapore (20%)<sup>5</sup> and Taiwan (19.9%),<sup>6</sup> while it was higher compared to the rates reported in Mongolia (10.7%)<sup>7</sup> and Bangladesh (11.9%).<sup>8</sup>

Myopia was noted to be the

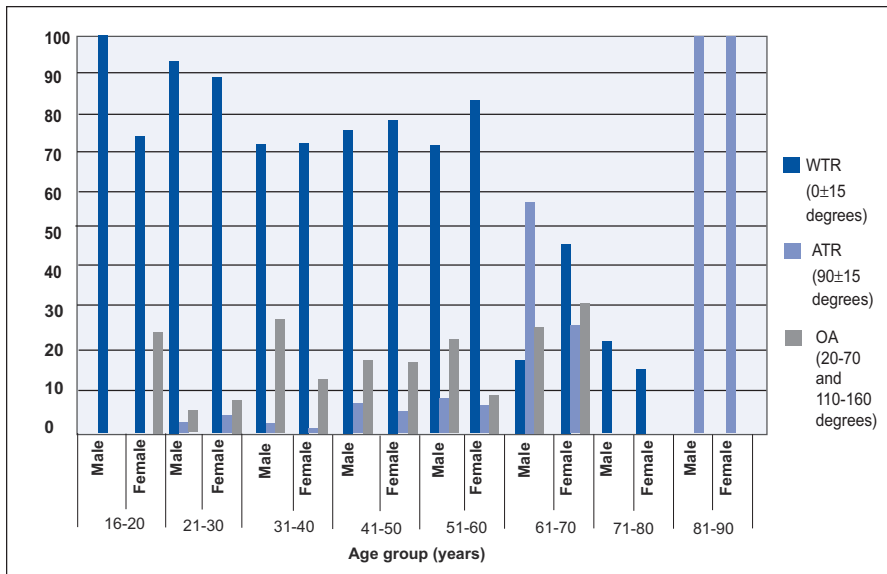
predominant refractive error type in this study. Similar to other East Asian population-based reports, which were done on a larger scale, myopia was also the leading type of refractive error, with rates at 31 to 40%.<sup>5-6,9</sup> Our smaller single-center population had a higher rate of myopia at 59% because patients specifically consulted for refractive or cataract screening, which created a bias toward higher degree of refractive errors.

The crude frequency of hyperopia in this study was 30%, which was similar to those reported in Singapore (35.9%),<sup>5</sup> Mongolia (32.9%),<sup>7</sup> and Japan (27.9%).<sup>3</sup>

Age is one of the factors known to correlate with refractive errors. The age-related changes in the human optical system shift the refraction over time: a trend towards myopia during high school to college years, followed by a hyperopic shift in the elder years. Other changes are a shift from with-the-rule astigmatism to against-the-rule astigmatism and steepening of the corneal curvature with age.<sup>12</sup> In this study, the younger population was more myopic, and as the age group increased the frequency of myopia decreased, illustrating a hyperopic shift with age. The reasons for this hyperopic shift are unknown.<sup>13</sup> We also observed that shorter axial lengths were correlated with older age groups. Others reported that corneal curvature flattens with age.<sup>3,12</sup> In this study, only the flattest K (measured by the IOL Master) was correlated with age in the female group.

Refractive astigmatism was correlated with age; increased negative cylinders were seen in the older age group consistent with other reports.<sup>3,4,6-8,10</sup> However, keratometric astigmatism showed an inverse correlation with age in this study, in contrast to a previous report<sup>3</sup> where astigmatic K was not correlated with age.

The shift from with-the-rule astigmatism to against-the-rule



**Figure 6.** Prevalence (in percent) of keratometric astigmatism (MR-measured) in 955 astigmatic eyes by age and gender groups.

astigmatism with increasing age as demonstrated in this study is well corroborated in other studies.<sup>3,12,14</sup> Correlation of age with axis values was not statistically significant in this study in either the refractive or keratometric methods.

There was no significant difference between gender groups in the manifest refraction measurements. Some studies<sup>15,16</sup> reported that white females were significantly more myopic than white males. But other studies did not show any significant differences between the gender groups.<sup>3,6</sup> In this report, axial length and keratometric measurements were found to be significantly different between gender groups, similar to that reported in Japan.<sup>3</sup>

This study had several limitations: eye diseases such as corneal problems, cataract, glaucoma, and retina that may affect the refractive status were not reported, including previous ophthalmic surgical interventions. Visual acuity was also excluded and vector analysis was not performed in calculating the astigmatism.

Nevertheless, the results of this study gave a picture of the types of refractive errors present in patients seeking eye care. A community based-

survey is needed, however, to obtain a more representative sample of the refractive errors in the general population.

In summary, the older population was characterized by shorter axial length and more prevalent hyperopia. Differences between the refractive and keratometric astigmatism indicate that other factors, such as lens changes or higher-order aberrations, may play a role in the astigmatic changes in the eye. The type of astigmatism changes with age where against-the-rule was more prevalent in the older age group.

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