Original Article

Relative Distribution of Refractive Errors: An Audit of Retinoscopic Findings

Muhammad Zia-ul-Haque Ansari, Abrar Ali, Adnan Afaq, Tabassum Ahmed, Khawaja Sharif-ul-Hassan

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See end of article for authors affiliations

Correspondence to:
M. Zia-ul-Haque Ansari
Department of Ophthalmology
Baqai Medical University
Karachi

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Purpose: To observe the relative distribution of refractive errors in the mixed ethnic population of Karachi and review the current concepts into the pathophysiology of refractive errors.

Material and Methods: We retrospectively analyzed the retinoscopic findings of 1924 eyes of 962 patients presenting with refractive problems from January 1984 to December 1991 to determine their refractive status. Refraction was performed objectively on all patients by one of us (KSH) using streak retinoscope. Sphero-cylindrical method of refraction was used to minutely neutralize the reflex. Subsequently, retinoscopic findings were subjectively verified. Half-diopter cross cylinder was used to verify and refine the power and axis of any cylindrical lens. Any error, stigmatic (spherical) or astigmatic (cylindrical), of ¼-diopter or more was considered an error and included in the analysis.

Result: Astigmatism was the most common refractive error found in this retinoscopic analysis (914 of 1898 eyes; 48.16%) followed by myopia (894 of 1898 eyes; 47.10%) and hypermetropia (90 of 1898 eyes; 4.74%). Myopic error (stigmatic and astigmatic myopia combined) comprised the largest group among the analyzed population (1554 of 1898 eyes; 81.88%) followed by hypermetropic error (stigmatic and astigmatic hypermetropia combined) (265 of 1898 eyes; 13.96%) and mixed error (mixed astigmatism) (39 of 1898 eyes; 2.05%).

Conclusion: Myopia and myopic astigmatism were the major refractive errors found in the mixed ethnic population of Karachi city in the age group from 1 to 40 years.

Refractive errors are a significant cause of visual impairment worldwide[1]. The most common cause of mild to moderate visual impairment observed in comparable surveys is uncorrected refractive error[2]. Refractive errors are also a significant cause of morbidity besides having social and economic implications[3].

A refractive error, or ametropia, is an optical state wherein parallel rays of light passing through the optical media fail to converge on to the neurosensory retina when the eye is at rest[4]. In terms of optics, the second principal focus of an unaccommodated eye does not coincide with the retina[5]. Ametropia results from an imbalance between the refractive power and the axial length of the eyeball[6]. The purpose of this article is to present clinic based audit of the refractive status of the ametropic mixed ethnic population of Karachi and to review the current concepts into the pathophysiology of refractive errors.

MATERIALS AND METHODS

We retrospectively analyzed the retinoscopic findings of 1924 eyes of 962 patients presenting with refractive problems to determine their refractive status. All patients were examined at a private clinic located in a medical complex in the central part of the city where patients of multiple ethnic origins used to report from different districts of Karachi. Records of patients seen from January 1984 to December 1991 were included in the analysis. Refraction was performed objectively on all patients by one of us (KSH) using streak retinoscope. Sphero-cylindrical method of refraction was used to minutely neutralize the reflex (one meridian was neutralized by spherical lens and the perpendicular meridian was neutralized by an appropriate cylindrical lens when required). Subsequently, retinoscopic findings were subjectively verified. Half-diopter cross cylinder was used to verify and refine the power and axis of any cylindrical lens.

Cycloplegic refraction, after instillation of atropine eye ointment for three days, was performed on all children less than 5 years of age. Older children were refracted 40 to 60 minutes following topical instillation of 1% Cyclopentolate eye drops twice at 5 to 10 minute interval.

A complete adnexal and biomicroscopic anterior segment examination on slit-lamp was performed on all patients. Fundus examination was also performed using direct ophthalmoscope.

All efforts were made to exclude pathological causes of refractive errors from the audit. Records of patients with any adnexal, anterior segment and posterior segment pathology were not included in the analysis; records of patients with pathological myopia were, therefore, also excluded. Records of patients less than one year and more than forty years were also excluded.

Any error, stigmatic (spherical) or astigmatic (cylindrical), of ¼-diopter or more was considered an error and included in the analysis.

RESULTS

Retinoscopic findings of 1924 eyes of 962 patients presenting with refractive problems were analyzed. The gender distribution of the 962 patients whose records were analyzed revealed a slight preponderance of males over the females as shown in (Table 1).

Unfortunately, we were not been able to retrieve conclusive information about ethnicity of all the patients and it would not been possible for us to give a valid account of the ethnicity of the patients. However, we would not be far away from truth in postulating an almost equal proportion of patients belonged to the different ethnic groups residing in this cosmopolitan city of Karachi, namely, punjabi, pathan, baloch, old sindhi and new sindhi, with probably a slight preponderance of new sindhis which constitute the majority of the city's populace.

Table 2 summarizes the relative age distribution of the patients. Age group >10 to 20 years comprised the largest group and consisted of 393 of 962 patients (40.85%). Age group >20-30 years comprised the second largest group and consisted of 320 of 962 patients (33.26%). Age group >30-40 years comprised the third largest group and consisted of 151 of 962 patients (15.70%). Age group 1 to 10 years was the least populous group and consisted of only 98 of 962 patients (10.19%). Bilateral ametropia was found in 1898 eyes of 949 patients (98.65%) while unilateral ametropia was found in 26 eyes of 26 patients (1.35%). Right eye was emmetropic in 13 patients while left was emmetropic in the other 13 patients (Table 3).

Table 1: Gender distribution.

Male n (%)	Female n (%)	Total n(%)
549 (57.07)	413 (42.93)	962 (100)

Table 2: Relative age distribution of the patients.

Age Group (Yrs)	RE n(%)	LE n(%)	Total n(%)
1 to 10	98 (10.19)	98 (10.19)	196 (10.19)
>10 to 20	393 (40.85)	393 (40.85)	786 (40.85)
>20-30	320 (33.26)	320 (33.26)	640 (33.26)
>30-40	151 (15.70)	151 (15.70)	302 (15.70)
Total	962 (100)	962 (100)	1924 (100)

Table 4 summarizes the relative distribution of three major refractive errors in 1898 eyes with ametropia. Astigmatism was the most common refractive error found in this retinoscopic analysis; of the 1898 eyes with ametropia, 914 eyes (48.16%) were astigmatic. Myopia was also common and found in

894 of 1898 eyes (47.10%), while hypermetropia was the least common and found in only 90 of 1898 eyes (4.74%).

Table 3: Bilateral vs unilateral ametropia.

Refractive Status	No. of Patients n(%)	No. of Eyes n(%)
Bilateral Ametropia	949 (98.65%)	1898 (98.65%)
Unilateral Ametropia	13 (01.35%)	26 (01.35%)
Total	962 (100%)	1924 (100%)

Table 4: Relative distribution of astigmatism, myopia, & hypermetropia.

Refractive Status	RE n(%)	LE n(%)	Total n(%)
Astigmatism	462 (48.68)	452 (47.63)	914 (48.16)
Myopia	438 (46.16)	456 (48.05)	894 (47.10)
Hypermetropia	49 (05.16)	41 (04.32)	90 (04.74)
Total	949 (100)	949 (100)	1898 (100)

Table 5: Relative distribution of myopic (Combined stigmatic and astigmatic myopia), hypermetropic (Combined stigmatic and astigmatic hypermetropia) and mixed error (Mixed astigmatism).

Refractive Status	RE (%)	LE (%)	Total (%)
Myopic Error	795 (82.64)	799 (83.06)	1594 (84.00)
Hypermetropic Error	131 (13.80)	134 (14.12)	265 (13.96)
Mixed Error (Mixed astigmatism)	23 (02.42)	16 (01.69)	39 (02.05)
Total	949 (100)	949 (100)	1898 (100)

Table 5 summarizes the relative distribution of myopic (stigmatic and astigmatic myopia combined), hypermetropic (stigmatic and astigmatic hypermetropia combined), and mixed error (mixed astigmatism). Myopic error (stigmatic and astigmatic myopia combined) comprised the largest group among the analyzed population. Of the 1898 ametropic eyes, myopic error (stigmatic and astigmatic myopia combined) was present in 1554 eyes (84%). Hypermetropic error (stigmatic and astigmatic hypermetropia combined) was relatively less prevalent refractive error in the analyzed population and found in 265 of 1898 eyes with ametropia (13.96%). Prevalence of mixed error (mixed astigmatism) was relatively rare in the analyzed population. Of the 1898 ametropic eyes, mixed astigmatism found in only 39 eyes (2.05%).

Table 6 summarizes the relative distribution of different types of myopic error (stigmatic myopia, compound myopic astigmatism, and simple myopic astigmatism). Among the patients with myopic error (stigmatic and astigmatic myopia combined), stigmatic myopia was the most common and found in 894 of 1594 eyes (56.09%). Compound myopic astigmatism found in 583 of 1594 eyes (36.57%), while simple myopic astigmatism, which was the least common, found in 117 of 1594 eyes (7.34%) with stigmatic and astigmatic myopia combined.

Table 6: Relative distribution of different types of myopic error (stigmatic myopia, compound myopic astigmatism, and simple myopic astigmatism).

Refractive Status	RE n(%)	LE n(%)	Total n(%)
Stigmatic myopia	438 (55.10)	456 (57.07)	894 (56.09)
Compound myopic astigmatism	300 (37.74)	283 (35.42)	583 (36.57)
Simple myopic astigmatism	57 (07.16)	60 (07.51)	117 (07.34)
Total	795 (100)	799 (100)	1594 (100)

Table 7 summarizes the relative distribution of different types of hypermetropic error (stigmatic hypermetropia, compound hypermetropic astigmatism, and simple hypermetropic astigmatism). Among the patients with hypermetropic error (stigmatic and astigmatic hypermetropia combined), compound

hypermetropic astigmatism was the most common and found in 160 of 265 eyes (60.38%). Stigmatic hypermetropia found in 90 of 265 eyes (33.96%), while simple hypermetropic astigmatism, which was the least common, found in only 15 of 265, eyes (5.66%) with stigmatic and astigmatic hypermetropia combined.

Table 7: Relative distribution of different types of hypermetropic error (stigmatic hypermetropia, compound hypermetropic astigmatism, and simple hypermetropic astigmatism).

Refractive Status	RE n(%)	LE n(%)	Total n(%)
Compound hypermetropic astigmatism	77 (58.78)	83 (61.94)	160 (60.38)
Stigmatic hypermetropia	49 (37.40)	41 (30.60)	90 (33.96)
Simple hypermetropic astigmatism	5 (03.82)	10 (07.46)	15 (05.66)
Total	131 (100)	134 (100)	265 (100)

DISCUSSION

The World Health Organization (WHO) has grouped uncorrected refractive error with cataract, macular degeneration, infectious disease, and vitamin A deficiency among the leading causes of blindness and vision impairment in the world. 'Vision 2020', a global initiative for the elimination of avoidable blindness by the WHO, also included refractive errors among the five conditions of immediate priority[7]. According to the national survey conducted by the Ministry of Health in collaboration with WHO during 1987-90 to determine the prevalence of different causes of blindness in the country, refractive errors were the third leading cause of preventable blindness in Pakistan after cataract and corneal opacities[8].

In spite of extensive search of the local, regional and international literature we were unable to find a comparable audit of retinoscopic findings on ametropic patients. It is, therefore, not possible for us to compare our results and to find out any similarities or differences. Most studies presented prevalence of refractive errors in a given population or a selected group of individuals. We would like to review the prevalence of refractive errors as presented by some of the recently conducted studies before giving a brief review of the current concepts into the most speculative and controversial topic of pathophysiology of refractive errors.

The prevalence of astigmatism is high in infants. Mohindra et al reported astigmatism of >1 D in about 50% of full-term infants[9]. The prevalence decline with age; Howland et al reported about 15% prevalence of astigmatism of >1 D in adult population[10].

The prevalence of myopia and hypermetropia varies by country and by ethnic group. In Baltimore, US study prevalence of myopia of -0.5 D or worse in a sample of 2659 whites aged 40 or above was 28.1% while it was 19.4% in 2200 blacks of same age group; the prevalence of hypermetropia of greater than +0.5 D was a little higher in both the groups[11]. In Victoria, Australia myopia of -0.5 D or worse was present in 16.9% among 4506 individuals aged 40 or above, while the prevalence of hypermetropia of greater than +0.5 D was greater than that of myopia in the same population[12]. In Andhra Perdesh, India the prevalence of myopia of -0.5 D or worse was 36.6% among 3588 individuals aged 40 or above; the prevalence of hypermetropia of greater than +0.5 D was almost identical[13]. In Taiwan myopia of -0.25D or worse was present in 53.9% of 11,178 children 7 to 18 years of age[14]. Prevalence of myopia is highest in Singapore; 20% of children were myopic at 7 years at the start of their primary education, with prevalence exceeding 70% upon completing college education[15].

The prevalence of pathological myopia is estimated at 1 to 3% in population based studies[16]. Genetic studies of families with a strong history of pathological myopia have uncovered two polymorphisms and two separate loci for high myopia, indicating an autosomal dominant predisposition for the development of pathological myopia[17].

At birth, most infants are 2 to 3 D hypermetropic. From approximately 6 years of age there is a gradual decrease in the amount of hypermetropia which continues through puberty[18]. This process, wherein the refractive state of children's eyes shifts in magnitude and reduces in variance to reach near emmetropia, is called emmetropisation.

Genetic factors and environmental influences interact to determine the refractive status of an individual's eyes. The prevalence of myopia in children with two parents with myopia is 30% to 40%, decreasing to 20% to 25% in children with one parent with myopia and to less than 10% in children with no parents with myopia; monozygotic twins tend to resemble each other in refractive error more than do dizygotic twins[19-21].

Clinical and laboratory evidence strongly suggests that environment is as important as or more important than genetics. A study of the correlation between refractive error in parents and siblings showed stronger correlation than would be expected by chance[22]. A longitudinal prospective study conducted by Zadnik et al showed that children with myopic parents, although not yet myopic themselves, tended to have longer eyes than children with non-myopic parents, resulting in a predisposition to becoming myopic later in life[23]. An analysis of the Health Interview Survey revealed that individuals who read for long periods of time are more likely to have myopia[24]. A large-scale study of U.S. patients showed that the incidence of myopia increases with education. Among 18 to 24 years with less than five years of schooling, only 3.1% were myopic as compared to 30% in the same age group with more than 12 years of education[25]. A study of Eskimo volunteers from Barrow, Alaska showed that the prevalence of myopia was 8.4 percent among parents and 58 percent among children. This study also showed that no Eskimos over the age of 51 were myopic. Researchers observed that prior to 1947 this community only offered the first six grades of education. After 1947, children were required to attend through eighth and ninth grades. Myopia in the group without compulsory education was 1.5% and in those with compulsory education were 40.3 %[26].

Researchers in Asia point to their rigorous schooling system and the long hours children spend studying as being responsible for the high rates of myopia in Asia[27-29]. Support for an important role for near work also comes from animal studies that have demonstrated the plasticity of refractive error in response to environmental stimuli. Neonatal chicks, tree shrews, or monkeys experience increased ocular growth and become myopic or less hypermetropic after wearing minus lenses, presumably to compensate for the hyperopic defocus produced by these lenses[30-33].

Hypermetropic defocus from a deficient accommodative response in juvenile myopes is theorized to be the connection between near work in human myopia and the minus lens results from animal studies[34]. This retinal blur initiates a biochemical process in the retina to stimulate biochemical and structural changes in the sclera and choroid that lead to axial elongation and myopia[35].

Most probably, in children with a familial or ethnic predisposition to myopia the emmetropisation process continues, leading to mild myopia early in life. When they are exposed to myopiogenic factors, such as extensive near work, myopisation proceeds unchecked, causing further axial elongation and moderate myopia in late adolescence. Additional myopiogenic factors such as extensive near work in secondary or postgraduate school or in an occupation can lead to higher degrees of myopia.

We thought the process of emmetropization stops nearer to the customary working distance of an individual. In individuals who are not exposed to the environmental myopiogenic factors, especially extensive near work, the process of emmetropization stops at their customary far working distance and they stay nearer to emmetropia. On the other hand, individuals who are engaged in extensive near work and occupation requiring extensive near work achieve emmetropisation for their customary close working distance and become myopic for distance. Therefore, It seems prudent to advice the parents to avoid prolonged near tasks for their children and encourage regular daily outdoor activity. This would probably help to minimize the role of accommodation and keep the process of myopization within limits.

We would like to classify refractive errors as 'primary'', 'secondary' and 'consecutive' or 'iatrogenic'. When refractive error is the only deficit in an otherwise normal eye it should be labeled as 'primary'. On the other hand, refractive errors caused by 'pathological alteration' in the normal anatomical or structural parameters of any of the components of the eye or its adnexa should be categorized as 'secondary'. Table 8 summarizes some the causes of 'secondary' refractive errors.

Finally, refractive errors induced by surgical alterations of the normal anatomical, structural or refractive elements of the eye should be categorized as 'consecutive' or 'iatrogenic'. Table 9 summarizes some of the causes of 'consecutive' refractive errors.

Table 8: Some the causes of 'secondary' refractive errors.

Pathology	Secondary' Refractive Error
Lid tumours/Chalazion	Astigmatism
Pterygium	Astigmatism
Keratoconus	Myopic astigmatism
Kertoglobus / Megalo-cornea	Myopia
Nanophthalmos	Hypermetropia
Microophthalmos	Hypermetropia
Buphthalmos	Myopia
Terrian's marginal degeneration	Against the rule or oblique astigmatism
Pellucid marginal degeneration	Against the rule astigmatism
Corneal scarring	Irregular astigmatism
Cornea plana	Hypermetropia
Anterior lens displacement	Myopic error (stigmatic or astigmatic)
Posterior lens displacement	Hypermetropic error (stigmatic or astigmatic)
Sperophakia /Lenticonus	Myopia
Nuclear sclerosis	Myopia
Choroidal tumour/	Hypermetropia
Central serous chorioretinopathy (CSCR)	Hypermetropia
Posterior staphyloma formation	High ('degenerative') myopia

Silicone oil in an aphakic eye acts as a strong converging lens, causing high myopia. On the other hand, silicone oil in a phakic eye acts as a strong diverging lens by converting the convex posterior lens surface into a concave lens-silicone oil interface, inducing hypermetropia of 5 to 7 Diopters.

This division has clinical as well as psychological implications. 'Primary' refractive errors reflect a physiological variation of the normal and their distribution in a population exhibit a symmetrical, bell-shaped, 'Guassian' pattern like other characteristics such as height, weight, blood pressure, intraocular pressure and serum levels of haematological and biochemical substances. Therefore, when the eye is otherwise normal, the error induced by this physiological variation should be considered normal and labeled as 'primary'. It is quite reassuring for the patients or their parents when they come to know that the error of refraction they or their children have is the result of normal physiological variation rather than due to any defect or 'weakness' in the eyes.

Table 9: Some of the causes of 'consecutive' refractive errors.

Cause	Consecutive refractive error
Cataract surgery	Stigmatic or astigmatic error
Air bubble in the anterior chamber	Hypermetropia
Vitreoretinal surgery (silicone oil)	Myopia or hypermetropia*
Encircling buckle	Myopia
Keratoplasty	Astigmatism
Refractive surgery: all types	Residual or induced stigmatic or astigmatic error
IOL power miscalculation	Residual or induced stigmatic or astigmatic error
IOL decenteration or tilt	Induced astigmatic error

Author's affiliation

Dr. Muhammad Zia-ul-Haque Ansari
Assistant Professor of Ophthalmology
Baqai Medical University, Karachi

Dr. Abrar Ali
Professor of Ophthalmology
Hamdard Medical University, Karachi

Dr. Adnan Afaq
Assistant Professor of Ophthalmology
Baqai Medical University, Karachi

Dr. Tabassum Ahmad
Assistant Professor of Ophthalmology
Hamdard Medical University, Karachi

Professor Khwaja Sharif-ul-Hasan
Professor & Chairman
Department of Ophthalmology
Baqai Medical University, Karachi

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