Revista Mexicana de Oftalmología (Eng)

Permanyer

ORIGINAL ARTICLE

Anatomic alterations and prevalence of high myopia

Alteraciones anatómicas oculares y prevalencia de miopía alta

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Abstract

The purpose of this review was to describe the characteristic anatomic alterations in the eye with high myopia and to identify the prevalence of this condition in different populations. High myopia is characterized by elongation of the eyeball. The elongation of the posterior pole causes complications in the sclera, choroid and retina, and threatens central vision, which is why it is an important cause of low vision and preventable blindness in the world. Asia is the continent with the highest prevalence of high myopia; therefore, race is considered an important factor. This review indicates that there are differences in the definition of high myopia between studies, as well as in the method used for refractive measurement and for pathological classification.

Key words: *Myopia. Degenerative myopia. Ocular refraction. Prevalence.*

Resumen

El objetivo de esta revisión fue describir las alteraciones anatómicas características del ojo con miopía alta e identificar la prevalencia de esta condición en diferentes poblaciones. La miopía alta se caracteriza por el alargamiento del globo ocular. La elongación del polo posterior causa complicaciones en la esclera, la coroides y la retina, y amenaza la visión central, por lo que es causa importante de baja visión y ceguera prevenible en el mundo. El continente con mayor prevalencia de miopía alta es Asia, por lo que la raza se considera un factor importante. La revisión realizada indica que existen diferencias en la definición de miopía alta que utilizan los estudios, así como en el método que aplican para la medición refractiva y para la clasificación patológica.

Palabras clave: *Miopía. Miopía degenerativa. Refracción ocular. Prevalencia.*

Introduction

Myopia that generates a high risk of ocular morbidity is a condition characterized by excessive elongation of the eyeball (axial length (AL) >26 mm), associated with pathological changes in the fundus of the eye, giving rise to refractive errors with a spherical equivalent (SE) of -6.00 D or more[1-3], so it is also known as high myopia. As posterior staphylomas have been described in eyes without high myopia, an international panel of researchers recently proposed a classification system in which pathological myopia was defined as eyes with chorioretinal atrophy equal to or more severe than diffuse atrophy, i.e., without considering the magnitude of the refractive error or the increase of AL[4]. Other

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Date of reception: 06-08-2018
Date of acceptance: 18-12-2018
DOI: 10.24875/RMOE.M19000057

Available online: 01-03-2019
Rev Mex Oftalmol (Eng). 2019;93(2):62-69
www.rmo.com.mx

common names are *myopia magna* or *degenerative, progressive,* or *malignant myopia*.

Due to degenerative changes, this type of myopia causes an irreversible decrease in best-corrected visual acuity[5], which is why it causes low vision and blindness, especially in Eastern Asia[4], although the evidence indicates that also in Europe (7%) and in other Asian populations (12-27%)[6]. It is considered as the third most frequent cause of blindness or low vision, after glaucoma and cataracts[7,8].

Therefore, the objective of this review was to describe the characteristic anatomical alterations of eyes with high myopia and to identify the prevalence of this condition in different populations.

Anatomical alterations in pathological myopia

When there is progression of myopia, there is an axial elongation of the eyeball, which exerts a biomechanical stretch in the posterior pole, which leads to pathological changes in the posterior pole and in the peripheral retina, such as myopic crescent and tiger-striped appearance, posterior staphyloma, lacquer cracks, choroidal neovascularization (CNV), retinoschisis, epiretinal membrane, myopic maculopathy, dome-shaped macula and peripheral retinal lesions[9].

Myopic crescent and tiger-striped appearance

The scleral expansion that results from axial lengthening leads to a depigmentation around the optic disk called “myopic crescent,” and the most common presentation is in the temporal quadrant. These structural changes lead to retinal pigment epithelium atrophy, which causes a striated appearance of the fundus[10].

Posterior staphyloma

Posterior staphyloma is a protrusion of a delimited area of the posterior segment of the eye[11]. It has been identified that there are differences in the prevalence of macular anatomical alterations in high myopia with posterior staphyloma (53.65%) or without it (22.41%), and that the most frequent findings in eyes with staphyloma are foveoschisis, vascular traction and epiretinal membrane[12]. These changes predict alterations that threaten vision considerably. It has been identified that the prevalence of posterior staphyloma is 10%, a figure that increases with age[13,14].

There is an objective classification of posterior staphyloma based on 3D magnetic resonance, with 5 types according to the appearance of the edge and the location of the staphyloma, including whether it is wide (I), narrow (II), peripapillary (III), nasal (IV), inferior (V) or others. The most common type of posterior staphyloma is type I (74%). However, the described findings do not occur in all eyes with higher AL[11].

Lacquer cracks

The mechanical stretching of the choroid produces ruptures in Bruch’s membrane in the macular area, whose appearance is yellow and linear, reticular or stellate. Its presentation is more frequent in the temporal quadrant (44%) and occur generally in adults with an AL >29 mm[15].

Choroidal neovascularization (CNV)

Pathological myopia is one of the main causes of CNV under 50 years of age (62%)[16]. It consists of a flat, gray-colored subretinal membrane[17], associated with abnormal growth and invasion of choroidal vessels through Bruch’s membrane[18]. It has a high impact on visual acuity and approximately 5% to 11% of subjects with degenerative myopia develop CNV[19]. Although CNV can occur in any degree of myopia and even without the presence of the typical fundus changes, irregular atrophy and lacquer cracks may be predisposing factors for CNV development[20,21].

Retinoschisis

Myopic macular retinoschisis is described as a traction maculopathy, which appears more commonly in the external plexiform layer and, less frequently, with detachment of the internal limiting membrane[22], which can lead to vitreous detachment, macular holes and foveal detachment. This complication can occur in 9% of highly myopic eyes with posterior staphyloma[10,21].

Epiretinal membrane

It is composed of three layers, of which the innermost is composed of vitreous, the intermediate by fibroblast-like cells, and the outermost corresponds to the internal limiting membrane of the retina. A prevalence of 11.2% was found in eyes with high myopia associated with posterior staphyloma[12].

Myopic maculopathy

The presence of maculopathy may involve irreversible changes in visual acuity. The signs begin with anatomical changes in the choroid and retina, followed by a compromise of the macular area[9]. Although the incidence is of 0.05%, the rate of progression in patients with maculopathy can rise to 35%[23].

There is a current classification proposed in the META-PM study, with 5 categories according to the presence of pathological changes in the posterior pole. The classification includes: "no myopic retinal lesions" (Category 0), "tessellated fundus only" which indicates a mosaic color pattern in the fundus (Category 1), "diffuse chorioretinal atrophy" with a yellowish appearance generally surrounding the optic disc (Category 2), "patchy chorioretinal atrophy" with a defined grayish-white lesion in the macular area or around the optic disc (Category 3), and "macular atrophy" (Category 4)[24].

Dome-shaped macula

It is characterized by an anterior protrusion of the macular area. The incidence of this complication is of 8%[25]. The most relevant pathological causes are related to choroidal or scleral thickening[10,26] and serous retinal detachment[27], attributed to choroidal vascular changes[28].

Peripheral retinal lesions

The peripheral retina may be affected in high myopia, with anatomical changes such as palisade degeneration (lattice) and peripheral tears[29] both of which are risk factors for rhegmatogenous retinal detachment, if the vitreous passes through the holes or tears and separates the retina from the retinal pigment epithelium. It is frequent that the degeneration has the appearance of an elongated area of internal retinal thinning, with its axis parallel to the ora serrata. In some cases, crossed white lines are observed, which correspond to vessels covered with glial or hyaline tissue. The prevalence of these lesions may be up to 8% in the general population, and of 15.6% in eyes with high myopia[30-32].

Methodology

To identify the observational studies on the prevalence of high myopia, a search was made in Medline (PubMed) using the terms «myopia AND (prevalence OR epidemiology)» supplemented with the references of systematic reviews on the topic[6,33,34]. The search for information specifically in Spanish or Portuguese was done in LILACS.

Prevalence data were based on studies since 1990, with populations of more than 1,000 subjects. If the studies reported crude and adjusted prevalence rates, the latter were considered with their respective confidence intervals. The global prevalence of high myopia and some figures disaggregated by sex or race are reported.

Prevalence of high myopia

A 2016 meta-analysis that used data published since 1995 estimated that in 2000, there were 163 million people with high myopia (SE <-5.00 D), corresponding to 2.7% of the world population at the time (95% CI: 1.4-6.3). With these values, for the year 2050 a prevalence increase to 938 million people was estimated (9.8%, 95% CI: 5.7-19.4). It is estimated that by 2020, 2030, 2040 and 2050 the prevalence of degenerative myopia will be 5.2, 6.1, 7.7 and 9.8%, respectively, with significant regional differences[33].

The difference in the frequency of high myopia between different groups has been evidenced: in Caucasians the figures range from 2.71 to 7.8%, in Asians and Indians, from 1.8 to 21%, and in Africans, from 4.3 to 5.5%[35].

The prevalence of high myopia (≤-6.00 D), standardized by age, is relatively low in Europe (2.7%, 95% CI: 2.69-2.73), with higher values in young people between 15 and 19 years old (5.9%, 95% CI: 1.3-10.5), according to a meta-analysis based on 15 studies and grouping a total of 61,946 subjects[34]. The study published by the UK Biobank Eye and Vision Consortium, which included subjects from different races, found a prevalence of high myopia three times higher in Chinese. The modelling adjusted for gender, age and educational level, among other variables, indicated that people of Chinese origin are between 2.6 and 4.5 times more likely to suffer from high myopia compared with Caucasians[36].

In U.S.A. the prevalence of high myopia has been reported 5 times higher in Chinese subjects compared to Hispanics. This is the same tendency observed for myopia globally, although of greater magnitude. As a result, people of Chinese origin are at greater risk of ocular complications that severely affect vision, such as myopic macular degeneration[37].

Table 1 shows the prevalence of high myopia reported in different populations. It is not possible to make global comparisons because the studies used different procedures for the measurement of refractive errors, with different age groups and in different decades.

Table 1. Prevalence of high myopia in different regions and ethnic groups

Authors	Year	Population	n	Age	High myopia definition (SE)	Refraction method used	Cycloplegia	Prevalence of high myopia (% and 95% CI)
Asia								
Wong, et al.[44]	2000	Singapore (Chinese residents)	1.232	49-79	<–5.00 D	Autorefraction	No	9.1% (7.2-11.2) Men 7.5% (5.1-10.4), women 10.5% (7.6-13.3) Age-adjusted
Lin, et al.[52]	2004	Taiwan	10.889	18	<–6.00	Autorefraction	Yes	21%
Raju, et al.[47]	2004	India	2,508	>39	<–5.00 D	Subjective	No	4.32% Age and gender-adjusted
Bar Dayan, et al.[45]	2005	Israel	919,929	16-22	<–6.00	Autorefraction	No	Men 2.05%, women 2.4%
Krishnaiah, et al.[53]	2009	India (Andhra Pradesh Eye Disease Study)	3,642	≥40	<–5.00 D	Subjective	No	4.5% (3.8-5.2) Age, sex and area-adjusted. Men 5.2% (4.1-6.1), women 4.5% (3.5-5.4)
Wang, et al.[41]	2009	Taiwan	3,709	First-year university students	<–6.00 D	Autorefraction	No	36.9% Men 36.6%, women 37.2%
Liu, et al.[54]	2010	China (Beijing Eye Study 2001)	4,319	>40	≤–6.00 D	Subjective	No	2.5% of the eyes
Gao, et al.[55]	2011	China (The Handan Eye Study)	6,603	≥30	<–5.00 D	Subjective	No	2.1% > 40 years: 1.8% (1.5%-2.2%)
Tan, et al.[56]	2011	Singapore	1,835	55-89	<–6.00 D	Autorefraction	No	3.1%
Asakuma, et al.[57]	2012	Japan	1,892	≥40	<–5.00 D	Autorefraction	No	5.7%
Pan, et al.[58]	2012	Singapore	3,400	>40	<–5.00 D	Autorefraction	No	4.8% (4.0-5.7) Age and gender-adjusted
Kim, et al.[59]	2013	Korea	21,356	>20	<–6.00 D	Autorefraction	No	4.0% (3.7-4.3)
Lee, et al.[60]	2013	Korea	2,805	19	<–6.00 D	Autorefraction	Yes*	Men 6.8% (5.8-7.7)
Lan, et al.[40]	2013	China	2,478	3-6	≤–6.00 D	Autorefraction	Yes*	0.08%
You, et al.[46]	2014	Great Beijing	15,066	7-18	≤–6.00 D	Autorefraction	Yes* (1082 children)	4.3% (4.0-4.7)

(Continue)

Table 1. Prevalence of high myopia in different regions and ethnic groups *(continued)*

Authors	Year	Population	n	Age	High myopia definition (SE)	Refraction method used	Cycloplegia	Prevalence of high myopia (% and 95% CI)
Gao, et al.[61]	2015	China	1,565	6-21	≤–6.00 D	Autorefraction	Yes*	2.9% (2.1-3.7)
Gupta, et al.[62]	2015	Singapore	28,908 men	17-29	≤–6.00 D	Autorefraction	No	8.9%
Joseph, et al.[63]	2018	India	4,351	≥40	≤–6.00 D	Subjective	No	2.0%
Australia								
Attebo, et al.[64]	1999	Sidney	3,654	49-97	<–5.00 D	Autorefraction	No	1.8%
McCarty, et al.[65]	1997	Melbourne	3,262	≥40	<–5.00 D	Autorefraction	No	2.2%
Vongphanit, et al.[66]	2002	Sidney (Blue Mountains Eye Study)	3,654	≥49	≤–5.00 D	Lensometry Subjective	No	2.2%
North America								
Vitale, et al.[67]	2009	USA (National Health and Nutrition Examination Survey -NHANES)	1971-1972: 4,436 1999-2004: 8,339	12-54	≤–7.9 D	Lensometry, retinoscopy or autorefraction	No	1971-1972: 0.2% 1999-2004: 1.6% (1.3-2.0)
Villarreal, et al.[68]	2003	Mexico	1,035	12-13	≤–5.00 D	Autorefraction	Yes**	1.4% Boys 1.5%, girls 1.4%
Pan, et al.[37]	2013	USA	4,430	45-84	≤–5.00 D	Autorefraction	No	4.6% Chinese 11.8%, white 5.4%, black 3.1%, hispanic 1.8%
Willis, et al.[69]	2016	USA (several races)	8,865	>18	≤–6.00 D	Autorefraction	No	3.91% (3.44-4.45) Men 2.99% (2.47-3.63), women 4.8% (3.98-5.77)
Varma, et al.[42]	2017	USA (Chinese)	4,144	≥50	<–5.00 D	Autorefraction	No	7.4% (6.6-8.3) Men 7.2%, women 7.5%
Africa								
Ezelum, et al.[48]	2011	Nigeria	10,687	≥40	<–5.00	Autorefraction	No	2.1% (1.8-2.4) Excluding significant opacities from the lens: 0.7% (0.5-0.9)

(Continue)

Table 1. Prevalence of high myopia in different regions and ethnic groups *(continued)*

Authors	Year	Population	n	Age	High myopia definition (SE)	Refraction method used	Cycloplegia	Prevalence of high myopia (% and 95% CI)
Europe								
Matamoros, et al.[35]	2015	France	100,429 (Caucasians)	0 to > 80	<–6.00 D	Autorefraction	Not in adults, yes* in children	3.9% (3.8-4.0)
Cumberland, et al.[36]	2015	UK	107,452	40-69	≤–6.00 D	Autorefraction	No	4% (3.9-4.1)
South America								
Cortinez, et al.[70]	2008	Argentina	1,518	25-65	≤–5.00 D ≤–6.00 D	Subjective	No	2.30% 1.60%
Galvis, et al.[71]	2017	Colombia	1,228	8-17	≤–6.00 D	Retinoscopy/ Subjective	No	0.2%

*1% cyclopentolate cycloplegia; ** 0.5% tropicamide cycloplegia.

Discussion

In high myopia there may be progressive anatomical changes that affect the layers of the eyeball. These morphological changes include posterior staphyloma, lacquer cracks, CNV, myopic maculopathy and retinoschisis, among others[21]. Posterior staphyloma is a frequent pathological finding with a great clinical relevance, since its appearance can predict the occurrence of maculopathies, which would irreversibly affect central vision[38].

There are discrepancies in the classification of the stages of a posterior staphyloma. The Ohno-Matsui study proposes an objective classification based on 3D magnetic resonance that includes five types of findings according to the appearance of the edge and the location of the posterior staphyloma, simplifying the subjective classification proposed by Curtin in 1977[39]. This reclassification poses new challenges in research and simplifies its clinical presentation, making monitoring and identification of anatomical changes in the posterior pole more practical.

Regarding the prevalence of high myopia, it varies according to the region and the ethnic group. In this review, prevalence was found from 0.08% in Chinese children[40] to 36.9% in university students in Taiwan[41]. Other reviews have reported that the prevalence in young adults is higher in Asian populations (6.7-21.6%) compared to non-Asian (2.0-2.3%)[9]. Even a US-based study that only included Chinese individuals reported a prevalence of 7.4%[42], much higher than that of other studies conducted in the same country.

After the Asian countries, the highest prevalence has been found in European countries[6]. The few studies conducted in Australia and Latin America report even lower prevalence rates.

The definition of high myopia varies between studies, with values of SE lower than -5.00 or -6.00 D, so the results of research on prevalence may vary. This has been studied in low myopia, in which changes of -0.25 D in its definition make the estimates vary in the analysis of risk factors[43]. However, the impact of the reclassification has not been evaluated for high myopia, although it can be assumed that such a decision would also facilitate the performance of future meta-analysis[33].

Similarly, since there is no single definition of pathological myopia, some studies may have included subjects based only on the dioptric value, without considering the pathologic fundus changes[6]. This is another possible bias if the prevalence figures were to be grouped.

When assessing the prevalence of high myopia in different populations of the world, factors such as race, sex, occupation, income, educational level[44,45], urban or rural housing[46,47], age or the presence of nuclear sclerosis[47] must be considered, so that the rates are properly adjusted. For example, even after controlling for educational level, living in an urban environment continues to be associated with a higher prevalence of myopia of any degree, suggesting that there are other contributing factors[42]. Another difference observed among the populations of the studies was the inclusion of some adult patients with lens opacities, a factor that increases prevalence rates[48].

The rapid increase in the prevalence of high myopia appears to be based on the epidemic of school myopia, and studies suggest that it should be differentiated from high myopia of genetic origin. These two types of high myopia, genetic or acquired, differ in the age of onset and in their relationship with environmental risk factors. High myopia of genetic origin begins at 5 years of age, whereas acquired high myopia is identified at 11 or 12 years of age[49]. Studies suggest that children of 6 or 7 years with school myopia will reach the threshold of high myopia in 5 to 6 years, associated with the increase in educational demands that augment the reading and writing time in indoor spaces and reduce the hours that children are outdoors[50].

Based on animal studies, it has been proposed that the protective effect of the outdoors could be due to the high intensity of natural light (which triggers the release of dopamine, an inhibitor of ocular growth), to the spectral composition of daylight (the exposure to blue light would be protective against the development of myopia) or to increased levels of vitamin D in blood as a result of exposure to UVB radiation[51].

Myopia should be considered as a public health problem, due to its association with different eye diseases that can lead to blindness[2]. The prevalence increase estimated in 2050 has important implications for planning health services in terms of preventing complications and visual loss, since this would affect nearly 1,000 million people worldwide[33].

Several studies have been carried out on the prevalence of high myopia in Asian countries and, according to a meta-analysis[34], there are at least 15 studies in European countries. However, information on populations in the Americas is limited, and they indicate very low figures of high myopia compared to other continents. Therefore, there is a need to conduct population-based studies in Latin America, in different age groups and races, to obtain information for planning preventive public health actions.

Conclusion

The prevalence figures for high myopia vary between geographic regions. The high values identified in Asia pose a greater risk of eye morbidity from retinal disorders that could lead to low vision or blindness. The lack of epidemiological studies on high myopia in Latin American populations is clear.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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