• Investigation •

Prevalence of visual impairment and refractive errors in an urban area of Mexico

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Abstract
● AIM: To determine the distribution of refractive errors in a school-age population in Quintana Roo (Mexico) in the framework of an international cooperation campaign for the prevention of blindness.

● METHODS: A sample of 2647 school-age children (ranging from 5 to 14 years old) with a mean age of 9.1±1.9 years old were tested by trained volunteers for distance visual acuity (VA) and refractive errors. The first screening examination included uncorrected distance visual acuity (UDVA) and VA with a +2.00 D lens. Inclusion criteria for a second complete cycloplegic eye examination performed by an optometrist were UDVA <20/25 (0.10 logMAR or 0.8 decimal) and/or VA with +2.00 D ≥20/25.

● RESULTS: A total of 633 (23.9%) children underwent the second complete eye examination. Mean logMAR UDVA was 0.035±0.094 (range 1.00 to 0.00 logMAR) for the right eyes and 0.036±0.160 (range 1.00 to 0.00 logMAR) for the left eyes. Bilateral amblyopia was found in 17 children (2.7% of refracted eyes; 0.64% of the total). The main reason for visual impairment (VI) in the sample analyzed was found to be refractive errors. In 12 children (1.9% of refracted eyes; 0.45% of the total) the VI was bilateral and 9 (1.4% of refracted eyes; 0.34% of the total) achieved a corrected distance visual acuity of 20/25 or better in both eyes. Mean magnitude of sphere and refractive cylinder was +0.20±0.96 D and -0.43±0.85 D in right eyes, and +0.24±1.08 and -0.43±0.83 D in left eyes. The proportion of myopic eyes [standard equivalent (SE) ≤-0.50 D] was 4.6% of the whole sample (5290 eyes). The mean magnitude of myopia was -0.84±3.44 D for the right eyes and -0.82±5.21 D for the left eyes. The proportion of hyperopic patients (SE≥+2.00 D) was 2.4% (15/633), which corresponded to 0.60% of the whole sample (32/5290 eyes). No statistically significant correlation of age to manifest sphere or cylinder was found.

● CONCLUSION: VI due to uncorrected refractive errors can be easily corrected with glasses but it is still a burden to be treated. Myopia is prevalent in this sample. More efforts towards correcting uncorrected refractive errors are needed.

● KEYWORDS: myopia; hyperopia; refractive error; blindness; visual impairment

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INTRODUCTION

Uncorrected refractive errors (URE) constitute an important major public health problem in the world and continue to be the leading cause of visual impairment (VI)[1]. Global estimation indicates that 122.5 million people suffer VI due to URE[2]. This fact has been found to have a major social and economic impact, including a limitation in educational opportunities[3].

The cost of dealing with VI resulting from URE is very low in proportion to the loss of productivity associated with VI. It is estimated that the annual loss of global gross domestic product due to distance VI caused by URE is US$ 202 000 million[4].

URE are of importance for public health and preventive actions are needed to manage the problem[5], as a high URE burden is associated to a lower socioeconomic status[6]. Given the potential life of a child, a refractive error at a young age may have a lifelong impact[7]. Amblyopia secondary to URE in childhood can lead to visual and also social, educational and economic problems in adulthood[8].

Mexico has a high level of development for the Latin American area with a human development index of (HDI) of 0.774 (77/188)[9]. Quintana Roo is one of the youngest states of Mexico and was rapidly developed as tourist destination in the early 1970s. Despite the substantial growth in tourism, Quintana Roo contributes only 1.34 percent to the national gross domestic product, ranking it at 24 of 31 states. The rapid urbanization of the region has led to a growth of the poor population in the cities, who come searching for opportunities, public services and a place to live[10]. The American and the Caribbean regions have an overall prevalence of blindness of

0.45/1000, although the available data for these region show a wide disparity[11].

In this study, we evaluated the distribution of the refractive errors in school-age children of the suburbs of Cancun (Mexico). Although access to a vision specialist is available in the area, the low income families cannot afford the expenses of a specialist consultation plus the cost of the glasses as this must be covered by the patient, which is impossible for most people living in this area. Volunteers from the non-governmental organization “Vision Without Borders” invited by local associations (“Manos de apoyo y vida” and “Embracing the word Mexico”) screened school children, providing glasses to those needing them.

The aim of this study is to report the prevalence of URE and VI in this specific region. There are few publications regarding the prevalence of refractive error in children in Mexico. A study evaluating the refractive error in different states of Mexico did not include Quintana Roo[12].

SUBJECTS AND METHODS

Ethical Approval The principles outlined in the Declaration of Helsinki were followed. Consent was obtained from the parents for the study after explanation of the nature and possible consequences of the study.

Sample Selection A total of 2942 children attending 4 primary schools in Cancun (Mexico) were enumerated, and of these 2647 (89.9%) were included for eye examination in February 2014 because they were present on the day of the examination. The schools were contacted in advance by local people who informed them about the eye examination campaign.

All parents were informed prior to the date of examination about the eye screening activity and that all children attending the school would be examined during the two weeks of the program. The study was cross-sectional, with the objective of evaluating the prevalence of refractive errors and their impact on VI in the area.

Examination Protocol The protocol for examining the children was divided into two parts. Visual screening was performed on all subjects by a trained non-eye care group of volunteers guided by an optometrist. This test included uncorrected distance visual acuity (UDVA) (E Snellen chart at 5 m), pinhole VA and VA with a +2 D lens. The purpose of assessing VA with a +2 D lens was to detect cases of hyperopia. Patient name, school, class, age and sex were also recorded. The inclusion criteria for a further comprehensive examination was UDVA of 20/25 or worse or VA with +2 D of 20/25 or better.

The second revision was carried out by three experienced optometrists on those children who fulfilled the criteria and included the following: ocular motility, retinoscopy, cycloplegic and subjective refraction and dilated fundus examination. Cycloplegic refraction was measured 30min after instilling 2 drops of 1% cyclopentolate, each administered 5min apart. Additionally, anterior segment integrity was explored by means of a portable slit lamp.

The refractive errors were classified according to the magnitude of the spherical equivalent (SE): sphere+1/2 cylinder. Myopia was classified as a SE ≤-0.50 D, hyperopia as a SE ≥+2.00 D, and astigmatism equal or higher than 0.75 D (minus cylinder form was used)[13].

Children were considered as myopic if one or both eyes were myopic (including antimetropic patients), hyperopic if one or both eyes were hyperopic as long as neither eye was myopic, and emmetropic if neither eye was myopic nor hyperopic[14].

The prevalence of refractive errors was calculated on the assumption that eyes with normal or near-normal vision (VA≥0.8) were emmetropic. This hypothesis was made considering the fact that subjective refraction data were not available for this type of eyes. According to WHO definitions, a logMAR UDVA between 0.5 and 1.0 (between 0.05 and 0.3 in decimals) is considered as VI and logMAR UDVA lower than 0.5 (0.05) as blindness[15].

We define amblyopia as a difference of two lines or more between the two eyes or a corrected distance visual acuity (CDVA) of 20/30 or worse. The term VI comprises category 0 for mild or no VI (VA≥0.3), category 1 for moderate VI (0.3≥VA≥0.1), category 2 for severe VI (0.1≥VA≥0.05), categories 3, 4 and 5 for blindness and category 9 for unqualified VI[16]. We considered VI as a logMAR UDVA between 0.5 and 1.0 (0.05 and 0.3 decimal), which includes moderate and severe VI.

Refraction Notation The spherocylindrical refractions obtained were converted to vectorial notation using the power vector method described by Thibos and Horner. With this procedure, any spherocylindrical refractive error can be enunciated by 3 dioptric powers: M, J_0 and J_{45}, with M being a spherical lens equal to the SE of the given refractive error, and J_0 and J_{45} two Jackson crossed cylinders equivalent to the conventional cylinder. These numbers are the coordinates of a point in a three-dimensional dioptric space (M, J_0, J_{45}). The length of this vector is a measure of the whole blurring strength B of a spherocylindrical refractive error.

In accordance with the power vector method, manifest refractions in conventional script notation [S (sphere), C (cylinder) × φ (axis)] were converted to power vector coordinates and overall blurring strength (B) by the formulas: $M=S+C/2$; $J_0=(-C/2)\cos(2\varphi)$; $J_{45}=(-C/2)\sin(2\varphi)$; and $B=(M^2+J_0^2+J_{45}^2)^{1/2}$.

Statistical Analysis Data analysis was performed using the software SPSS for Windows version 19.0 (IBM, Armonk, NY, USA). Mean, standard deviation (SD) and range for each of

Table 1 Schools visited in the screening campaign performed and the number of children tested in each one

School name	Children screened	Children with VA≥20/25	Refracted by optometrist	Glasses prescribed
Año Del Centenario	764	562	202	26
Enrique Estrella Oxte	846	610	236	29
Pedro Balado	622	461	161	23
Diego Rivera	710	484	226	29
Missing data	-297	-105	-192	0
Total	2645	2012	633	107

Table 2 Summary of the refractive outcomes in conventional and vector notation.

Refractive parameters	Right eye, mean (SD)	Right eye (range)	Left eye, mean (SD)	Left eye (range)
Sphere (D)	+0.20 (0.96)	-4.00 to +12.00	+0.24 (1.08)	-3.25 to +12.50
Cylinder (D)	-0.43 (0.85)	-5.00 to 0.00	-0.43 (0.83)	-5.00 to 0.00
SE (D)	-0.01 (0.89)	-5.00 to +11.25	+0.02 (1.02)	-3.50 to 11.50
J_0	+0.17 (0.43)	-1.75 to +2.46	+0.17 (0.42)	-1.00 to 2.35
J_{45}	-0.01 (0.13)	-0.98 to +0.88	-0.01 (0.11)	-0.87 to +0.64
B (D)	+0.56 (0.85)	0.00 to 11.27	+0.57 (0.96)	0.00 to 11.54

the parameters were calculated. Normality of data samples was confirmed by the Kolmogorov-Smirnov test. The degree of correlation between different clinical variables was assessed using the coefficient of correlation (Pearson or Spearman depending on whether the condition of normality could be assumed). Correlations were considered to be statistically significant when *P*-value was <0.05.

RESULTS

A total of 2647 children (aged 5-14y) with a mean age of 9.1±1.9 years old were screened. Of them, a total of 633 (23.9%) who had a UDVA <20/25 (0.10 logMAR or 0.8 decimal) and/or VA with +2.00 D ≥20/25 underwent a second full eye examination by an optometrist. The gender distribution of the total sample was even, with 51.2% of males. The 40% of subjects were aged 8 or younger. According to the Kolmogorov-Smirnov test, UDVA and CDVA for right and left eyes were not normally distributed (*P*<0.001). Likewise, refractive data (*P*<0.001) were also found to be not normally distributed in our sample.

Table 1 shows the number of school-age children screened, the number of children refracted by optometrists and the glasses prescribed in each school.

Visual Outcomes Mean logMAR UDVA was 0.035±0.094 (range 1.00 to 0.00 logMAR) for the right eyes and 0.036±0.160 (range 1.00 to 0.00 logMAR) for the left eyes. Mean logMAR VA with +2 D was 0.036±0.094 (range 1.00 to 0.00 logMAR) for both eyes of the total sample of children.

An UDVA of 20/25 (0.1 logMAR, 0.8 decimal) or better and 20/200 (1 logMAR, 0.1 decimal) or worse was found in the better eye in 94% and 0.3% of eyes, respectively. VI was found in 23 (0.5%) right eyes and 28 (0.7%) left eyes of the total.

Amblyopia was found in 27 right eyes (2.1% of refracted eyes, 1% of the total) and in 28 left eyes (2.2% of refracted eyes, 1% of the total). Bilateral amblyopia was found in 17 children (2.7% of refracted eyes, 0.64% of the total).

Refractive errors were found to be the main reason for VI in the sample analyzed. Of the 23 children with VI (23/2645, 0.87% of the total) in the right eye and 28 (28/2645, or 0.86%) in the left eye, 16 (69.5%) and 19 (67.8%) right and left eyes achieved a CDVA of 20/25 or better with refractive correction. In 12 children, the VI (12/633 or 12/2645) was bilateral and 9 of these achieved a CDVA of 20/25 or better in both eyes. VI was also caused by retinal problems 2/23 (8.7%) in right and 2/28 (7.1%) left eyes respectively, and unknown causes in 5/23 (21.7%) right and 7/28 (25%) left eyes.

Refractive Outcomes Table 2 summarizes the refractive data in conventional format as well as in vector notation. Mean magnitude of sphere and refractive cylinder was +0.20±0.96 D and -0.43±0.85 D in right eyes, and +0.24±1.08 and -0.43±0.83 D in left eyes.

The proportion of myopic eyes (SE≤-0.50 D) was 19.6% (124/633) for the right eyes and 18.9% (120/633) for the left eyes of the refracted children which corresponded to 4.6% of whole sample (244/5290 eyes). If we consider myopia as a SE≤-0.75 D, then the mean data for both eyes was 12.8% (81/633) and of the total sample 3.1% (162/5290). Mean magnitude of myopia was -0.84±3.44 D for the right eyes and -0.82±5.21 D for the left eyes. The percentage of myopia in the sample according to these further definitions was: SE≤-1.00 D 9.6% (61/633) for the right eye and 9.1% (58/633) for the left eye. A SE≤-3.00 D was found in 0.6% (4/633) in both eyes.

The proportion of hyperopic patients (SE≥+2.00 D) was 2.4% (15/633) for the right eyes and 2.7% (17/633) for the left eyes of the refracted children which corresponded to 0.60%

of the whole sample (32/5290 eyes). If we define hyperopia as SE≥+1.00 D, then the total percentage would be 1.7% (90/5290).

If we define myopia as SE≤-0.50 D (244 eyes) and hyperopia as SE≥+1.00 D (90 eyes), then the incidence of refractive errors was 6.3%.

Refractive astigmatism of 0.75 D or more was present in 22.3% (141/633) of the right eyes (5.3% of the whole sample) and in 23% (146/633) of left eyes (5.5% of the whole sample).

No statistically significant correlation of age with manifest sphere (right eye: r=-0.06, P=0.15; left eye: r=-0.02, P=0.55) or SE (right eye: r=-0.07, P=0.07; left eye: r=-0.04, P=0.29) was found. Likewise, no significant correlation of age with manifest cylinder was found either (right eye: r=-0.02, P=0.63; left eye: r=-0.04, P=0.29).

DISCUSSION

The South American population encompasses a widely diverse group of nations, with some of them suffering significant social differences in the population. In the current study, we have evaluated the prevalence of VI in a child population of Mexico in the suburbs of Cancun (Quintana Roo). This area is especially relevant because a total of 7% of the population live in conditions of extreme poverty according to the annual report of Sedesol (Secretariat of Social Development, Mexico)[17], with no access to specialized eye care services. To our knowledge, this is the first study reporting the outcome of a massive screening visual campaign in this area. Screening programs bring to light an increased knowledge of vision disorders and can help us to manage them[18].

Distribution of Refractive Data According to a Meta-analysis that reviewed 163 articles on refractive error, the prevalence of child myopia SE≤-0.50 D in the Americas was found to be 8.4%, a lower number compared to the prevalence of 19% in our study[19]. In 2003, the prevalence of myopia was studied in a child population aged 12 to 13 years old from Monterrey (Mexico). The authors report a prevalence of myopia SE≤-0.50 D of 44%, whereas bilateral myopia was present in 37% of children in comparison to the prevalence of myopia in our study of 19%. In the total sample, high myopia SE≤-5.00 D was found in 1.4%[20]. This difference may be explained in part by the difference in the age of the children included in each study, with older children included in the Monterrey study. When our results were analyzed for the subgroup of patients of 12 to 13 years old from our sample, the prevalence of monocular and bilateral myopia (SE≤-0.50 D) was 29.5% and 27.9%, respectively. These values were closer to those reported by Villarreal *et al*[20] in an age-matched child population from Monterrey (Mexico).

Concerning the SE, we found in our sample a mean value of -0.01±0.89 D and +0.02±1.02 D in right and left eyes, respectively. These mean values contrast with those found by our research group using the same methodology in other rural areas of different countries (Paraguay, -0.25±1.44 D; Kenya, -0.32±1.36 D)[21-22]. Likewise, Choong *et al*[23] found in a Malaysian young population a mean binocular subjective refraction of -0.62±2.51 D (95%CI -1.07 to -0.16), which is also a higher myopic outcome than our mean SE. The result obtained in our sample may seem contradictory considering the global outcome reported in scientific journals of the myopic epidemy around the world[24]. However, it should be considered that definitions of myopia may differ between studies. Likewise, the prevalence of refractive errors varies significantly when rural and urban populations are compared, suggesting that environmental factors are crucial in the distribution of the refractive errors in a specific population. This has been also confirmed after a careful analysis of the peer-review literature on epidemiology of refractive errors[18].

Mean refractive vector parameters were more hyperopic than those reported in other studies (J_0: 0.17±0.43 D, J_{45}: -0.01±0.13, B: 0.56±0.85 D, right eye; J_0: 0.17±0.42 D, J_{45}: -0.01±0.11, B: 0.57±0.96 D, right eye)[21-22]. In Paraguay, our research group found more negative values for astigmatic power vector components (J_0: -0.08±0.70 D, J_{45}: -0.02±0.29, B: 1.07±1.25 D)[21], as well as in a rural population of Kenya[22].

Prevalence of Myopia and Hyperopia Myopia and hyperopia definitions vary from one paper to another. Some authors prefer to define myopia as SE≤-0.50 D and hyperopia as a SE>+0.50 D[25-26]. However, a bilateral myopia of -0.50 D can prevent a child from seeing the blackboard, whereas a hyperopia of +1.50 D cannot. In our sample, we found a proportion of eyes with SE≤-0.50 D of 19.6% and 18.9% for right and left eyes, respectively (4.6% of the total). The total prevalence is lower than the proportion of 21% found in Los Angeles for children who underwent cycloplegia in a study using the same definition of myopia but in younger children (preschool children of 3-5 years old)[27]. However, as previously mentioned, the prevalence of myopia found in our series was higher than those values reported in other studies performed in the Americas[20,28-29]. Carter *et al*[28] reported a prevalence from 1.2% to 1.4% according to the ethnicity in a study performed in Asuncion, Paraguay. Galvis *et al*[29] found that the prevalence of myopia was higher in urban areas compared to rural ones in Colombia. For 15 year olds the prevalence of myopia SE ≤-0.50 D was 14.7%, lower than that found in our study. In contrast, the prevalence of myopia obtained in our series is lower than values reported in European[30-31] and Asian countries[32-33].

Besides some differences in the way of reporting refractive errors between studies, other factors such as exposure to risk factors may account for this. One of these factors is time spent outdoors[34] which may be a critical issue for this higher prevalence of myopia in the Mexican area evaluated. This hypothesis should be confirmed in future studies on the prevalence of myopia in Mexico. One additional finding confirming a differential behavior compared to European and Asian countries is the absence of correlation between age and refractive errors, with no higher levels of myopia concentrated in older groups of children.

Concerning, the proportion of hyperopes, defined as an SE≥+2.00 D, this was 0.6% in our total sample (2.5% of the refracted eyes). This percentage was slightly higher than that reported by our research group in a rural area of Paraguay[21] (0.2%) using the same definition of hyperopia, and lower than that found in another rural area of Kenya (4%)[22].The prevalence of hyperopia in our population was consistent with that reported in Asian countries[35-36], but lower than prevalence reported in other American countries[29]. Specifically, a recent Meta-analysis showing global and regional estimates of prevalence of refractive errors, indicated that the estimated prevalence pool (EPP) in children with hyperopia was 4.6% (95%CI: 3.9-5.2). Specifically, the EPP of hyperopia ranged from 2.2% in South-East Asia to 14.3% in the Americas[19].

Prevalence of Visual Impairment Refractive error was the main reason for VI in the sample studied, as in other rural areas of other countries evaluated by our research group[21-22]. This confirms that most VI in the area evaluated is avoidable only by prescribing and providing spectacle correction. This contrasts with the outcomes reported in other low income countries, with ocular comorbidities such as glaucoma being one of the main factors associated to VI. Alabi *et al*[37] identified in schoolchildren from the Ogun State of Nigeria that the most common ocular morbidities associated to VI were refractive errors 39.7%, high/asymmetrical vertical cup-to-disc ratio (suggestive of glaucomatous optic neuropathy) 33.5%, allergic conjunctivitis 19.2%, corneal opacity 2.7% and lenticular opacity 2.2%.

Regarding amblyopia, the percentage reported in our study (around 1%) was consistent with that reported in other Asian[38] and American countries[21]. Xiao *et al*[39] using data from the multi-country refractive error study in children found that the prevalence of amblyopia varied with ethnicity and was highest in Hispanic children (1.43%), of this only 0.17% being bilateral, compared to our sample with 0.64% of bilateral amblyopia.

Limitations and Final Conclusions This study has some drawbacks, such as its design. A population-based study would have been a more suitable design. However, given the lack of information about the distribution of refractive errors in the area evaluated, we believe that our data can be of interest for the scientific community.

In conclusion, the main cause of VI in schoolchildren from the Quintana Roo region of Mexico was the presence of refractive errors, with a minimal incidence of ocular comorbidities and amblyopia. The prevalence of refractive errors was consistent with global estimates, showing a higher proportion of myopes than hyperopes. However, the prevalence of refractive errors in the sample evaluated was lower than those values reported in other low-income countries.

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