ORIGINAL INVESTIGATION

Refractive Error of Students (15- to 18-year-olds) in Northwest Mexico

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SIGNIFICANCE: We assessed the prevalence of refractive error in a sample of children of Northern Mexico using the Refractive Error Study in Children protocol of the World Health Organization, which allows for the comparison with other global studies.

PURPOSE: Uncorrected refractive error is the main cause of visual impairment in children. The purpose of this study was to assess the refractive error and visual dysfunctions of students (15 to 18 years old) in the upper-middle school system of Sinaloa, Mexico.

METHODS: A total of 3468 students in Sinaloa's high school system participated in the study from 2017 to 2019. Optometrists and student clinicians from the Optometry Program of the Autonomous University of Sinaloa conducted the testing. Tests included visual acuities and static retinoscopy. We did not use a cycloplegic agent.

RESULTS: The results showed a high prevalence of uncorrected refractive errors. Myopia, defined as a refractive error ≤–0.50 D, had a prevalence of 36.11% (95% confidence interval, 33.47 to 38.83%); hyperopia, defined as a refractive error ≥+2.00 D, had a prevalence of 1.49% (95% confidence interval, 0.09 to 2.33%); and astigmatism, defined as a refractive error with a cylinder ≥0.75 D, had a prevalence of 29.17% (95% confidence interval, 26.60 to 31.76%). We found a significant effect of sex on visual acuity.

CONCLUSIONS: Our results are consistent with a high prevalence of myopia reported in adolescents worldwide and in Mexico's northern regions. The results suggest that students attending high school and entering universities should be required to have an optometric eye examination. Additional studies are needed to investigate the prevalence of refractive errors in children in Mexico.

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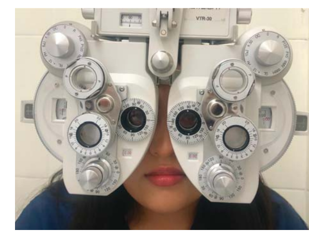

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One of the most prevalent, although treatable, visual impairments in the world is uncorrected refractive error.[1] Poor visual health impacts a teenager's life in multiple ways, affecting not only their school performance but also their overall development.[2] Because of a global increase in myopia prevalence, there has been a growing interest in the prevalence of refractive errors and other visual problems.[3–5] In the United States, refractive errors affect approximately one-third of people 40 years or older.[6] Similarly, 33.1% of the population 20 years or older have myopia (95% confidence interval, 31.5 to 34.7%).[7] The Latin population in the United States is also affected by these visual problems, having an overall prevalence of uncorrected refractive errors of 15.1%. This high prevalence is limited not only to the United States but also throughout Latin America.[8]

The availability of information on the prevalence of visual impairment in the Mexican population is scarce. Villarreal et al.[9] found a myopia prevalence of 44% in a sample population of 12- and 13-year-old adolescents in Northern Mexico. Conducted 17 years ago, this was the first study of refractive error prevalence in Mexico. Garcia-Lievanos et al.[10] performed a study on the refractive status of subjects aged 6 to 12 years, where the prevalence of myopia (spherical equivalent ≤–0.50 D), hyperopia (spherical equivalent ≥+0.50 D), and astigmatism (cylinder ≥1.50 D) were 9.7% (95% confidence interval, 6.52 to 13.07%), 4.4% (95% confidence interval, 2.14 to 6.66%), and 5.4% (95% confidence interval, 2.91 to 7.89%), respectively. These outcomes were better than those reported by Villarreal et al.[9] The differences in the subject's age ranges and demographics might explain discrepancies between these studies. Gomez-Salazar et al.[11] reported a myopia prevalence of 39.6% in Mexican subjects between 10 and 19 years old. However, they did not use representative samples of the general population because they included subjects examined in health clinics as their subjects. The government of Mexico has implemented programs to address visual impairments in children. One of these programs involves institutions that provide free eyeglasses for low-income subjects. These program's efforts are focused mainly on children at the basic educational level (<11 years old), and their outcomes are yet unknown. Because these programs addressed early childhood groups, we focused on student population in the upper-middle and high educational levels of the state, examining the prevalence of refractive errors and other visual problems using an internationally validated protocol.

The Refractive Error Study in Children (RESC)[12] is a standardized clinical protocol that provides a useful framework to evaluate children's refractive error prevalence and visual health. Moreover, it is a robust clinical protocol used to compare the prevalence of myopia among different populations and countries. It has been implemented in Iran,[13] Ghana,[14] Chile,[3] Tunisia,[15] Ireland,[16] and Saudi Arabia,[17] among many others. Regarding Latin America, RESC was implemented in Chile in 2018,[18] which found a refractive error prevalence of 14.70% in subjects 5 to 19 years old attending public schools in the urban areas of La Florida (Santiago metropolitan region) and Concepción (Biobío region). Another protocol implemented in 10 Colombian districts in 2018 found that myopia was present in 14.7% of 15-year-old teenagers.[19] However, there is a lack of information on the general prevalence of refractive errors in Latin America, which hinders the development of advancements that may improve its population's visual health.

This study assessed students' refractive status and ocular health in the upper-middle and higher secondary educational levels of Sinaloa, Mexico. Our project is the first epidemiological study conducted on students' visual problems in Mexico using an international protocol endorsed by the World Health Organization.

METHODS

We evaluated 3468 subjects (1913 female and 1555 male) with a median age of 16 years and an age range of 15 to 18 years from four high schools in Sinaloa. The study was carried out from September 2017 to December 2019 and involved the three schools' entire student populations. We based our study on the RESC protocol.[12] We did not use cycloplegic agents to perform refractions. The study followed the Declaration of Helsinki principles and was approved by the Autonomous University of Sinaloa's institutional review board. We obtained informed and written consent from all subjects and their parents before the evaluation.

We obtained the subjects' refractive status with streak retinoscopy. An experienced optometrist or an optometric intern performed the retinoscopy. The fixation target was a logMAR chart, which was located 6 m away from the subject. Each eye was tested separately. The subject's glasses (if wearing any) were measured with a lensmeter (GJD-6 Manual Lensmeter; Vision-Star, Chongqing, China). Subjects wore a blurring lens over their habitual correction or the uncorrected eye if no glasses were worn, +2.00 D when retinoscopy was done at 50 cm or +1.50 D when done at 67 cm. The opposite eye was also fogged with the same blurring lens (from +1.50 to +3.00 D). We followed the RESC guidelines to define refractive errors. Subjects presenting with a spherical equivalent ≤–0.50 D were considered myopic, those with a spherical equivalent ≥+2.00 D were considered hyperopic, and those with a cylinder ≥0.75 D were designated as astigmatic. We measured visual acuity with a logMAR chart 3 m away from the subjects.[20] Three visual acuity evaluations per subject were performed: without correction, with a pinhole, and with correction. The term "with correction" was used when the subjects used their habitual glasses. In another case, the acuity was reported as "without correction" or "with pinhole." These evaluations were implemented monocularly with an occluder to cover one eye each time. Subjects failed if the distance visual acuity was equal to or less than 20/40 (≥0.3 logMAR).[20] Finally, we included a questionnaire to characterize population demographics and visual health.

Stata (version 14; Stata, College Station, TX) and R statistics packages (version 1.3.1.1093; R statistics, Auckland, New Zealand)[21] were used to perform logistic, ordered-logistic, and mixed-effects regression analyses. We used the Wilcoxon rank sum test with continuity correction to evaluate data with nonparametric distributions. The Jonckheere-Terpstra test was used to compare refractive errors with an ordinal variable. Values with $P \leq .05$ were considered statistically significant.

RESULTS

Fig. 1 shows the refractive status of the subjects. Fig. 1A shows the proportion of the distribution of the refractive errors found in subjects wearing no habitual correction. Likewise, Fig. 1B shows the distribution of the refractive errors found in subjects who currently wear glasses. Fig. 1C presents the proportion of subjects who

1. currently wear glasses with appropriate prescriptions;
2. have no glasses but need them (refractive error ≤–0.5 D);
3. wear outdated glasses (refractive error ≤–0.50 D);
4. have no glasses and no significant refractive error.

The percentage of subjects with myopia was 36.11% (confidence interval, 30.45 to 35.70%), and that with hyperopia was 1.49% (confidence interval, 0.09 to 2.33%). Astigmatism was detected in 29.27% (confidence interval, 26.6 to 31.76%). Moreover, the proportion of subjects who did not have glasses but needed them (refractive error more myopic than ≤0.5 D) was 13.32% (confidence interval, 11.50 to 15.32%). Similarly, the proportion of subjects who had outdated glasses was 13.40% (confidence interval, 11.57 to 15.40%). Meanwhile, 43.21% (confidence interval, 40.47 to 46.00%) do not need glasses because they have emmetropic eyes. We did not find any significant association between refractive errors and age (Jonckheere-Terpstra test: JT = 1,073,846, P = .57) or sex (Jonckheere-Terpstra test: JT = 784,840, P = .99). We also found no significant differences in refractive errors among the schools (Kruskal-Wallis test: χ^2 = 2.5, P = .47).

We found that a large proportion of subjects, 24.36%, had bilateral myopia (Table 1), which was defined as refractive error more myopic than ≤–0.50 D in both eyes. However, only 47% (397 subjects) used glasses during the study among the subjects with bilateral myopia. Subjects with clinically significant myopia, which was defined as refractive error more myopic than ≤–0.75 D in at least one eye, represented 27.91% of the population, wherein 53% (513 subjects) of them wore glasses during the evaluation and the remaining subjects (454 subjects) who presented with clinically significant myopia did not have glasses. Last, subjects with high myopia, which was defined as refractive error more myopic than ≤–5.00 D in at least one eye, represented only 2.36% of the study population, wherein 6% (5 students) did not have glasses during the study.

Visual Acuity

Uncorrected visual acuities of 20/32 or better in the better eye were found in 68.21% (n = 2355) of subjects. Meanwhile, 33% (n = 1144) of subjects had vision impairment (uncorrected vision of 20/40 or worse in the better eye). Of the 1144 subjects with vision impairment, only 228 (20%) wore glasses and achieved normal vision. Out of the remaining 1144 subjects, 779 achieved normal

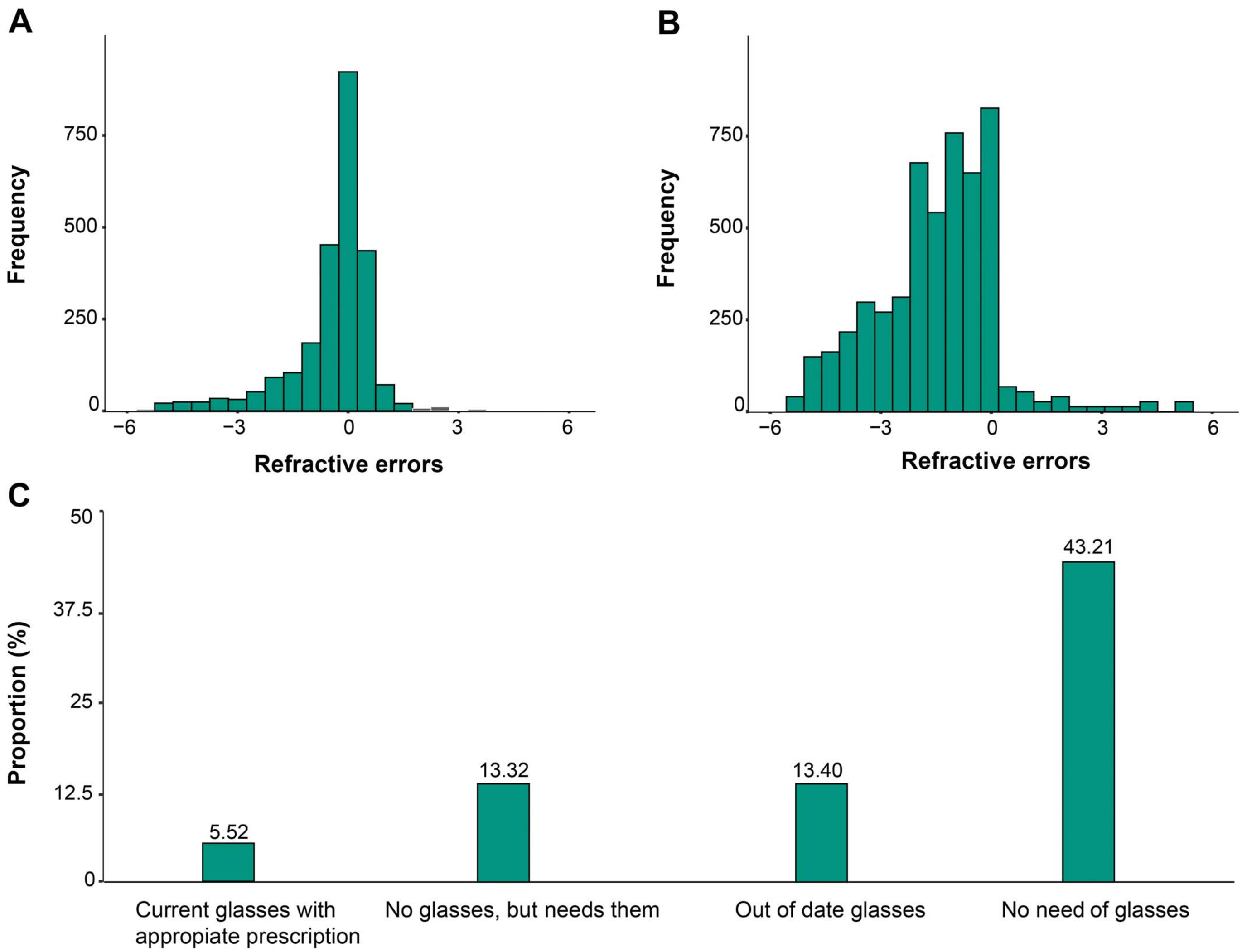

FIGURE 1. Uncorrected (A) and corrected (B) refractive errors of students and the proportion of subjects (C) who (1) currently wear glasses with appropriate prescriptions, (2) have no glasses but need them, (3) wear outdated glasses, and (4) have no glasses and no significant refractive error.

vision after correction. The percentage of corrected refractive errors (n = 3468) is shown in Appendix Table A1, available at http://links.lww.com/OPX/A533.

Most subjects had significantly improved visual acuity when using the pinhole occluder or their correction glasses for the right eye (paired t test, t_{442} = 18.56; P < .0001; mean [standard

TABLE 1. Percentage of uncorrected refractive errors (n = 3468)

Group	Definition	Total (%)	Male	Female
Myopia	SE ≤−0.50 D in at least one eye	36.11 (95% CI, 33.47–38.83)	14.66 (95% CI, 12.76–16.73)	21.45 (95% CI, 19.22–23.81)
Bilateral myopia	SE ≤−0.50 D in both eyes	24.36 (95% CI, 22.02–26.82)	9.93 (95% CI, 8.34–11.71)	14.43 (95% CI, 12.54–16.48)
Clinically significant myopia	SE ≤−0.75 D in at least one eye	27.91 (95% CI, 25.46–30.47)	11.27 (95% CI, 9.58–13.14)	16.64 (95% CI, 14.63–18.80)
High myopia	SE ≤−5.00 D in at least one eye	2.36 (95% CI, 1.60–3.36)	1.02 (95% CI, 0.05–1.74)	1.34 (95% CI, 0.01–2.13)
Hyperopia	SE ≥+2.00 D in at least one eye	1.49 (95% CI, 0.09–2.33)	0.36 (95% CI, 0.27–1.23)	0.86 (95% CI, 0.43–1.54
Astigmatism	Cylinder ≥0.75 D in at least one eye	29.17 (95% CI, 26.60–31.76)	11.75 (95% CI, 10.0–13.76)	17.42 (95% CI, 15.3–19.6)
Emmetropia	−0.50 < SE < +0.50 D in at least one eye	61.11 (95% CI, 58.37–63.81)	27.76 (95% CI, 25.30–30.31)	33.35 (95% CI, 30.76–36.03)

CI = confidence interval; SE = spherical equivalent.

deviation], 0.17 [0.021] vs. 0.43 [0.006] characters without it) and left eye (paired *t* test; $t_{380} = 13.59$; $P < .001$; mean [standard deviation], 0.17 [0.02] vs. 0.38 [0.02] characters without it).

Next, we applied mixed-effects regressions for each visual test, using the refractive status and demographic data as predictors (age and sex) and the eye as the random effect. We found a significant effect of refractive status and sex on the visual acuity tests. Female subjects obtained a worse visual acuity for both left ($z = 2.14$; $P = .03$) and right ($z = 3.38$; $P = .001$) eyes. As expected, visual acuity for both eyes is significantly better for subjects wearing their own glasses ($z = 8.70$; $P < .001$) and those who had worn them for longer periods ($z = 11.60$; $P < .001$).

DISCUSSION

In this study, we assessed students' refractive errors in the upper-middle and higher school system (15 to 18 years old) of Sinaloa, Mexico, using a protocol based on the RESC protocol of the World Health Organization. To date, no study had examined the prevalence of visual problems within this specific group using the said World Health Organization protocol.

Our results showed that 36.11% of Sinaloa subjects had myopia, yet more than 67.56% did not wear glasses. Moreover, we found that 13.32% of subjects in the study did not have glasses but needed glasses to correct significant refractive errors. Also, 13.40% of them had glasses but still presented with significantly uncorrected refractive errors.

The student's refractive error analysis showed an uncorrected myopia prevalence of 36.11%. This result is consistent with global reports of an increase in myopia's prevalence[4,22,23] and is similar to the reported prevalence of myopia in the United States.[7] A prevalence of 44% of myopia had already been reported in the Northern Mexican region.[9] In Chile, a refractive error prevalence of 5.8% was reported in 2010,[3] which increased to 14.7% in 2018.[18] Similarly, a refractive error prevalence of 14.70% was reported in Colombia.[19] As the results show, visual acuity is not a precise instrument to be used as an indicator of visual impairments. The proportion of subjects with visual acuity 20/20 and who present a spherical equivalent different from +0.00 D is 38%, which is explained in terms of the eye's accommodation ability. However, visual acuity is still being used by many visual programs in Mexico to screen for visual dysfunctions in children. We recommend using a better procedure, such as the RESC protocol. Further studies can be performed to test this hypothesis.

Using noncycloplegic refraction, the proportion of subjects with hyperopia in Northwest Mexico was 1.49%. Similarly, Quek et al.[24] found a 1.5% prevalence of hyperopia after they did a study on a population in Singapore with the same age ranges as those in the current study. Likewise, in Ghana, hyperopia was found to affect 0.3% of subjects aged 12 to 15 years.[14] Similarly, the prevalence of hyperopia in subjects aged 12 to 20 years in Saudi Arabia was 2.2%.[17] A higher prevalence might have been identified using cycloplegic refraction, as was shown by Villarreal et al.,[9] who found hyperopia in 6% of children 12 to 13 years of age. Moreover, other studies around the world have observed higher values of hyperopia using a cycloplegic agent. In South Brazil, the prevalence of hyperopia was 13.4% in children from 6 to 12 years old.[25] A hyperopia prevalence of 13.1% was reported in a Polish population (6 to 18 years old).[26] A study in Australia found a prevalence of 13.2% of hyperopia in children from 6 to 12 years old.[27] Harrington et al.[28] reported a prevalence of 25% of hyperopia in Irish children from ages 6 to 7 years and from 12 to 13 years.

The proportion of subjects with astigmatism found in the current study is high. A total of 29.17% of the study population was found to suffer from this visual disorder. This is comparable with the 32% prevalence of astigmatism in Equatorial Guinea found by Soler et al.[29] In South America, astigmatism was found to affect 27% of the Chilean population.[3] In Singapore, astigmatism reached a prevalence of 36.6%.[24] Meanwhile, in 2003, Villarreal et al.[9] found astigmatism to be prevalent in 9.5% of subjects in Northern Mexico. These data are interesting and worth noting because they suggest an increase in this refractive error proportion. However, differences in the ages of the subjects in both studies must be taken into consideration. We should recall that the previous studies were also performed with the RESC protocol, which allows us to compare the results.

The visual health of children should be a priority of educational authorities. The high percentage of refractive errors observed needs to be addressed because such visual problems directly impact these young student's learning capacity, academic performance, and social development.[30,31]

CONCLUSIONS

Myopia was found in 36.11% of the current study's population, close to the maximum value of the refractive error in Mexico (44%) and Latin America (14.70%).[18] These are among the highest in the world. These results highlight the potential vision problems in this particular sample student population in Northern Mexico.

Educational authorities should promote visual health care by carrying out periodic visual health checkups for the civilian population. This is already being applied in many universities. Once visual problems are determined, palliative measures must be taken.[32] Refractive problems can be resolved with access to optometric care and with the provision of free eyeglasses or eyeglasses at a low cost.[33,34] These measures would positively impact the quality of life of the students and enable them to achieve their social and developmental potentials.[30,35–37]

ARTICLE INFORMATION

Supplemental Digital Content: Appendix Table A1, available at http://links.lww.com/OPX/A533, lists the percentage of corrected refractive errors in the subjects examined.

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