



Research Article

# Prevalence of Refractive Error and Visual Impairment in the Guna Indians of Panama

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## Abstract

**Background:** The Guna Indians, an indigenous group in Panama, face significant health disparities. The prevalence of refractive error and vision impairment have not been studied in this population and compared to other demographic groups. **Purpose:** To assess the prevalence of refractive error, visual impairment, and blindness among the Guna Indians in the Guna Nega community of Panama City. **Materials and methods:** A quantitative descriptive study was performed involving 638 Guna Indians. Presenting Visual Acuity (PVA) was measured using standard logMAR charts. Refractive errors were assessed through static and subjective retinoscopy, with cycloplegic refraction applied to children under 18 years. Myopia was defined as a Spherical Equivalent (SE) refractive error of  $\leq -0.50$  D, hyperopia as  $SE \geq 2$  D, and astigmatism as a cylinder  $\geq 1$  D. Visual impairment and blindness were classified according to World Health Organization criteria. **Results:** The prevalence of myopia was (40.4%), hyperopia (5.9%), and astigmatism (36.6%). The prevalence of visual impairment was 41.1%, while blindness was observed in 2.5% of the population. Myopia was most prevalent in individuals aged 21 to 40 years, hyperopia in those aged 51 to 70 years, and astigmatism in both the 21 to 30 years and 61 to > 81 years age groups. The prevalences of the refractive errors did not differ among the sexes, but they were greater than the global rates. **Conclusions:** The prevalence of refractive error, visual impairment, and blindness among the Guna people exceeds that of the global population and represents the highest rates among indigenous groups in Latin America.

**Keywords:** Myopia; Hyperopia; Astigmatism; Vision impairment, Latin America; Indigenous

## Introduction

Visual impairment and blindness are significant public health concerns worldwide, impacting individuals' quality of life and affecting economic stability. Globally, the prevalence of visual impairment is 7.0% (95% CI 6.5 to 7.6), and that of blindness is 0.55% (95% CI 0.48 to 0.68) [1]. Uncorrected refractive errors are the leading cause of visual impairment and the second leading cause of blindness worldwide [2-5].

The indigenous population of Latin America total approximately 58 million people in the region (10% of the population) and 12% of the Panamanian population [6]. Indigenous populations often

experience health disparities, including limited access to eye care services, which can exacerbate the prevalence of uncorrected refractive errors and visual impairment [7,8]. Despite their vulnerability to visual health issues, limited research exists on the prevalence of refractive errors and visual impairment among indigenous populations in the Americas [8]. A few studies have reported higher rates of refractive error and visual impairment among indigenous groups than among nonindigenous populations, yet no comprehensive study has been conducted among the Guna Indians, the second-largest indigenous group in Panama [9-15].

This study aimed to determine the prevalence of refractive error and visual impairment among the Guna Indians of Panama City. We employed the categories of visual impairment recommended by the World Health Organization [16] and defined refractive

error based on the spherical equivalent, as used in most refractive error studies [17]. Additionally, we specifically determined the refractive error among the children in our sample under cycloplegia for greater validity, in line with the recommended protocol [18]. The outcomes of this research are expected to provide valuable insights into the eye health status of the Guna Indian community, shedding light on their specific visual needs and informing targeted interventions. By addressing the unmet visual health needs of indigenous populations such as the Guna Indians, we can work toward achieving more equitable access to eye care services and ultimately improve their quality of life and economic well-being.

## Materials and Methods

The Inter American University of Puerto Rico Institutional Review Board approved the project (1602789-1). Adult participants and parents of participating children provided written informed consent before enrolment and after the study protocol had been explained to them. For children older than seven years, assent was also obtained. The study followed the tenets of the Declaration of Helsinki for research on human subjects.

## Study design and population

This is a quantitative descriptive study of refractive error and visual impairment in an indigenous community in Panama. The indigenous community lives in Guna Nega, a complex of approximately 125 houses in Panama City. There are approximately 1,500 indigenous people in Guna Nega, approximately 1,000 of whom are Gunas. The sample included 638 participants who self-identified as members of the Guna Indians, among whom 380 (59.6%) were examined from May 25 to May 27, 2022, while the remaining 258 participants (40.4%) were examined from August to December 2022.

Two teams examined the participants. The first team included six faculty members from the Inter American University of Puerto Rico School of Optometry (5 optometrists, one ophthalmologist, and one optician) and 15 advanced optometry students. The second team included four faculty members (3 optometrists and one ophthalmologist) and 18 advanced optometry students from the University of Las Americas of the Panama optometry program.

## Ocular examination protocol

The protocol for the ocular examination included assessments of distance (6 m) and near (40 cm) visual acuities using standard logMAR charts. Patients underwent autorefractometry (Quick See<sup>®</sup> in children and Retinomax 3<sup>®</sup> in adults) and static and subjective refraction examinations with portable phoropters. The phoropters had a spherical range between +20 D and -20 D and a negative cylinder range from -0.25 D to -6.00 D. All children (between 1 and 17 years of age) underwent cycloplegic refraction; cycloplegia

was achieved by the initial instillation of 0.5% proparacaine hydrochloride followed by two drops of 1% cyclopentolate hydrochloride 5 minutes apart.

The outcomes were the prevalence of refractive error, visual impairment, and blindness. Refractive errors, including myopia and hyperopia, were defined using the Spherical Equivalent (SE), which was determined as  $SE = \text{sphere} + 0.5 \times \text{cylinder}$ . Myopia was defined as an  $SE \leq -0.50$  D, hyperopia was defined as an  $SE \geq +2.0$  D, and astigmatism was defined as a cylinder  $\geq 1$  D. Visual impairment was defined based on the World Health Organization's recommendations, which use the Presenting Visual Acuity (PVA) [16], the visual acuity of the patient upon presentation to the examination. If the person shows up to the examination with eyeglasses or contact lenses, the PVA is taken with the correction in place; otherwise, the PVA can be considered the unaided visual acuity if the person presents without correction. This definition allows us to compare the results with those of previous studies.

## Statistical analysis

The main demographic variables were analyzed using descriptive statistics (mean, median, standard deviation). Since the distribution of refractive error was not normal, we used primarily nonparametric tests in our analyses. The Kruskal–Wallis test was used to determine any significant differences in the spherical equivalent of the refractive error among the age groups [19]. The two-sample Mann–Whitney rank-sum test was used to determine whether there were significant differences in the prevalence of the spherical equivalent of the refractive error (myopia, hyperopia) or astigmatism) between males and females. Independent chi-square tests of independence were used to determine the associations between the prevalence of refractive errors (myopia, hyperopia, and astigmatism) and age groups. The prevalence values in the present study were compared to the findings of other studies using the binomial test. All the statistical analyses were performed using IBM SPSS<sup>®</sup> version 29 software [20]. The level of statistical significance was set at 5%.

The prevalence of refractive error, visual impairment, and blindness in our study were compared to those of other studies. Since the criteria for refractive error can differ among studies, our results were recalculated using these criteria. We used the independent chi-square test to determine if the prevalence (as a proportion) significantly differed at the 5% level.

## Results

The Pearson product–moment correlation coefficient between the spherical equivalent of the refractive error of the right eye and that of the left eye was  $r=0.86$ ,  $p<0.001$  [95% confidence interval (CI) 0.83–0.88]. According to Cohen's standard, this correlation indicates a large effect [21]. Therefore, we used the right eye as

a valid representation of the refractive error of each participant in the statistical analysis.

**Distribution of participants by sex and age**

This study recruited six hundred thirty-eight participants who self-identified as members of the Guna indigenous community. Four hundred nineteen (65.7%) were females, and two hundred nineteen (34.5%) were males. The mean age of the participants was  $40.7 \pm 22.3$  years, while the median age was 42.5 years. The youngest participant was 1 year old, and the oldest was 92 years old (range 91 years). Table 1 shows the distribution of participants by sex and age group.

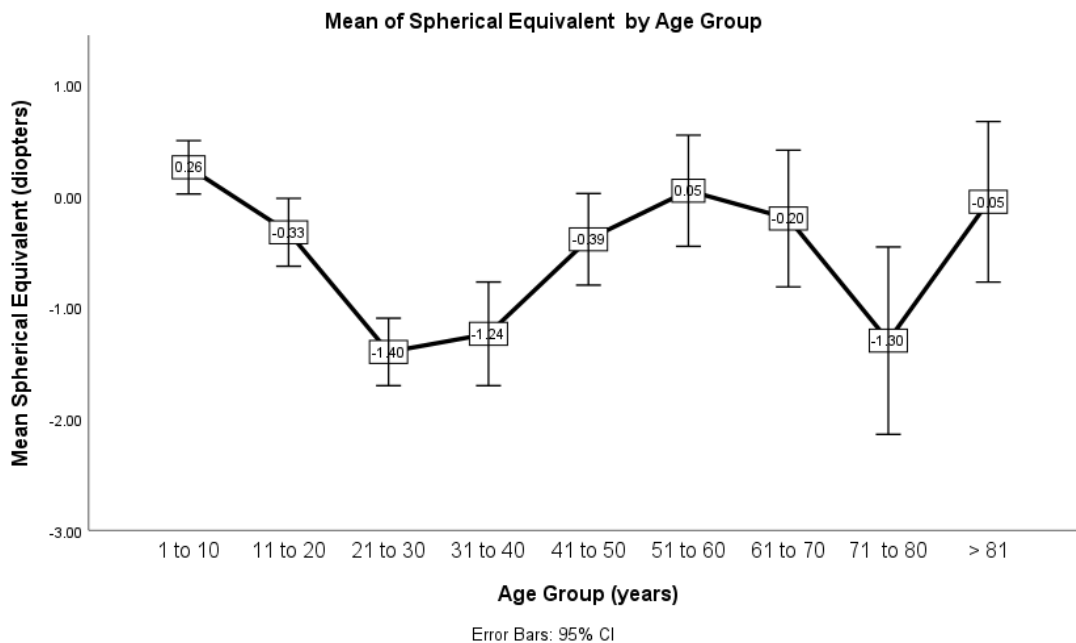
| Age group | Sex         |               | Total, n (%) |
|-----------|-------------|---------------|--------------|
|           | Male, n (%) | Female, n (%) |              |
| 1–10      | 27 (12.3)   | 35 (8.4)      | 62 (9.7)     |
| 11–20     | 30 (13.7)   | 64 (15.3)     | 94 (14.7)    |
| 21–30     | 18 (8.2)    | 70 (16.7)     | 88 (13.8)    |
| 31–40     | 8 (3.7)     | 52 (12.4)     | 60 (9.4)     |
| 41–50     | 34 (15.5)   | 67 (16)       | 101 (15.8)   |
| 51–60     | 38 (17.4)   | 59 (14.1)     | 97 (15.2)    |
| 61–70     | 31 (14.1)   | 42 (10)       | 73 (11.4)    |
| 71–80     | 23 (10.5)   | 19 (4.5)      | 42 (6.6)     |

|   |           |           |           |
|---|-----------|-----------|-----------|
| > 81  | 10 (4.6)  | 11 (2.6)  | 21 (3.3)  |
| Total   | 219 (100) | 419 (100) | 638 (100) |
| n = Number of participants by age group and sex |           |           |           |

**Table 1:** Distribution of participants by age group and sex.

**Spherical equivalent of the refractive error by age group and sex**

Four hundred and two participants (63%) had no previous eye exam. Ninety-eight participants (15.4%) had distance or near correction during testing. The mean SE refraction by age group is shown in Figure 1. The Kruskal–Wallis test revealed that the SE refraction significantly differed between age groups ( $\chi^2(8)=107.91$ ,  $p<.001$ ). Pairwise comparisons between the age groups using Dunn’s procedure with Bonferroni’s correction revealed that the 21- to 30-year age group was significantly more myopic than the 1- to 20-year and 41- to 70-year age groups ( $p<0.05$ ). The individuals in the 1- to 20-year age groups were significantly more hyperopic than those in the 21- to 40-year age group ( $p<0.05$ ). The 31-to-40-year age groups were significantly more myopic than the 41- to 60-year age groups were ( $p<0.05$ ). Finally, the 51- to 60-year age group was significantly more hyperopic than the 71- to 80-year age group ( $p<0.05$ ). The two-sample Mann–Whitney rank-sum test revealed that the spherical equivalent was not significantly different between the sexes ( $U=43852$ ,  $z=-1.29$ ,  $p=.196$ ).



**Figure 1:** Spherical equivalent of the refractive error (diopters) by Age groups (years).

### Prevalence of refractive error among the Guna people

A reliable measure of the refractive error was obtained for 609 participants. Twenty-nine patients had ocular conditions (principally cataracts and significant pterygia) that hindered the determination of their refractive error. Based on the SE of the refractive error, 40.4% (95% CI 36.6–44.3) of the Guna participants had myopia (SE equal to or less than -0.50 D), 5.9% (95% CI 4.3–8.1) had hyperopia, and 36.6% (95% CI 32.9–40.5) had astigmatism (Table 2).

| Age group (n) | Myopia, n (%) | 95% CI    | Hyperopia, n (%) | 95% CI    | Astigmatism, n (%) | 95% CI    |
|---------------|---------------|-----------|------------------|-----------|--------------------|-----------|
| 1–10 (60)     | 7 (11.7)      | 5.5–22.5  | 1 (1.7)          | 0.0–9.7   | 17 (28.3)          | 18.4–40.8 |
| 11–20 (93)    | 31 (33.3)     | 24.6–43.4 | 3 (3.2)          | 0.7–9.5   | 26 (28)            | 19.8–37.9 |
| 21–30 (87)    | 62 (71.3)     | 61.0–79.8 | 0 (0)            | 0.0–5.1   | 38 (43.7)          | 33.7–54.2 |
| 31–40 (56)    | 36 (64.3)     | 51.1–75.6 | 1 (1.8)          | 0.0–10.3  | 21 (37.5)          | 26.0–50.6 |
| 41–50 (101)   | 34 (33.7)     | 25.2–43.4 | 3 (3)            | 0.7–8.7   | 29 (28.7)          | 20.8–38.2 |
| 51–60 (94)    | 21 (22.3)     | 15.0–31.8 | 10 (10.6)        | 5.7–18.7  | 35 (37.2)          | 28.1–47.3 |
| 61–70 (67)    | 26 (38.8)     | 28.0–50.8 | 15 (22.4)        | 14.0–33.8 | 28 (41.8)          | 30.7–53.7 |
| 71–80 (34)    | 21 (61.8)     | 45.0–76.1 | 2 (5.9)          | 0.7–20.1  | 20 (58.8)          | 42.2–73.7 |
| > 81 (17)     | 8 (47.1)      | 26.2–69.0 | 1 (5.9)          | 0.0–2.9   | 9 (52.9)           | 31.0–73.8 |
| Total (609)   | 246 (40.4)    | 36.6–44.3 | 36 (5.9)         | 4.3–8.1   | 223 (36.6)         | 32.9–40.5 |

n = Number of participants by age group, CI = Confidence interval

**Table 2:** Prevalence of myopia, hyperopia, and astigmatism by age group.

Table 3 shows the prevalence of refractive error (myopia, hyperopia, and astigmatism) in the Gunas group compared to other indigenous groups in the Americas. We found nine studies of refractive error in the indigenous populations of the Americas. The criteria for refractive error and the age ranges were different across these studies. To compare our results with the results of these investigations, the prevalence of refractive error among the Guna people was recalculated using each study’s refractive criteria and age ranges (Table 3). We used the independent chi-square test to determine if the prevalences (as proportions) were significantly different.

| First author and year     | Subjects                                | Number of participants | Country  | Age range | Definition myopia | Prevalence myopia % (95% CI) | Our study (Gunas) % (95% CI) | Definition hyperopia | Prevalence hyperopia % (95% CI) | Our study (Gunas) % (95% CI) | Definition astigmatism | Prevalence astigmatism % (95% CI) | Our study (Gunas) % (95% CI) | Significance   |
|---------------------------|---|------------------------|----------|-----------|-------------------|------------------------------|------------------------------|----------------------|---------------------------------|------------------------------|------------------------|-----------------------------------|------------------------------|--|
| Carter, 2013 <sup>9</sup> | Indigenous Macca children (cycloplegia) | 118                    | Paraguay | 5–16      | SE $\leq$ -0.5 D  | 0 (0.0–3.4)                  | 18 (12.0–26.0)               | SE $\geq$ 2 D        | 32.2 (24.4–41.1)*               | 3.4 (1.1–8.8)                | Cylinder $\geq$ 1 D    | 12.7 (7.8–20.0)                   | 25.6 (18.6–34.3)*            | Guna children have more myopia and astigmatism and less hyperopia than Macca children. |

|                                    |   |      |        |       |                 |                      |                          |                |                      |                      |                      |                         |                          |   |
|------------------------------------|---|------|--------|-------|-----------------|----------------------|--------------------------|----------------|----------------------|----------------------|----------------------|-------------------------|--------------------------|---|
| Thorn, 2005 <sup>10</sup>          | Indigenous Brazilians (cycloplegia)                 | 259  | Brazil | 12–59 | SE<br>≤ -1<br>D | 2.3<br>(0.9–<br>5.1) | 33.3<br>(28.9–<br>39.6)* | SE<br>≥ 2<br>D | 5.4<br>(3.2–<br>8.9) | 3.5<br>(2.0–<br>5.8) | Cylinder<br>≥ 1 D    | 15<br>(11.2–<br>20.0)   | 35.1<br>(30.6–<br>39.8)* | Gunas have more myopia and astigmatism and the same hyperopia as indigenous Brazilians. |
| Pensyl, 1997 <sup>11</sup>         | Indigenous Sioux (cycloplegia < 14 years)           | 130  | USA    | 0–40  |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1 D    | 46.2<br>(37.8–<br>54.7) | 36.6<br>(32.9–<br>40.5)* | Gunas have less astigmatism than Sioux  |
| Pensyl, 1997 <sup>11</sup>         | Indigenous Sioux children (cycloplegia < 14 years)  | 77   | USA    | < 19  |                 |                      |                          |                |                      |                      | Cylinder<br>> 1 D    | 44.2<br>(33.6–<br>55.3) | 29.2<br>(22.3–<br>37.1)* | Guna children have less astigmatism than Sioux children.                                |
| Adler-Grinberg, 1986 <sup>13</sup> | Indigenous Sioux of all ages (no cycloplegia)       | 1886 | USA    | 0–62+ |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1 D    | 39.1<br>(36.9–<br>41.3) | 36.5<br>(32.8–<br>40.5)  | Gunas the same astigmatism as Sioux   |
| Harvey, 2006 <sup>22</sup>         | Indigenous Tohono O’odham children (no cycloplegia) | 1326 | USA    | 5–16  |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1 D    | 34.7<br>(32.2–<br>37.3) | 25.6<br>(18.6–<br>34.3)* | Guna children have less astigmatism than Tohono O’odham children.                       |
| Dobson, 2008 <sup>23</sup>         | Indigenous Tohono O’odham children (no cycloplegia) | 972  | USA    | 4–13  |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1 D    | 42.6<br>(39.5–<br>45.7) | 26.6<br>(19.6–<br>35.0)* | Guna children have less astigmatism than Tohono children                                |
| Mohindra, 1977 <sup>12</sup>       | Indigenous Zuni children (no cycloplegia)           | 382  | USA    | 6–8   |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1.25 D | 45.3<br>(40.4–<br>50.3) | 39.3<br>(23.5–<br>57.6)  | Guna children have the same astigmatism as Zuni children                                |
| Mohindra, 1977 <sup>12</sup>       | Indigenous Navajo children (no cycloplegia)         | 337  | USA    | 6–8   |                 |                      |                          |                |                      |                      | Cylinder<br>≥ 1.25 D | 37.1<br>(32.1–<br>42.4) | 39.3<br>(23.5–<br>57.6)  | Guna children have the same astigmatism as Navajo children                              |

CI: Confidence interval; Notes: \*P<0.05 for the independent chi-square test for the prevalence of myopia, hyperopia, and refractive astigmatism compared with Gunas.

**Table 3:** Comparison of the prevalence of myopia, hyperopia, and refractive astigmatism among indigenous groups and the Guna people of Guna Nega (Panama).

### Refractive status by age group and sex

We conducted the independent chi-square test to determine whether the prevalence of the different refractive statuses (myopia, hyperopia, and emmetropia) was independent of age group (9 levels). All assumptions of the test were met: all cells had expected values greater than zero, and 81.5% of the cells had expected frequencies of at least five. The results were significant ( $\chi^2(16) = 138.8, p < .001$ ): myopia was more frequent than expected in the 21- to 40-year age group, while hyperopia was more frequent than expected in the 51- to 70-year age group.

The chi-square test was used to determine whether the prevalence of astigmatism was independent of age group. The results indicated statistical significance ( $\chi^2(8) = 19.35, p = .01$ ); astigmatism was more frequent than expected in the 21- to 30-year and the 61- to >81-year age groups. The prevalence of myopia (alpha.05,  $U = 6150, z = -0.69, p = .49$ ), hyperopia (alpha.05,  $U = 159.5, z = -0.07, p = .948$ ), and astigmatism (alpha.05,  $U = 5711.5, z = -0.12, p = .901$ ) was similar between males and females according to the two-tailed Mann–Whitney U test.

### Visual impairment

Visual acuity data were obtained for 633 of the 638 Guna participants. According to the World Health Organization (WHO) criteria, 276 (41.1%) patients were visually impaired, and 16 (2.5%) were blind (Table 4).

| Category of visual impairment           | Number of participants, n (%) | 95% CI    |
|---|-------------------------------|-----------|
| None ( $\geq 20/40$ )                   | 357 (56.4)                    | 52.5–60.2 |
| Mild ( $< 20/40$ to $\geq 20/63$ )      | 118 (18.6)                    | 15.8–21.9 |
| Moderate ( $< 20/63$ to $\geq 20/200$ ) | 134 (21.2)                    | 18.2–24.5 |
| Severe ( $< 20/200$ to $\geq 20/400$ )  | 8 (1.3)                       | 0.6–2.5   |
| Total visual impairment                 | 260 (41.1)                    | 37.3–45.0 |
| Blindness ( $< 20/400$ )                | 16 (2.5)                      | 1.5–4.1   |
| Total                                   | 633 (100)                     |           |

n=Number of participants, CI=Confidence Interval

**Table 4:** Visual impairment and blindness among Guna participants (Based on the eye with the best presenting distance visual acuity).

Table 5 compares the prevalence of visual impairment and blindness between the Guna people and other indigenous groups of the Americas using the data from four published studies of indigenous populations of the Americas that used the presenting visual acuity to determine visual impairment and blindness, as recommended by the WHO [16]. However, the visual impairment and blindness criteria used in those studies differed from those recommended by the WHO. The studies also used populations with age ranges different from ours. To compare our results with those of these four studies, we recalculated visual impairment using the criteria and age ranges of each study (Table 5).

| First author and year              | Subjects  | Number of participants | Country                  | Age range | Definition of vision impairment | Prevalence vision impairment % (95% CI) | Our study (Gunas) | Definition of blindness | Prevalence blindness % (95% CI) | Our study (Gunas) |
|------------------------------------|---|------------------------|--------------------------|-----------|---------------------------------|---|-------------------|-------------------------|---------------------------------|-------------------|
| Fernandes, 2021 <sup>24</sup>      | Indigenous (Xingu)                                  | 2099                   | Brazil                   | 0–45+     | $< 20/32$ to $\geq 20/400$      | 8.3 (7.1–9.5)                           | 52.4 (48.5–56.2)* | $< 20/400$              | 1.8 (1.3–2.4)                   | 2.5 (1.5–4.1)     |
| Jimenez-Corona, 2014 <sup>14</sup> | Indigenous (Chiapas)                                | 512                    | Mexico                   | $\geq 20$ | $< 20/60$ to $\geq 20/400$      | 10 (6.9–14.3)                           | 24.9 (21.2–28.9)* | $< 20/400$              | 0 (0.0–3.8)                     | 3.3 (1.9–5.3)*    |
| Carter, 2013 <sup>9</sup>          | Indigenous (Asunción)                               | 117                    | Paraguay                 | 0–17      | $< 20/40$                       | 6 (2.7–12.0)                            | 18.1 (12.3–25.8)* |                         |                                 |                   |
| McClure, 2009 <sup>15</sup>        | Native Americans/Alaska Natives (Pacific Northwest) | 414                    | United States of America | $\geq 40$ | $\leq 20/40$                    | 12.8 (9.9–16.4)                         | 66.4 (61.2–71.2)* | $\leq 20/200$           | 0.5 (0.1–1.54)                  | 9.1 (6.4–12.6)*   |

CI: Confidence Interval; Notes: \*  $P < 0.05$  for the independent chi-square test of independence for the prevalence of visual impairment and blindness.

**Table 5:** Prevalence of visual impairment and blindness among indigenous groups of the Americas and the Guna of Guna Nega (Panama).

## Discussion

### Comparison of refractive error among the Gunas to global refractive error estimates

The estimated global prevalence of myopia in children under 20 years of age, according to the criterion of a cycloplegic SE  $\leq$  -0.5 D, was 11.7% (95% CI 10.5 to 13.0) [25]. The prevalence among Guna children of the same age and using the same criteria was significantly greater ( $p < 0.001$ ), at 24.3% (95% CI 18.0 to 32.0). For adults over 30 years of age, according to the criterion of SE  $<$  -0.5 D, the estimated global prevalence of myopia is 26.5% (95% CI 23.4 to 29.6). For Gunas in the same age group and using the same refractive criteria, the prevalence is significantly greater ( $p < 0.001$ ), at 35.8% (95% CI 31.1 to 40.8). A tendency toward increasing myopia from early childhood to adolescence has been observed in other studies [17,26-36]. Among the Gunas, the trend toward myopia persists until the fourth decade. A second trend toward myopia in the 71- to 80-year age group is likely related to cataract formation [37].

### Comparison of refractive error between the Gunas and other indigenous groups of the Americas

Two previous refractive error studies involved indigenous populations in Latin America. Both studies used the cycloplegia refraction for the paediatric participants. In children 5 to 16 years of age, we found a significantly greater prevalence of myopia and refractive astigmatism in the Guna children than in the Macca children of Paraguay. We found significantly less hyperopia among the Guna children than among the Macca children [9]. Among individuals aged 12 to 59 years, our results revealed a significantly greater prevalence of myopia and refractive astigmatism in the Guna population than in the Brazilian indigenous population, while there was no significant difference in the prevalence of hyperopia [10]. There are seven refractive studies involving indigenous populations in the United States addressing refractive astigmatism. Only one study used cycloplegia when assessing refractive error in children [11]. A study on 130 Sioux in the United States revealed significantly more refractive astigmatism among participants of all ages and participants aged at least 19 years than among Gunas of the same age ranges [11]. However, a study with a larger sample of 1886 Sioux patients aged 0 to 62 years indicated that the prevalence of refractive astigmatism was comparable to what we observed among the Guna peoples [13]. Two studies among Tohono O'odham children (5 to 16 years and 2 to 15 years) also showed that significantly more had refractive astigmatism with respect to the Guna children in our study [22,38]. A study involving young Zuni and Navajo children (6 to 8 years old) yielded a similar prevalence of refractive astigmatism to what we observed among Guna children [12].

The above studies indicate that Gunas have a greater prevalence of myopia and refractive astigmatism than the two mentioned indigenous groups in the Latin American region. However, refractive astigmatism is equally or less likely than among the four indigenous groups in the United States described above.

### Comparison of refractive error between the Gunas and nonindigenous groups in Latin America

The prevalence of myopia among Guna children under cycloplegia between 5 and 17 years of age was 19.7% (95% CI 13.5 to 27.7), which is not significantly different from that of a sample of same-aged children assessed under cycloplegia in Puerto Rico, 20.7% (95% CI 19.2 to 22.2). However, the prevalence of astigmatism among the Guna children was 27.1% (95% CI 19.9 to 35.6), which was significantly greater ( $p < 0.001$ ) than that among nonindigenous Puerto Rican children (10.4%, 95% CI 9.3 to 11.5) [17].

The prevalence of myopia among the Guna children between 6 and 18 years of age was 22.5% (95% CI 16.1 to 30.5), which was significantly greater ( $p < 0.001$ ) than the 14.6% (95% CI 13.3 to 15.9) prevalence among children from Northwest Mexico. Among those with a cylinder equal to or greater than 0.75 D, Gunas had a prevalence of myopia of 68.9% (95% CI 56.4 to 79.1), which is significantly greater ( $p < 0.001$ ) than the prevalence of 18.6% (95% CI 17.2 to 20.1) among Mexican children. Regarding hyperopia (an SE equal to or greater than 1 D), the prevalence among the Guna children was 14.0% (95% CI 8.9 to 21.1), which was significantly greater ( $p < 0.001$ ) than the prevalence among Mexican children (3.2%; 95% CI 2.6 to 4.0). However, the Mexican study only used cycloplegia in children with poor distance visual acuity ( $\leq$  20/40), which may have led to an underestimation of the prevalence of hyperopia in that group [39].

Among adults aged  $\geq$ 40 years, the prevalence of myopia (SE  $<$  -0.5 D) among the Gunas was significantly greater ( $p < 0.001$ ) (30.9%, 95% CI 26.1 to 36.2) than that among adults in Puerto Rico (14.7%, 95% CI 12.4 to 17.3). In the same age group, the prevalence of hyperopia (SE  $>$  0.5 D) among the Gunas was 35.9% (95% CI 30.9 to 41.3), which was significantly lower ( $p < 0.001$ ) than the 51.5% (95% CI 48.0 to 55.0) prevalence among adults in Puerto Rico. The prevalence of astigmatism (Cylinder  $\geq$  1 D) among the Gunas was 76.6% (95% CI 71.6 to 80.9), which was significantly greater ( $p < 0.001$ ) than that among adults in Puerto Rico (69.6%, 95% CI 66.3 to 72.8) [40].

In summary, Guna children and adults have a greater prevalence of refractive astigmatism than the values reported in Latin American refractive error studies. The prevalence of myopia in Guna children is similar to or greater than that in nonindigenous children. Finally, the prevalence of myopia in Guna adults is greater than that in the adult clinical population of Puerto Rico.

Myopia could be considered a pandemic condition, with a predicted prevalence of 50% by 2050 [41,42]. Genetic and environmental factors contribute to the risk of myopia, such as Asian ancestry, long periods of near work, decreased time outdoors, and a high-fat diet [43,44].

Several factors are potentially related to the high prevalence of myopia among the Gunas. The ancestors of the indigenous populations of the Americas came from Asia [45]. The original diet in San Blas included seafood and coconuts, which the Guna people found nearby when they arrived. However, the scarcity of some traditional ingredients and loss of traditional knowledge have increased the consumption of processed foods high in fat and instant beverages high in sugar [46]. The native environment of the Gunas is the San Blas Islands, which have open seashores. At Guna Nega, they live in a densely populated and closed environment, with up to 12 people per home. Children are exposed to traditional schools, decreasing their time outdoors. Further research should seek to clarify the associations of these factors with the prevalence of myopia among Gunas.

High myopia is associated with retinal detachment, glaucoma, myopic macular degeneration, and cataracts [47]. Guna children are particularly vulnerable to myopia progression, which should be mitigated through ophthalmic and pharmacologic treatments to avoid the development of high myopia during adolescence [48,49]. Guna children should receive annual visual examinations to determine their refractive status and ocular health.

The estimated global prevalence of astigmatism, using the criterion of a cylinder of more than 0.5 D, was 14.9% (95% CI 12.7 to 17.1) in children less than 20 years of age [25]. The prevalence among Guna children of the same age and using the same criterion was significantly greater ( $p < 0.001$ ), at 41.0% (95% CI 33.2 to 49.1). Astigmatism in children can significantly impact their reading and visual information processing [23,50].

Among adults over 30 years of age, the global prevalence of astigmatism of more than 0.5 D was 40.4% (95% CI 34.3 to 46.6) [25]. In the Guna sample, the prevalence of this astigmatism in the same age range was significantly greater ( $p < 0.001$ ), at 51.8% (95% CI 46.7 to 56.8). As shown in other studies, the Gunas in our study demonstrated a greater prevalence of astigmatism among older individuals (those above 61 years of age). In adults, uncorrected astigmatism is related to visual phenomena such as haloes, glare, diplopia, and decreased quality of life [51].

The global prevalence of hyperopia in those under 20 years of age, according to the  $SE \geq 2D$  criterion, is 4.6% (95% CI 3.9 to 5.2) [25]. Among the Gunas in our study, the prevalence of hyperopia in those under 20 years of age who met the same refractive error

criterion was not significantly different, at 2.8% (95% CI 0.84 to 7.2). Among adults over 30 years of age and using the criterion of  $SE \geq 0.5 D$ , the global prevalence of hyperopia was 30.6% (95% CI 26.1 to 35.2) [25]. The Gunan participants of the same age range and meeting the same criterion demonstrated a significantly greater hyperopia prevalence ( $p < 0.001$ ), at 37.4% (95% CI 32.6 to 42.4).

In summary, Gunan children and adults were significantly more likely to be myopic and astigmatic than the global population. In contrast, compared to the global population, while Gunan adults were significantly more likely to be hyperopic, Gunan children had approximately the same prevalence of hyperopia. Providing primary eye care and ophthalmic correction can significantly increase the productivity and quality of life of indigenous people [15,52].

### **Comparison of visual impairment between the Gunas and the worldwide population**

The prevalence of visual impairment among the Gunas was 41.1% (95% CI 37.3 to 45.0), approximately six times greater than that of the overall global population (7.0%, 95% CI 6.5 to 7.6). The prevalence of blindness in the Guna sample was 2.5% (95% CI 1.5 to 4.1), approximately 4.5 times that of the global population (0.55%, 95% CI 0.48 to 0.61) [1].

### **Comparison of visual impairment between the Gunas and other indigenous groups of the Americas**

Table 5 summarizes the prevalence of visual impairment among Gunas relative to other indigenous groups of the Americas. Among children aged 0 to 17 years, Guna children had a significantly greater prevalence of visual impairment than did indigenous children of Paraguay [9]. Across all age groups, the Gunas had a significantly greater prevalence of visual impairment than did the indigenous groups from the Xingu Indigenous Park in Brazil, while no differences were observed in terms of the prevalence of blindness [24]. Among adults above 20 years of age, Gunas had a greater prevalence of visual impairment and blindness than did the Chiapas indigenous group in Mexico [14]. Among adults over 40 years of age, Gunas also had a greater prevalence of visual impairment and blindness than did American Indians and Alaskan Natives from the Pacific Northwest [15].

In summary, the prevalence of visual impairment in our sample of Gunas was significantly greater than that in any other Latin American or North American indigenous group. The prevalence of blindness among the Gunas was greater than that of a Mexican Chiapas indigenous group but lower than that of the Brazilian Xingu indigenous group.



## Comparison of visual impairment between the Gunas and the Panamanian population

A study using the Rapid Assessment of Avoidable Blindness (RAAB) survey in Panama revealed that among people 50 years of age and older, the prevalence of moderate and severe visual impairment was 13.1% (95% CI 12.1 to 14.2), while that among our Panamanian Guna sample population in this age group was 31% (95% CI 25.6 to 37.1), which was significantly greater than that reported in the RAAB study ( $p < 0.001$ ). For adults in the same age group, the RAAB study revealed a prevalence of blindness of 4.5%, 3.0% (95% CI 2.5 to 3.6), which was not significantly different from that of the Guna sample (4.5%, 95% CI 2.4 to 8.0) [53].

The Gunas had a significantly greater prevalence of visual impairment than other indigenous groups of Latin America. They also had a greater prevalence of visual impairment than the overall Panamanian population and the global population.

## Conclusions

The Gunas in the Guna Nega community of Panama have one of the highest prevalences of myopia and astigmatism worldwide; they also demonstrate one of the highest prevalences of visual impairment globally. The indigenous people of Panama suffer significant health disparities. The life expectancy is nine years less than that of the nonindigenous population (72 versus 63.2 years); furthermore, approximately 98% of these indigenous peoples live in poverty, and 86% live in extreme poverty [54]. Panama invests approximately 8.1% of its gross domestic product in health, which is below the median for countries in the Americas [55]. Panama's public health system covers most citizens but does not offer eye care services (exams or eyewear) [56].

Eye health promotes the achievement of the United Nations Sustainable Development Goals [57,58]. The provision of eye care services increases work productivity, income, and educational outcomes and care also helps reduce poverty and hunger [1,59]. Therefore, the provision of eye care services to the Guna and other indigenous populations should be a priority within the public health system of Panama.

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## Ethical Guidelines

This study was approved by the Institutional Review Board (IRB) of the Inter American University of Puerto Rico School of Optometry, in accordance with the ethical principles outlined in the Declaration of Helsinki. This approval ensures that the rights and welfare of human subjects involved in the research were protected, and that the study complies with all relevant federal and state regulations.

## Conflict of Interest

The authors have no conflict of interest to disclose related to the study.

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