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Children's Ocular Components and Age, Gender, and Ethnicity

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Abstract

Purpose—This cross-sectional report includes ocular component data as a function of age, gender, and ethnicity from the Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study.

Methods—The ocular components of 4881 school-aged children were examined using cycloplegic autorefractometry (refractive error), keratometry (corneal curvature), ultrasonography (axial dimensions), and videophakometry (lens curvature).

Results—The average age ($\pm$ SD) was 8.8 ± 2.3 years, and 2458 were girls (50.4%). Sixteen percent were African American, 14.8% were Asian, 22.9% were Hispanic, 11.6% were Native American, and 34.9% were White. More myopic/less hyperopic refractive error was associated with greater age, especially in Asians, less in Whites and African Americans. Corneal power varied slightly with age, with girls showing a greater mean corneal power. Native-American children had greater corneal toricity with a markedly flatter horizontal corneal power. Anterior chambers were deeper with age, and boys had deeper anterior chambers. Native-American children had the shallowest anterior chambers and Whites the deepest. Girls had higher Gullstrand and calculated lens powers than boys. Boys had longer vitreous chambers and axial lengths, and both were deeper with age. Native Americans had the longest vitreous chambers and Whites the shortest.

Conclusions—Most ocular components showed little clinically meaningful variation by ethnicity. The shallower anterior chambers and deeper vitreous chambers of Native-American children appeared to be offset by flatter corneas. The relatively deeper anterior chamber and shallower vitreous chambers of White children appeared to be offset by steeper corneas. Asian children had more myopic spherical equivalent refractive errors, but for a given refractive error the ocular parameters of Asian children were moderate in value compared to those of other ethnic groups. Asian children may develop longer, myopic eyes more often than other ethnic groups, but the eyes of Asian emmetropes do not appear to be innately longer.

Keywords

hyperopia; myopia; refractive error; ocular components; children; astigmatism

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The Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study is a multi-center, observational investigation of ocular and refractive development in schoolchildren. It is an extension of the Orinda Longitudinal Study of Myopia (OLSM), which was a cohort study designed to investigate normal eye growth and to assess risk factors for the onset of myopia.¹ There was one major limitation of the OLSM. The study sample consisted of predominantly non-Hispanic Whites, which made it impossible to generalize the study results to the United States pediatric population as a whole. Study sites were added to increase ethnic diversity in the study sample including African-American children in Eutaw, Alabama; Asian children in Irvine, California; Hispanic children in Houston, Texas; and Native-American children near Tucson, Arizona. The Native-American cohort's data were not available until after the publication of the original CLEERE baseline paper;¹ thus, the purpose of this paper is to present the distribution of refractive error and the ocular dimensions from the baseline examination by age, gender, and ethnicity for the entire CLEERE cohort as well as for the original OLSM cohort.

Methods

The study was supported through a cooperative agreement with the National Eye Institute of the National Institutes of Health, Department of Health and Human Services. The protocol was approved by the institutional review boards for the six participating sites (University of Alabama at Birmingham; University of California, Berkeley; University of Houston; The Ohio State University; Southern California College of Optometry; and the University of Arizona). A parent or guardian of each study patient gave written informed consent, and study subjects gave assent.

By design, each of the study sites concentrated on recruiting and examining children from a specific ethnic group. The investigators selected schools to participate based on their proximity to the study site and the ethnic distribution of the children enrolled at each school. Once the schools were selected, all children in the first through the eighth grades, regardless of ethnicity, were invited to participate. Recruitment was slightly different in Arizona. There, all of the schools in and around the Tohono O'odham Nation with a high percentage enrollment of Tohono O'odham children were invited to participate, and all schools accepted the invitation. All children in the first through eighth grades were invited to participate at two of the six schools. At the remaining four schools, children in the first and second grades were not invited to participate because they were already participating in an ongoing study of visual development.² At these four schools, all children in the third through eighth grades were invited to participate.

Each eligible child received an enrollment packet consisting of a letter of introduction, an informed consent form, and a medical history form to be taken home from school. Parents gave consent and children provided assent before the children were examined.

Date of birth and ethnicity were included on the medical history form completed by the parents of study subjects. Parents selected one of the following six race/ethnicity designations (corresponding to the categories used by the National Institutes of Health at the time): American Indian or Alaskan Native; Asian or Pacific Islander; black, not of Hispanic origin; Hispanic; white, not of Hispanic origin, and other, or unknown. When parents designated two or more of any of the ethnic categories, the child was designated as belonging to the target ethnic group at that site (e.g., if the parent checked both white and Hispanic and the child was enrolled at the Houston site, the child was coded as Hispanic). This amended assignment occurred for 2% of the children. If neither of the two reported ethnic categories corresponded to the target ethnic group at that site, the child was designated as belong to the non-White ethnic group (0.6% of children). If parent-supplied data were missing or "other" was designated, ethnicity data were

used as generated by the clinical site personnel (designations: black, Asian, Hispanic, Native-American, or white) based on their observations of the child or responses by the child to questions about their parents' countries of birth. The clinicians' ethnic designation was used for only 2% of the children in this report.

Gender was recorded by the examiner. All measurements were made on the right eye only. Cycloplegia was obtained by using one drop of proparacaine 0.5% (to minimize the discomfort of the cycloplegic drops), followed by two drops of tropicamide 1%, separated by five minutes for light irises (Seddon grade 1 and 2).⁵ For dark irises (Seddon grade 3 and 4), one drop of proparacaine 0.5% and one drop of tropicamide 1.0% immediately followed by one drop of cyclopentolate 1% were instilled. All subjects tested in Orinda, California were cyclopleged with two drops of tropicamide 1% only instilled five minutes apart after one drop of proparacaine 0.5%. The protocol using the iris color grading and cyclopentolate 1% was added after the OLSM was initiated in order to provide adequate cycloplegia with children with dark irises.⁶ Measurements were made 25 to 30 minutes after instillation of the first cycloplegic drop.

Cycloplegic refractive error was measured by autorefraction (Canon R-1 through 2000, Grand Seiko WR-5100K from 2001 on). The Grand Seiko has been reported to give significantly more hyperopic values than the Canon R-1, with a mean difference $\pm$ SEM of $0.43 \text{ D} \pm 0.04 \text{ D}$.³ Each clinic's autorefractor was checked regularly for drift using model eyes, and the maximum deviation for any device of either type was 0.34 D .¹ The Grand Seiko autorefractor has been reported to compare well with subjective refraction, with a mean difference of $0.14 \text{ D} \pm 0.35 \text{ D}$, $p = 0.67$.⁴ Comparison of 67 consecutive cycloplegic subjective refractions by one of the authors (JDT) with Grand Seiko autorefractors on the same subjects showed no significant differences between the two methods of measurement ($0.07 \text{ D} \pm 0.37 \text{ D}$, $p = 0.11$; unpublished data).

Ocular components compared in this report include vertical corneal power, horizontal corneal power, corneal toricity, anterior chamber depth, crystalline lens thickness, crystalline lens equivalent index of refraction, Gullstrand crystalline lens power, calculated crystalline lens power, vitreous chamber depth, and axial length. The detailed methods for measurement of the ocular components have been described elsewhere.¹ In brief, corneal power was measured using the Alcon Auto-Keratometer (Alcon Systems Inc., St. Louis, MO). Corneal toricity is defined as the difference between the corneal power in the vertical minus the horizontal meridian (i.e., positive values were with-the-rule). Anterior chamber depth, lens thickness, vitreous chamber depth, and axial length were measured using A-scan ultrasonography (Allergan-Humphrey A-scan model 820, San Leandro, CA) in semi-automatic mode. Corneal anesthesia (one drop of proparacaine 0.5%) was necessary for A-scan ultrasonography. Crystalline lens radii of curvature were obtained using videophakometry.⁷ Gullstrand lens power is the equivalent lens power calculated using those radii of curvature and Gullstrand-Emsley schematic eye values. An equivalent index of refraction was calculated for each child in an iterative process to produce an equivalent crystalline lens power that created agreement between the data from phakometry, the axial components from ultrasound, corneal power, and the measured refractive error. Calculated lens power is the equivalent lens power calculated using radii of curvature from phakometry and each child's individual index of refraction.¹

Sample Size for Analysis

In total, 4929 children were enrolled in this study. Forty-eight children were excluded from these analyses because the child's parent or guardian selected an ethnic category that did not fall into one of the five main ethnic groups, leaving a total of 4881 subjects. Furthermore, in the ANOVA/ANCOVA models, subjects were excluded if their subgroup, defined by age, gender and ethnicity, had fewer than 10 subjects (Table 1).

Statistical Methods

The data entry, verification of the data, and the construction of datasets were conducted by the Optometry Coordinating Center at The Ohio State University College of Optometry. A double data entry system was used and any data discrepancies were verified against the original data sheet. All statistical analyses were performed using SAS software version 9.1 (SAS Institute, Cary, NC). Analysis of variance (ANOVA) methods were used to compare spherical equivalent refractive error among categories of age, gender, and ethnicity. Analysis of covariance (ANCOVA) models were used to assess the relationship of age, gender, and ethnicity with each ocular component using spherical equivalent refractive error as the covariate. This method allows for comparisons of the levels of age, gender, and ethnicity while equalizing the effect of refractive error on each component. The inclusion of refractive error as a covariate in each model ensures that any observed differences in ocular components by ethnicity are not the result of underlying differences in refractive error distribution. Initial models included all possible interactions of the three factors of interest; however, non-significant interactions ($p > 0.01$) were removed from the final model. The significance level was set at 0.01 instead of the more typical 0.05 because of multiple comparisons between the various age, gender, and ethnic subgroups. To control the overall alpha level for multiple comparisons, post-hoc pair-wise *t*-tests were performed using the methods described by Tukey, when appropriate, or the more conservative methods described by Bonferroni.

Given the large amount of data available for analysis, there was a risk of finding statistically significant differences that would not be considered clinically meaningful, so clinically meaningful differences in each ocular component were determined *a priori*. For the purposes of these analyses, a clinically meaningful difference was defined as 0.50 D or more of spherical equivalent refractive error, corneal power, and corneal toricity, 0.1 mm or more in crystalline lens thickness, 0.75 D or more in crystalline lens power, 0.003 in crystalline lens equivalent index of refraction, 0.20 mm or more in vitreous chamber depth or axial length, and 0.1 mm or more in anterior chamber depth.

To achieve smoothed curves for data presentation, mixed linear modeling techniques were used to model the relationship between each ocular component and age, gender, and ethnicity. Interactions of age, gender, and ethnicity identified in the ANCOVA were included in the modeling.

Results

Table 1 presents a distribution of the 4881 subjects, as a function of age, gender, and ethnicity. The average age ($\pm$ standard deviation [SD]) was 8.8 ± 2.3 years and slightly more than half (50.4%) were girls. Sixteen percent were African American, 14.8% were Asian, 22.9% were Hispanic, 11.6% were Native American, and 34.9% were White. Tables 2 through 12 contain descriptive statistics (mean $\pm$ standard deviation) for each of the ocular components as a function of age, gender, and ethnicity. Table 13 summarizes the findings from all ANCOVA models examining the effects of age, gender and ethnicity on each ocular component.

The mean refractive error was more myopic/less hyperopic at older ages. Differences in spherical equivalent refractive error among the age groups depended on ethnicity (ANCOVA, interaction $p < 0.0001$). Figure 1 depicts the relationship between age and ethnicity. The refractive error differs among ethnic groups at all age groups ($p < 0.01$ for all comparisons). Across all ethnicities, there was a shift in refractive error in the direction of more negative power (more myopic/less hyperopic) with age ($p < 0.02$ for each ethnic group). Asian children showed the greatest association between more myopic/less hyperopic refractive error and age. There was no difference in refractive error between boys and girls ($p = 0.16$).

Corneal power in the horizontal meridian did not differ significantly among age groups ($p=0.22$). There was a slight age effect in the vertical meridian in the direction of less power ($p=0.003$). Corneal power in both meridians differed significantly by gender ($p<0.001$) and ethnicity ($p<0.001$). Regardless of age or ethnicity, girls showed a greater mean corneal power when compared to boys (vertical meridian: 44.27D vs. 43.52D, $p<0.001$; horizontal meridian: 43.17D vs. 42.49D, $p<0.001$); these differences were clinically meaningful. As shown in Figure 2, regardless of age or gender, there were differences among ethnic groups in corneal power in the vertical and in the horizontal meridians. A clinically meaningful difference in the mean corneal power of the vertical meridian was observed between Native-American and Asian children, with Asian children showing greater corneal power in the vertical meridian (difference=0.52 D, $p<0.0001$). Differences in mean corneal curvature in the horizontal meridian between Native-American children and children from each of the other four ethnic groups were both statistically significant and clinically meaningful (differences ≥ 1.1 D, $p<0.0001$ for each comparison). In addition, White children had greater corneal power in the horizontal meridian when compared with all other ethnic groups (differences ≥ 0.50 D, all $p<0.0001$).

Figure 3 displays the relationship between age and ethnicity with respect to corneal toricity (interaction $p=0.001$). Significant differences among ethnic groups in the mean corneal toricity were observed in each age group ($p<0.001$), with Native Americans having the most toricity and Whites the least. Greater corneal toricity with age was observed only among the Native-American and White children ($p<0.001$ for each comparison). Age was not a significant factor for corneal toricity for any of the other three ethnic groups ($p>0.30$ for each comparison). Regardless of age or ethnicity, girls had a slightly greater mean corneal toricity than boys (1.11 D versus 1.03 D, $p=0.002$), although this was not clinically significant.

As shown in Figure 4, the anterior chamber was deeper with age, however, this difference was not consistent across ethnic groups (interaction $p=0.0003$). Significant age effects were observed for all groups except Native Americans ($p=0.76$). Ethnic group differences existed only at ages 6 years or younger and 7 years ($p<0.001$ for each comparison). Regardless of age or ethnicity, boys had, on average, deeper anterior chambers compared to girls (3.64 mm vs. 3.56 mm; $p<0.001$), but this difference was not clinically meaningful.

There were no crystalline lens thickness differences between boys and girls ($p=0.26$). As shown in Figure 5, age differences in lens thickness depended on ethnicity (interaction $p=0.0003$). There were differences in the mean crystalline lens thickness across the age groups for all ethnic groups ($p<0.001$ for each comparison) but only for the younger age groups. (6 years or younger ($p<0.001$), 7 years ($p<0.001$), and 8 years ($p=0.005$)). The association between age and greater crystalline lens thickness was the most substantial in Asian children and the least important in Hispanic children.

Regardless of age or ethnicity, girls had, on average, higher crystalline lens equivalent index of refraction compared to boys (1.426 vs. 1.424; $p<0.001$); nevertheless, this was not a clinically meaningful difference. Age differences in lens equivalent index depended on ethnicity, and, conversely, ethnic differences depended on age (interaction $p<0.001$) as demonstrated by the non-parallel lines in Figure 6. There were differences in the mean lens equivalent index among the five ethnic groups for age groups 6 years or younger ($p<0.001$), 7 years ($p<0.001$), 8 years ($p<0.001$), and 11 years ($p<0.001$). African-American children had higher lens equivalent indices at younger ages, while Whites showed high values at young ages. There were differences in the mean lens equivalent index of refraction across the age groups for all ethnic groups ($p<0.001$) except for the Native-American group ($p=0.90$).

There was a significant difference between the Gullstrand crystalline lens powers of boys (20.76 D) and girls (20.43 D, $p<0.0001$); however, this difference was not clinically meaningful. As shown in Figure 7, Gullstrand lens power was lower as a function of age, and this difference was consistent across ethnic groups ($p<0.001$). The mean Gullstrand lens power was higher at age 6 years or younger compared to ages 11-14 years (all differences ≥ 1.00 D, all $p<0.0001$). Similarly, differences were observed between age 7 years and ages 10-14 years (differences ≥ 0.80 D, $p<0.0001$ for each comparison) and between age 8 years and age 12 years (difference = 0.92 D, $p<0.0001$). While the ANCOVA indicated significant differences among ethnic groups, none of these differences was clinically meaningful (i.e. ≥ 0.75 D).

As with Gullstrand lens power, there was a statistically significant and clinically meaningful difference in mean calculated lens power between boys and girls (22.97 D vs. 22.11 D; $p<0.001$). Figure 8 shows the interaction between age and ethnicity (interaction $p=0.001$). There were differences in the mean calculated crystalline lens power among the five ethnic groups at age groups 6 years or younger ($p<0.001$), 7 years ($p<0.001$), 8 years ($p<0.001$), and 11 years ($p<0.001$). African-American and White children tended to have the highest calculated lens powers at the youngest ages. There were differences in the mean calculated crystalline lens power across the age groups for all ethnic groups ($p<0.005$ for each comparison) with lower mean calculated lens powers at the older ages.

Boys had longer vitreous chambers compared with girls (16.29 mm vs. 15.91 mm; $p<0.001$). As shown in Figure 9, vitreous chamber depth was longer as a function of age group ($p<0.001$) in a consistent pattern across ethnic groups. Clinically meaningful differences were observed between the 6 years or younger age group and the 8-14 year age groups (differences ≥ 0.33 mm, $p<0.0001$ for each comparison), between the 7 year age group and the 9-14 year age groups (differences ≥ 0.31 mm, $p<0.0001$ for each comparison) and between the 8 year age group and the 10-14 year age groups (differences ≥ 0.25 mm, $p<0.0001$ for each comparison). Regardless of age or gender, the mean vitreous chamber depth of White children was shorter compared to all other ethnic groups (differences ≥ 0.20 mm, all $p<0.0001$). In addition, both the Asian and African-American children had shorter vitreous chamber depths compared to the Native-American children (differences ≥ 0.28 mm, all $p<0.0001$).

Boys had longer axial length when compared to girls (23.39 mm vs. 22.92 mm; $p<0.001$), which was a clinically meaningful difference. As shown in Figure 10, axial length was longer as a function of age group ($p<0.001$). This age effect was consistent across ethnic groups. Clinically meaningful differences in mean axial length were observed between the 6 years or younger age group and the 8-14 year age groups (differences ≥ 0.33 mm, $p<0.0001$ for each comparison), between the 7 year age group and the 10-14 year age groups (differences ≥ 0.24 mm, $p<0.0001$ for each comparison), and between the 9 year age group and the 12-14 year age groups (differences ≥ 0.20 mm, $p<0.0001$ for each comparison). Native-American children had longer eyes than the African-American children (difference = 0.24 mm, $p<0.0001$), Asian (difference=0.23 mm, $p<0.0001$) and White (difference=0.34 mm, $p<0.0001$) children. In addition, the mean axial length was longer for Hispanic children than African-American (difference=0.21 mm, $p<0.0001$) and White (difference=0.31 mm, $p<0.0001$) children.

Table 14 compares the five ethnic groups at age 10 years. Age 10 years was chosen because it was in the middle of the age range and before the onset of myopia in most children. Ten-year old Asian children had the most myopic spherical equivalent refractive error; however, they did not have a relatively longer vitreous chamber depth or axial length after adjustment for refractive error. In fact, for a given refractive error at age 10 years, White children appeared to have the shortest eyes and Native-American and Hispanic children the longest. The differences were offset by White children having the highest corneal powers and Native American and Hispanic children the lowest. Native American 10 year olds also had the flattest

corneal curvatures and greatest corneal toricity. No differences between ethnic groups were present in the mean anterior chamber depth, lens thickness, lens index and calculated lens power of 10 year old children. The magnitude of differences in average component values as a function of ethnicity can be put into perspective by comparison of the differences depicted in Figures 2-10 to their respective standard deviations in Tables 3-12. Most component differences between groups were less than the underlying standard deviations within a group (vertical meridian corneal power, lens thickness, Gullstrand lens power, calculated lens power, vitreous chamber depth, and axial length). The inter-ethnic group differences in anterior chamber depth and crystalline lens refractive index were similar to the standard deviations. Only inter-ethnic differences in horizontal meridian corneal power and corneal toricity exceeded their standard deviations.

Discussion

This paper presents cross-sectional data for the first study visit for the OLSM and CLEERE cohorts of ethnically diverse children in the United States. This paper concentrates on the ocular components and their relation to age, gender, and ethnicity, including the first comprehensive cross-sectional data on a large sample of Native-American children. While age and gender are relatively straightforward variables, ethnicity is a complex variable. The term “ethnicity” relates to large groups of people classified according to common racial, national, tribal, religious, linguistic, or cultural origin or background. Therefore, the variable “ethnicity” is a combination of genetic and environmental factors and is difficult to define. Having stated that, ethnicity is an important concept in the United States, both in theory and in practice. This study succeeded in enrolling an ethnically diverse sample of study subjects, in accordance with the current understanding of the concept in the United States. In short, within the confines of the study's ethnic categories, children were classified according to their parent's designation of the child's ethnicity.

There is no assumption of homogeneity within an ethnic group. In this study, parents who identified their child as Hispanic were mainly recruited in Houston, Texas, with a subset coming from Southern Arizona. Many Hispanic subjects in our study would identify with the term “Mexican American” and most had ancestors who had immigrated from Mexico. Parents who identified their child as Asian in this study were mainly recruited and examined in Irvine, California and had ancestors who immigrated from China, Japan, Vietnam, Korea, or other East Asian or South Asian countries. The parents who identified their child as African American in this study were mainly recruited in Eutaw, Alabama and had ancestors who immigrated from Africa during the last several hundred years. The parents who identified their child as White in this study were mainly recruited in Orinda, California and had ancestors who immigrated mainly from Europe and the United Kingdom during the last several hundred years. The parents who identified their child as Native American were recruited in and around the Tohono O'odham Nation in Southern Arizona. While we did not ask about tribal affiliation, the vast majority of Native Americans in our study identified themselves as Tohono O'odham, although it is possible that a minority identify as Pascua Yaqui, Apache, or another tribe. This is important because there are intertribal differences in the distribution of astigmatism, for example.⁸

As expected, we found that the older age groups tended to be more myopic/less hyperopic in all five ethnic groups under study. Many studies have found a similar relationship.⁹⁻¹⁹ There was no difference in spherical equivalent refractive errors between boys and girls ($p=0.16$). Zadnik et al.,¹ who reported on an earlier subset of these data, did not find a statistically significant gender effect. A study of 2535 multi-ethnic schoolchildren aged 4 to 12 years from Australia⁹ also found no significant difference in refractive error between girls and boys. In a population-based study of refractive error in 5067 school-aged children ages 5 to 15 in Eastern

Nepal,¹⁰ myopia was not significantly associated with gender. In a population-based study of refractive error of children (n= 5303) aged 5 to 15 years in a suburban area of Santiago, Chile, 11 females were found to have a higher risk of hyperopia than males but not a significantly higher risk of myopia.

Several other studies have found myopia to be associated with female gender. Ip et al.²⁰ found that girls had a significantly higher prevalence of myopia than boys (14.1% vs. 9.7%) with a less hyperopic mean spherical equivalent (0.39 D vs. 0.58 D). A study of 1035 12- and 13-year-old children in a metropolitan setting in Mexico¹² found that the prevalence of myopia was greater in girls than boys. Thirty-one percent of the girls showed clinically significant myopia, defined as greater than or equal to -0.75 D of myopia in at least one eye compared to 21% of the boys.

Lin et al. performed a nationwide survey to determine the prevalence and severity of myopia among schoolchildren in Taiwan.¹³ They examined 10,889 students aged 7 to 18 years and found that girls had a higher prevalence and more severe degree of myopia than boys. Two population-based studies of refractive error in China, one in a metropolitan area of southern China¹⁵ and one in a rural area of China,¹⁶ found that myopia was associated with female gender. In a population-based study of refractive error in school-aged children in urban India,¹⁷ girls were more likely to be highly myopic than boys; however, for low and moderate amounts of myopia, there was no difference between girls and boys. In a population-based study of refractive error in school-aged children in rural India,¹⁸ myopia was associated with female gender.

In this report, differences in refractive error among the age groups depended on ethnicity (interaction $p < 0.0001$), and Figure 1 depicts this relationship. The refractive error differs between ethnic groups at all age groups ($p < 0.01$ for all comparisons). Asian children had the greatest effect of age associated with more myopic/less hyperopic spherical equivalent refractive error. Ip et al.²⁰ found that East Asian and South Asian children were more myopic than European Caucasian and Middle Eastern children (39.5% and 31.5% vs. 4.6% and 6.1%, respectively).

Corneal power in the horizontal meridian did not differ significantly among the different age groups ($p = 0.22$). Corneal power in both meridians differed significantly by gender ($p < 0.001$) and ethnicity ($p < 0.001$). Regardless of age or ethnicity, girls showed a greater mean corneal power in both meridians when compared to boys ($p < 0.001$). The findings of Ip et al.²⁰ are similar. While there were statistically significant differences between ethnic groups in the vertical meridian, the differences in our study were borderline when one considers a clinically significant difference level as 0.50 D. When considering the corneal power in the horizontal meridian, the difference was marked. Native Americans had much flatter corneas in the horizontal meridian, which contributed to greater corneal toricity, seen in Figure 3. The higher prevalence of corneal toricity in Tohono O'odham children has been reported previously,²¹ but Figures 2 and 3 clearly demonstrate the contrast with other ethnic groups. The White ethnic group had the least corneal toricity, on average, while African-American, Asian, and Hispanic ethnic groups showed similar moderate amounts of corneal toricity.

Anterior chamber depth was greater as a function of age; however, this difference was not consistent across ethnic groups. Lin^{13, 14} also found that the anterior chamber depth was deeper at older ages. The White ethnic group had the deepest anterior chambers, and Native Americans had the shallowest. The finding that Native-American children, specifically Tohono O'odham children, had more shallow anterior chambers compared to other ethnic groups suggests that angle-closure glaucoma could be more prevalent at older ages in the Native Americans. This has been reported in the Inuits of Greenland, Canada, and Alaska.²² Boys had deeper anterior

chambers than girls, and this too was found in an Australian study of ocular components,²⁰ although the difference of 0.12 mm is only slightly greater than what might be considered clinically meaningful.

The crystalline lens was thinner as a function of younger ages and then thicker at older ages, and the mean power was lower, consistent with previous findings.¹ Lin¹³ 14²³ found that the lenses were thinner as a function of age. There were no crystalline lens thickness differences between boys and girls. There were differences in the mean crystalline lens thickness across age groups for all ethnic groups ($p < 0.001$ for each comparison). The effect of age on lens thickness appeared to be the most substantial in Asian children, as shown by the steeper curve in Figure 5, and the least important in Hispanic children. While girls had, on average, higher lens equivalent index of refraction when compared to boys (1.426 vs. 1.424, respectively), this was not a clinically meaningful difference. Age differences in crystalline lens equivalent index of refraction depended on ethnicity as demonstrated by the non-parallel lines in Figure 6. Regardless of age or ethnicity, girls had, on average, greater Gullstrand and calculated crystalline lens powers compared to boys. This small difference is not clinically meaningful.

The mean vitreous chamber depth and axial length were both longer as a function of age group. Selovic et al²⁴ found that axial length was greater as a function of age but that axial length showed a closer correlation to height and weight than to age. The CLEERE Study boys tended to have longer vitreous chambers and axial length compared to girls. Other studies have reported the same finding.^{20, 24} There were ethnic differences in vitreous chamber depth and axial length, with Native-American children having the longest eyes, and White children the shortest. These differences in length were offset by the lower mean corneal power in Native American children and the higher mean corneal power in White children (Table 14). Interestingly, Asian children, who demonstrated the most myopia/least hyperopia, had mean vitreous chamber depths and axial lengths in the middle between the two extremes. In fact, the correlation between axial length and refraction has been reported to be particularly strong in East Asian Children.²⁰ This finding highlights the importance of adding refractive error as a covariate in this analysis of axial length. Adjustment for refractive error eliminates the differences in axial length as a function of ethnicity that result purely from the differing refractive error prevalences among ethnic groups. The analysis essentially puts the different ethnic groups on the same footing with respect to refractive error, comparing emmetropes to emmetropes, -2.00 D myopes to -2.00 D myopes, and so on. This adjustment allows for a better view of whether there are intrinsic differences in the ocular component characteristics as a function of ethnicity as opposed to merely differences in the average refractive error of different ethnic groups. For example, more Asian children are myopic, so Asians would logically have a longer than average axial length compared to other ethnic groups without controlling for refractive error, which is a well-described, trivial, and uninteresting finding. The more interesting finding is that the average Asian child's eye, within a given refractive error, is not the longest despite the more frequent occurrence of myopia in Asian children.

Table 14 summarizes the relationship between the ocular parameters at age 10 among the five ethnic groups. The spherical equivalent refractive error in Asian children was the least hyperopic/most myopic, while their mean vitreous chamber depths and axial lengths were in the mid-range. In fact, all of the ocular components of the Asian children were in the mid-range for each component, which implies that it is not any one ocular component that is responsible for the higher prevalence of myopia in Asians but rather the usual mismatch between the ocular components responsible for most children's myopia that happens to occur more frequently in Asian children. This suggests that the explanation for the differences in rates of myopia as a function of ethnicity is more than a simple model of intrinsically longer eyes in ethnic groups with higher prevalences and that more complex risk factor models may need to be invoked. One possible model is that each ethnic group has its own set of genetic or environmental risk

factors for myopia. Alternatively, the same risk factors might apply across ethnicities but may differ in the magnitude of their effect in different ethnic groups. The risk of myopia might also vary by ethnicity even if risk factors and their effects were similar across ethnicities if the frequency at which a risk factor occurred in one ethnic group was greater than in another. The similarity of ocular component values across ethnicities suggests that the latter model is a likely possibility. Similar effects in ethnic groups have already been reported for parental myopia. For example, Ip et al. found that the effect of two myopic parents increased the odds of myopia uniformly in two ethnic groups by a factor of 7.9 compared to having no myopic parents for both East Asian and European Caucasian children (i.e., there was no ethnicity-by-parent interaction).²⁵ Longitudinal data leading to models for predicting myopia onset that include ethnicity will be needed to evaluate this issue fully, including factors such as parental myopia, environmental exposures, and ocular component predictors.

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Figure 1.
The interaction between age and ethnicity with respect to spherical equivalent refractive error.

Figure 2.
Ethnicity and corneal power in the horizontal and vertical meridians.

Figure 3.
The interaction between age and ethnicity with respect to corneal toricity.

Figure 4.
The interaction between the age and ethnicity with respect to anterior chamber depth.

Figure 5.
The interaction with age and ethnicity with respect to crystalline lens thickness.

Figure 6.
The interaction between age and ethnicity with respect to crystalline lens refractive index.

Figure 7.

The interaction between age and ethnicity with respect to Gullstrand crystalline lens power.

Figure 8.
The interaction between age and ethnicity with respect to calculated crystalline lens power.

Figure 9.
The interaction between age and ethnicity with respect to vitreous chamber depth.

Figure 10.

The interaction between age and ethnicity with respect to axial length.

Table 1
Children enrolled in the OLSM and CLEERE studies as a function of age, gender, and ethnicity.

Ethnic Group/Gender	Age at last birthday (years)										Total
	6 or younger	7	8	9	10	11	12	13	14 or older		
African American											
Girls	118	64	37	25	24	31	23	33	21	376	
Boys	107	66	31	38	42	34	24	37	21	400	
Asian											
Girls	141	45	40	38	32	27	15	8	3	352	
Boys	152	48	32	41	24	51	16	8	1	370	
Hispanic											
Girls	136	158	56	52	50	48	36	31	13	580	
Boys	116	130	63	54	49	33	40	30	21	536	
Native American											
Girls	11	50	76	64	51	27	13	9	10	311	
Boys	10	39	61	57	38	21	18	6	5	255	
White											
Girls	446	64	90	32	36	97	43	20	10	838	
Boys	389	160	81	35	24	100	57	11	6	863	
All ethnicities combined											
Girls	852	381	299	211	193	230	130	101	57	2458	
Boys	774	443	268	225	177	239	155	92	54	2424	
TOTAL	1626	824	567	436	370	469	285	193	111	4881	

Table 2

Refractive error (spherical equivalent in diopters) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	0.95 ± 1.00	0.92 ± 0.96	0.76 ± 1.22	0.23 ± 1.05	0.17 ± 1.15	0.06 ± 1.31	-0.27 ± 1.42	0.14 ± 0.76	0.34 ± 1.87	
Boys	0.72 ± 1.10	0.78 ± 1.14	0.45 ± 0.70	0.54 ± 0.80	0.51 ± 1.27	-0.01 ± 1.21	0.31 ± 0.76	0.27 ± 0.86	-0.01 ± 2.23	
Asian										
Girls	0.51 ± 0.95	0.68 ± 0.82	0.18 ± 1.16	-0.48 ± 2.12	-0.57 ± 1.56	-0.79 ± 2.20	-1.31 ± 2.01	-----	-----	
Boys	0.56 ± 0.73	0.45 ± 1.14	-0.05 ± 1.27	-0.38 ± 1.70	-0.40 ± 1.59	-0.54 ± 1.99	-0.65 ± 1.90	-----	-----	
Hispanic										
Girls	0.84 ±0.99	0.68 ± 1.38	0.50 ± 1.53	0.17 ± 1.46	0.17 ± 1.21	-0.29 ± 1.77	-0.27 ± 1.75	-0.68 ± 1.72	-0.97 ± 2.03	
Boys	0.83 ± 0.97	0.56 ± 1.03	0.73 ± 1.07	0.66 ± 1.24	0.79 ± 1.24	0.00 ± 1.76	0.11 ± 1.82	-0.15 ± 1.51	0.03 ± 4.11	
Native American										
Girls	0.71 ± 0.75	0.63 ± 1.16	0.33 ± 1.22	0.21 ± 1.12	0.13 ± 1.05	-0.16 ± 1.49	0.16 ± 1.36	-----	0.13 ± 1.74	
Boys	0.99 ± 1.03	0.56 ± 1.17	0.40 ± 0.98	0.49 ± 1.33	0.17 ± 1.34	0.23 ± 1.17	-0.19 ± 1.54	-----	-----	
White										
Girls	0.90 ± 0.92	0.97 ± 1.39	0.67 ± 1.14	0.92 ± 2.05	0.47 ± 1.06	0.18 ± 1.26	0.34 ± 0.98	0.55 ± 1.16	-1.64 ± 2.80	
Boys	0.85 ± 0.72	0.93 ± 0.68	0.62 ± 0.86	0.31 ± 1.00	0.60 ± 0.91	0.32 ± 1.75	0.59 ± 0.84	-0.15 ± 1.74	-----	
Total										
Girls	0.83 ± 0.96	0.75 ± 1.24	0.50 ± 1.26	0.18 ± 1.62	0.09 ± 1.23	-0.09 ± 1.56	-0.15 ± 1.54	-0.24 ± 1.45	-0.39 ± 2.12	
Boys	0.77 ± 0.83	0.71 ± 0.98	0.51 ± 1.00	0.36 ± 1.30	0.40 ± 1.33	0.04 ± 1.72	0.21 ± 1.40	-0.15 ± 1.44	0.04 ± 2.99	

Table 3

Corneal power (vertical meridian in diopters) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)								
	6 or younger	7	8	9	10	11	12	13	14 or older
African American									
Girls	44.21 ± 1.58	44.47± 1.64	43.97 ±1.74	44.86 ±1.64	44.91 ±1.76	44.16 ±1.34	44.82 ±1.66	44.08 ±1.88	43.88 ±1.68
Boys	43.55 ± 1.69	43.74± 1.67	43.44 ±1.31	43.15 ±1.37	43.69 ±1.96	43.37 ±1.59	43.89 ±1.70	43.81 ±1.29	43.76 ±1.66
Asian									
Girls	44.65 ± 1.35	44.37± 1.63	45.07 ±1.65	44.61 ±1.37	44.30±1.49	44.14 ±1.56	45.24 ±1.61	-----	-----
Boys	43.77 ± 1.35	43.57± 1.51	43.85 ±1.21	44.01 ±1.44	44.05 ±1.45	43.56 ±1.63	43.67 ±1.56	-----	-----
Hispanic									
Girls	44.29 ± 1.37	44.29± 1.67	44.36 ±1.32	44.10 ±1.25	43.99 ±1.89	44.97 ±1.63	43.59 ±1.78	44.06 ±1.33	44.29 ±1.09
Boys	43.53 ± 1.36	43.63± 1.52	43.75 ±1.59	43.47 ±1.29	42.95 ±1.76	43.51 ±1.63	43.18 ±1.59	43.23 ±1.73	43.20 ±1.50
Native American									
Girls	44.08 ± 1.07	44.18 ±1.73	44.11 ±1.63	43.86 ±1.54	43.51 ±1.29	43.77 ±1.26	43.94 ±1.73	-----	44.84 ±2.63
Boys	43.92 ± 1.87	43.41 ±1.58	43.21 ±1.65	43.12 ±1.45	43.36 ±1.50	43.55 ±1.35	43.67 ±1.74	-----	-----
White									
Girls	44.40 ± 1.43	44.96 ±1.36	44.50 ±1.36	44.06 ±1.72	44.54 ±1.58	44.53 ±1.52	44.66 ±1.37	44.44 ±1.54	45.15 ±1.62
Boys	43.65 ± 1.41	43.77 ±1.47	43.69 ±1.64	43.79 ±1.52	43.81 ±1.41	43.31 ±1.52	43.68 ±1.29	44.43 ±1.79	-----
Total									
Girls	44.39 ±1.43	44.42 ±1.63	44.38 ±1.54	44.21 ±1.52	44.13 ±1.66	44.23 ±1.51	44.39 ±1.69	44.07 ±1.62	44.37 ±1.76
Boys	43.65 ±1.44	43.67 ±1.52	43.59 ±1.55	43.47 ±1.44	43.48 ±1.70	43.42 ±1.55	43.58 ±1.52	43.72 ±1.54	43.42 ±1.55

Table 4

Corneal power (horizontal meridian in diopters) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	43.22 $\pm$ 1.59	43.54 $\pm$ 1.69	43.09 $\pm$ 1.79	44.07 $\pm$ 1.65	43.95 $\pm$ 1.68	43.34 $\pm$ 1.35	43.86 $\pm$ 1.49	43.20 $\pm$ 1.85	42.97 $\pm$ 1.41	
Boys	42.72 $\pm$ 1.65	42.87 $\pm$ 1.71	42.49 $\pm$ 1.14	42.39 $\pm$ 1.31	42.91 $\pm$ 2.07	42.55 $\pm$ 1.50	43.06 $\pm$ 1.51	42.70 $\pm$ 1.47	43.02 $\pm$ 1.45	
Asian										
Girls	43.63 $\pm$ 1.40	43.34 $\pm$ 1.48	43.73 $\pm$ 1.62	43.56 $\pm$ 1.37	43.15 $\pm$ 1.63	42.97 $\pm$ 1.61	44.06 $\pm$ 1.41	-----	-----	
Boys	42.84 $\pm$ 1.31	42.41 $\pm$ 1.31	43.03 $\pm$ 1.23	43.19 $\pm$ 1.27	43.08 $\pm$ 1.40	42.93 $\pm$ 1.32	42.62 $\pm$ 1.59	-----	-----	
Hispanic										
Girls	43.32 $\pm$ 1.34	43.28 $\pm$ 1.61	43.21 $\pm$ 1.31	43.10 $\pm$ 1.19	43.04 $\pm$ 1.72	43.16 $\pm$ 1.72	42.74 $\pm$ 1.79	42.96 $\pm$ 1.46	43.17 $\pm$ 0.83	
Boys	42.53 $\pm$ 1.30	42.61 $\pm$ 1.40	42.72 $\pm$ 1.61	42.65 $\pm$ 1.13	42.13 $\pm$ 1.69	42.54 $\pm$ 1.62	42.19 $\pm$ 1.45	42.48 $\pm$ 1.60	41.94 $\pm$ 1.17	
Native American										
Girls	43.02 $\pm$ 1.26	42.12 $\pm$ 1.39	42.00 $\pm$ 1.39	41.82 $\pm$ 1.62	41.86 $\pm$ 1.47	42.13 $\pm$ 1.57	41.76 $\pm$ 1.90	-----	42.35 $\pm$ 1.95	
Boys	42.41 $\pm$ 1.99	41.32 $\pm$ 1.23	41.43 $\pm$ 1.49	41.34 $\pm$ 1.56	41.63 $\pm$ 1.35	41.45 $\pm$ 1.55	40.97 $\pm$ 1.64	-----	-----	
White										
Girls	43.88 $\pm$ 1.41	44.38 $\pm$ 1.27	43.94 $\pm$ 1.32	43.59 $\pm$ 1.82	44.02 $\pm$ 1.38	44.23 $\pm$ 1.47	43.94 $\pm$ 1.29	44.20 $\pm$ 1.47	43.77 $\pm$ 0.64	
Boys	43.17 $\pm$ 1.36	43.33 $\pm$ 1.37	43.22 $\pm$ 1.29	43.33 $\pm$ 1.43	43.64 $\pm$ 1.44	43.07 $\pm$ 1.42	43.33 $\pm$ 1.11	43.13 $\pm$ 1.50	-----	
Total										
Girls	43.65 $\pm$ 1.45	43.36 $\pm$ 1.64	43.18 $\pm$ 1.62	42.99 $\pm$ 1.71	43.04 $\pm$ 1.76	43.49 $\pm$ 1.68	43.39 $\pm$ 1.71	43.22 $\pm$ 1.72	43.03 $\pm$ 1.36	
Boys	42.92 $\pm$ 1.42	42.78 $\pm$ 1.52	42.59 $\pm$ 1.54	42.47 $\pm$ 1.53	42.54 $\pm$ 1.77	42.75 $\pm$ 1.51	42.65 $\pm$ 1.57	42.84 $\pm$ 1.60	42.43 $\pm$ 1.37	

Table 5

Corneal toricity at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	0.99 ± 0.65	0.93 ± 0.56	0.88 ± 0.66	0.79 ± 0.62	0.96 ± 0.64	0.82 ± 0.65	0.96 ± 0.76	0.88 ± 0.58	0.91 ± 1.08	
Boys	0.83 ± 0.71	0.87 ± 0.96	0.94 ± 0.88	0.75 ± 0.59	0.78 ± 0.59	0.82 ± 0.65	0.83 ± 0.61	1.11 ± 0.93	0.74 ± 0.86	
Asian										
Girls	1.02 ± 0.58	1.03 ± 0.59	1.34 ± 1.23	1.05 ± 0.59	1.15 ± 0.69	1.17 ± 0.68	1.18 ± 0.83	-----	-----	
Boys	0.94 ± 0.86	1.15 ± 0.91	0.82 ± 0.55	0.82 ± 0.56	0.97 ± 0.47	0.63 ± 1.21	1.04 ± 1.21	-----	-----	
Hispanic										
Girls	0.97 ± 0.69	1.00 ± 0.74	1.15 ± 0.79	1.01 ± 0.79	0.96 ± 0.87	0.81 ± 0.78	0.85 ± 0.76	1.10 ± 0.78	1.12 ± 0.66	
Boys	1.00 ± 0.76	1.02 ± 0.92	1.04 ± 0.93	0.82 ± 0.68	0.82 ± 0.71	0.97 ± 0.72	0.99 ± 1.01	0.75 ± 0.82	1.26 ± 1.15	
Native American										
Girls	1.05 ± 0.58	2.06 ± 1.42	2.11 ± 1.36	2.04 ± 1.27	1.65 ± 0.99	1.64 ± 1.31	2.18 ± 1.52	-----	2.49 ± 1.33	
Boys	1.52 ± 1.17	2.09 ± 1.35	1.78 ± 1.11	1.78 ± 1.17	1.73 ± 0.93	2.09 ± 1.54	2.70 ± 1.71	-----	-----	
White										
Girls	0.51 ± 0.53	0.58 ± 0.58	0.55 ± 0.65	0.47 ± 0.82	0.52 ± 0.67	0.29 ± 1.17	0.71 ± 0.59	0.24 ± 0.45	1.39 ± 1.53	
Boys	0.48 ± 0.57	0.44 ± 0.61	0.47 ± 0.99	0.46 ± 0.65	0.17 ± 0.55	0.24 ± 0.74	0.35 ± 0.71	0.30 ± 0.73	-----	
Total										
Girls	0.74 ± 0.63	1.06 ± 0.90	1.21 ± 1.14	1.22 ± 1.08	1.09 ± 0.90	0.73 ± 1.10	1.00 ± 0.91	0.85 ± 0.71	1.34 ± 1.23	
Boys	0.71 ± 0.73	0.90 ± 0.98	1.00 ± 1.06	1.00 ± 0.93	0.94 ± 0.84	0.67 ± 1.07	0.93 ± 1.21	0.88 ± 0.96	0.99 ± 0.99	

Table 6

Anterior chamber depth (mm) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	3.36 $\pm$ 0.27	3.40 $\pm$ 0.29	3.55 $\pm$ 0.30	3.59 $\pm$ 0.20	3.55 $\pm$ 0.22	3.58 $\pm$ 0.26	3.68 $\pm$ 0.29	3.60 $\pm$ 0.19	3.52 $\pm$ 0.23	
Boys	3.48 $\pm$ 0.26	3.52 $\pm$ 0.24	3.62 $\pm$ 0.24	3.64 $\pm$ 0.25	3.61 $\pm$ 0.28	3.68 $\pm$ 0.22	3.75 $\pm$ 0.21	3.72 $\pm$ 0.28	3.70 $\pm$ 0.26	
Asian										
Girls	3.45 $\pm$ 0.24	3.43 $\pm$ 0.22	3.52 $\pm$ 0.23	3.55 $\pm$ 0.24	3.55 $\pm$ 0.22	3.57 $\pm$ 0.23	3.68 $\pm$ 0.24	-----	-----	
Boys	3.53 $\pm$ 0.24	3.57 $\pm$ 0.23	3.57 $\pm$ 0.21	3.57 $\pm$ 0.27	3.69 $\pm$ 0.24	3.72 $\pm$ 0.24	3.66 $\pm$ 0.24	-----	-----	
Hispanic										
Girls	3.51 $\pm$ 0.22	3.56 $\pm$ 0.20	3.56 $\pm$ 0.23	3.62 $\pm$ 0.22	3.68 $\pm$ 0.24	3.66 $\pm$ 0.26	3.66 $\pm$ 0.21	3.70 $\pm$ 0.28	3.69 $\pm$ 0.22	
Boys	3.59 $\pm$ 0.23	3.66 $\pm$ 0.21	3.66 $\pm$ 0.26	3.61 $\pm$ 0.23	3.68 $\pm$ 0.25	3.66 $\pm$ 0.28	3.64 $\pm$ 0.25	3.75 $\pm$ 0.23	3.63 $\pm$ 0.46	
Native American										
Girls	3.40 $\pm$ 0.20	3.44 $\pm$ 0.22	3.51 $\pm$ 0.20	3.50 $\pm$ 0.21	3.49 $\pm$ 0.24	3.51 $\pm$ 0.25	3.50 $\pm$ 0.18	-----	3.52 $\pm$ 0.31	
Boys	3.58 $\pm$ 0.22	3.50 $\pm$ 0.18	3.58 $\pm$ 0.23	3.54 $\pm$ 0.22	3.60 $\pm$ 0.25	3.58 $\pm$ 0.21	3.59 $\pm$ 0.30	-----	-----	
White										
Girls	3.51 $\pm$ 0.22	3.56 $\pm$ 0.25	3.61 $\pm$ 0.25	3.61 $\pm$ 0.22	3.62 $\pm$ 0.29	3.75 $\pm$ 0.21	3.70 $\pm$ 0.21	3.78 $\pm$ 0.32	3.80 $\pm$ 0.27	
Boys	3.61 $\pm$ 0.23	3.65 $\pm$ 0.21	3.68 $\pm$ 0.25	3.75 $\pm$ 0.20	3.71 $\pm$ 0.28	3.81 $\pm$ 0.23	3.76 $\pm$ 0.22	3.81 $\pm$ 0.23	-----	
Total										
Girls	3.48 $\pm$ 0.24	3.50 $\pm$ 0.24	3.56 $\pm$ 0.24	3.56 $\pm$ 0.22	3.58 $\pm$ 0.25	3.66 $\pm$ 0.25	3.67 $\pm$ 0.23	3.65 $\pm$ 0.27	3.62 $\pm$ 0.27	
Boys	3.57 $\pm$ 0.24	3.61 $\pm$ 0.22	3.63 $\pm$ 0.24	3.62 $\pm$ 0.24	3.65 $\pm$ 0.26	3.73 $\pm$ 0.24	3.70 $\pm$ 0.24	3.73 $\pm$ 0.25	3.68 $\pm$ 0.35	

Table 7

Crystalline lens thickness (mm) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	3.58 ±0.18	3.56 ±0.16	3.49 ±0.16	3.45 ±0.16	3.44 ±0.17	3.47 ±0.20	3.35 ±0.18	3.46 ±0.19	3.48 ±0.18	
Boys	3.54 ±0.19	3.53 ±0.19	3.54 ±0.16	3.48 ±0.19	3.45 ±0.18	3.42 ±0.19	3.40 ±0.15	3.48 ±0.19	3.55 ±0.15	
Asian										
Girls	3.56 ±0.15	3.49 ±0.14	3.44 ±0.15	3.43 ±0.18	3.41 ±0.20	3.49 ±0.15	3.40 ±0.12	-----	-----	
Boys	3.56 ±0.14	3.53 ±0.18	3.45 ±0.17	3.43 ±0.20	3.42 ±0.17	3.42 ±0.14	3.33 ±0.16	-----	-----	
Hispanic										
Girls	3.50 ±0.15	3.46 ±0.16	3.45 ±0.16	3.40 ±0.16	3.40 ±0.15	3.40 ±0.14	3.42 ±0.16	3.41 ±0.16	3.37 ±0.19	
Boys	3.49 ±0.17	3.44 ±0.14	3.46 ±0.17	3.44 ±0.13	3.41 ±0.19	3.43 ±0.13	3.44 ±0.17	3.43 ±0.19	3.49 ±0.28	
Native American										
Girls	3.49 ±0.12	3.52 ±0.16	3.41 ±0.14	3.46 ±0.15	3.41 ±0.15	3.49 ±0.17	3.38 ±0.20	-----	3.47 ±0.16	
Boys	3.53 ±0.20	3.47 ±0.14	3.43 ±0.15	3.41 ±0.16	3.40 ±0.14	3.44±0.19	3.36 ±0.16	-----	-----	
White										
Girls	3.57 ±0.15	3.49 ±0.14	3.48 ±0.15	3.43 ±0.19	3.42 ±0.16	3.42 ±0.15	3.42 ±0.17	3.45 ±0.16	3.48 ±0.17	
Boys	3.55 ±0.15	3.52 ±0.16	3.47 ±0.15	3.37 ±0.17	3.42 ±0.18	3.41 ±0.14	3.43 ±0.15	3.38 ±0.14	-----	
Total										
Girls	3.56 ±0.16	3.49 ±0.16	3.45 ±0.15	3.43 ±0.16	3.41 ±0.16	3.43 ±0.16	3.40 ±0.17	3.44 ±0.17	3.44 ±0.18	
Boys	3.54 ±0.16	3.49 ±0.16	3.46 ±0.16	3.43 ±0.17	3.42 ±0.17	3.42 ±0.15	3.41 ±0.16	3.45 ±0.18	3.50 ±0.22	

Table 8

Crystalline lens refractive index (D) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	1.434±0.010	1.430±0.012	1.424±0.010	1.428±0.011	1.427±0.016	1.427±0.009	1.424±0.008	1.423±0.011	1.427±0.006	
Boys	1.432±0.011	1.426±0.010	1.423±0.010	1.422±0.010	1.422±0.008	1.422±0.008	1.424±0.009	1.422±0.009	1.421±0.005	
Asian										
Girls	1.430±0.009	1.423±0.009	1.423±0.011	1.425±0.010	1.424±0.010	1.420±0.009	1.421±0.008	-----	-----	
Boys	1.428±0.009	1.425±0.010	1.423±0.008	1.419±0.009	1.417±0.011	1.423±0.010	1.416±0.010	-----	-----	
Hispanic										
Girls	1.429±0.011	1.426±0.011	1.425±0.009	1.425±0.008	1.424±0.011	1.426±0.011	1.426±0.008	1.426±0.006	1.427±0.005	
Boys	1.427±0.010	1.424±0.012	1.423±0.008	1.421±0.007	1.423±0.010	1.421±0.010	1.423±0.009	1.421±0.008	1.427±0.008	
Native American										
Girls	1.423±0.012	1.423±0.008	1.424±0.009	1.425±0.009	1.424±0.009	1.425±0.008	1.425±0.005	-----	1.424±0.006	
Boys	1.427±0.005	1.421±0.007	1.422±0.009	1.419±0.010	1.422±0.009	1.422±0.009	1.420±0.007	-----	-----	
White										
Girls	1.433±0.008	1.432±0.008	1.429±0.009	1.424±0.010	1.425±0.011	1.429±0.007	1.424±0.009	1.424±0.011	1.420±0.009	
Boys	1.431±0.008	1.428±0.009	1.438±0.008	1.425±0.011	1.420±0.011	1.426±0.008	1.425±0.009	1.421±0.010	-----	
Total										
Girls	1.432±0.009	1.427±0.011	1.426±0.010	1.425±0.009	1.424±0.011	1.427±0.009	1.424±0.008	1.423±0.009	1.425±0.007	
Boys	1.430±0.009	1.426±0.010	1.424±0.009	1.421±0.010	1.421±0.010	1.424±0.009	1.423±0.009	1.421±0.009	1.423±0.008	

Table 9

Gullstrand crystalline lens power (D) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	21.26 ±1.47	21.40 ±1.63	21.39 ±1.61	20.31 ±1.49	20.93 ±1.18	20.30 ±1.56	20.10 ±1.89	20.52 ±1.64	20.70 ±1.61	
Boys	21.02 ±1.50	21.45 ±1.89	20.88 ±1.54	21.00 ±1.91	20.31 ±1.83	20.11 ±1.58	19.48 ±1.12	20.20 ±1.54	20.61 ±1.44	
Asian										
Girls	21.60 ±1.41	21.72 ±1.73	20.74 ±1.54	20.43 ±1.41	20.40 ±1.70	20.19 ±1.33	19.92 ±1.07	-----	-----	
Boys	21.33 ±1.29	20.93 ±1.48	20.65 ±1.18	20.56 ±1.72	20.23 ±1.22	19.90 ±1.48	19.79 ±1.05	-----	-----	
Hispanic										
Girls	21.54 ±1.55	21.36 ±1.54	21.11 ±1.40	20.56 ±1.52	20.25 ±1.69	20.31 ±1.27	19.90 ±1.25	19.99 ±1.18	19.87 ±1.34	
Boys	21.37 ±1.70	20.92 ±1.37	20.59 ±1.44	20.69 ±1.51	20.23 ±1.39	20.43 ±1.30	20.08 ±1.48	19.72 ±1.47	19.26 ±1.55	
Native American										
Girls	21.69 ±1.48	21.90 ±1.56	21.24 ±1.47	21.31 ±1.54	20.75 ±1.24	20.90 ±1.65	20.04 ±0.83	-----	20.67 ±1.13	
Boys	20.89 ±1.15	21.05 ±1.29	20.83 ±1.30	20.91 ±1.54	20.52 ±1.49	20.74 ±1.53	19.49 ±0.80	-----	-----	
White										
Girls	21.53 ±1.39	21.06 ±1.40	21.08 ±1.47	20.68 ±1.21	20.43 ±1.36	20.10 ±1.24	20.00 ±1.16	19.91 ±1.54	20.03 ±1.17	
Boys	21.02 ±1.28	20.91 ±1.45	20.52 ±1.31	19.95 ±1.55	20.25 ±1.32	19.90 ±1.31	19.74 ±1.17	19.65 ±0.99	-----	
Total										
Girls	21.51 ±1.43	21.43 ±1.57	21.11 ±1.44	20.76 ±1.49	20.52 ±1.47	20.28 ±1.37	19.98 ±1.29	20.19 ±1.51	20.30 ±1.39	
Boys	21.13 ±1.39	21.01 ±1.50	20.67 ±1.35	20.65 ±1.65	20.31 ±1.47	20.07 ±1.42	19.78 ±1.22	20.03 ±1.46	20.08 ±1.64	

Table 10

Calculated crystalline lens power (D) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	25.40 $\pm$ 1.95	24.80 $\pm$ 2.45	23.35 $\pm$ 2.67	22.84 $\pm$ 1.84	23.39 $\pm$ 3.18	22.77 $\pm$ 2.67	21.91 $\pm$ 2.55	22.11 $\pm$ 2.07	23.29 $\pm$ 1.75	
Boys	24.64 $\pm$ 2.15	23.80 $\pm$ 2.13	22.49 $\pm$ 2.33	22.34 $\pm$ 1.63	21.55 $\pm$ 1.82	21.34 $\pm$ 1.93	21.21 $\pm$ 1.75	21.60 $\pm$ 1.86	21.85 $\pm$ 2.06	
Asian										
Girls	24.89 $\pm$ 2.09	23.46 $\pm$ 1.99	22.34 $\pm$ 2.48	22.34 $\pm$ 2.00	22.15 $\pm$ 2.53	21.12 $\pm$ 1.73	20.97 $\pm$ 1.67	-----	-----	
Boys	24.18 $\pm$ 1.92	23.12 $\pm$ 2.58	22.22 $\pm$ 2.08	21.10 $\pm$ 2.16	20.41 $\pm$ 2.42	21.42 $\pm$ 2.44	19.66 $\pm$ 2.25	-----	-----	
Hispanic										
Girls	24.46 $\pm$ 2.26	23.64 $\pm$ 2.33	23.26 $\pm$ 2.09	22.63 $\pm$ 1.63	21.89 $\pm$ 2.14	22.53 $\pm$ 2.20	22.02 $\pm$ 2.04	22.11 $\pm$ 1.56	22.45 $\pm$ 1.87	
Boys	23.82 $\pm$ 2.01	22.75 $\pm$ 2.41	22.05 $\pm$ 1.65	21.82 $\pm$ 1.71	21.80 $\pm$ 2.23	21.62 $\pm$ 2.26	21.56 $\pm$ 2.31	20.88 $\pm$ 2.13	21.54 $\pm$ 2.19	
Native American										
Girls	23.29 $\pm$ 2.41	23.68 $\pm$ 1.83	23.03 $\pm$ 2.14	23.33 $\pm$ 2.00	22.65 $\pm$ 2.06	23.00 $\pm$ 1.71	22.05 $\pm$ 1.31	-----	22.48 $\pm$ 0.93	
Boys	23.51 $\pm$ 1.86	22.23 $\pm$ 1.63	22.24 $\pm$ 1.94	21.57 $\pm$ 2.35	21.86 $\pm$ 1.59	22.11 $\pm$ 2.11	20.46 $\pm$ 1.55	-----	-----	
White										
Girls	25.55 $\pm$ 2.05	24.84 $\pm$ 2.13	24.03 $\pm$ 1.99	22.50 $\pm$ 2.65	22.33 $\pm$ 2.49	23.04 $\pm$ 1.80	21.83 $\pm$ 2.32	21.71 $\pm$ 2.82	20.79 $\pm$ 2.07	
Boys	24.56 $\pm$ 2.02	23.68 $\pm$ 2.04	23.27 $\pm$ 1.93	21.91 $\pm$ 2.21	21.11 $\pm$ 2.62	22.15 $\pm$ 2.00	21.74 $\pm$ 2.28	20.77 $\pm$ 2.62	-----	
Total										
Girls	25.22 $\pm$ 2.13	24.01 $\pm$ 2.28	23.32 $\pm$ 2.26	22.79 $\pm$ 2.04	22.39 $\pm$ 2.41	22.66 $\pm$ 2.07	21.82 $\pm$ 2.13	21.78 $\pm$ 2.10	22.28 $\pm$ 2.02	
Boys	24.37 $\pm$ 2.03	23.24 $\pm$ 2.25	22.54 $\pm$ 1.99	21.72 $\pm$ 2.06	21.47 $\pm$ 2.14	21.80 $\pm$ 2.15	21.26 $\pm$ 2.25	21.09 $\pm$ 2.07	21.57 $\pm$ 2.17	

Table 11

Virreous chamber depth (mm) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	15.42 ±0.61	15.41 ±0.81	15.77 ±0.90	15.78 ±0.80	15.75 ±0.87	16.09 ±0.77	16.13 ±0.95	16.14 ±0.84	16.10 ±0.87	
Boys	15.79 ±0.71	15.77 ±0.3	16.17 ±0.62	16.29 ±0.56	16.32 ±0.77	16.68 ±0.81	16.41 ±0.76	16.36 ±0.64	16.37 ±1.17	
Asian										
Girls	15.36 ±0.61	15.67 ±0.63	15.83 ±0.86	16.28 ±1.14	16.44 ±0.97	16.70 ±0.94	16.47 ±0.67	-----	-----	
Boys	15.75 ±0.62	16.01 ±0.61	16.26 ±0.98	16.51 ±0.78	16.61 ±0.83	16.76 ±0.97	16.99 ±0.70	-----	-----	
Hispanic										
Girls	15.54 ±0.67	15.69 ±0.74	15.86 ±0.81	16.18 ±0.70	16.24 ±0.76	16.37 ±0.78	16.63 ±1.06	16.49 ±0.91	16.69 ±0.97	
Boys	15.93 ±0.63	16.12 ±0.61	16.06 ±0.73	16.25 ±0.67	16.51 ±0.89	16.63 ±1.00	16.76 ±0.92	16.81 ±0.93	16.81 ±1.19	
Native American										
Girls	15.60 ±0.54	15.71 ±0.63	16.18 ±0.70	16.19 ±0.81	16.45 ±0.79	16.38 ±0.85	16.54 ±0.82	-----	16.27 ±0.66	
Boys	15.72 ±0.83	16.34 ±0.59	16.42 ±0.68	16.61 ±0.76	16.67 ±0.73	16.68 ±0.94	17.24 ±0.86	-----	-----	
White										
Girls	15.09 ±0.63	15.14 ±0.69	15.43 ±0.70	15.71 ±0.81	15.80 ±0.69	15.76 ±0.68	15.91 ±0.70	15.87 ±0.87	16.71 ±1.29	
Boys	15.52 ±0.62	15.61 ±0.64	15.84 ±0.69	16.25 ±0.71	16.10 ±0.56	16.32 ±0.89	16.14 ±0.59	16.29 ±0.83	-----	
Total										
Girls	15.26 ±0.65	15.55 ±0.75	15.80 ±0.81	16.09 ±0.88	16.18 ±0.85	16.11 ±0.83	16.28 ±0.91	16.35 ±0.96	16.42 ±0.97	
Boys	15.66 ±0.65	15.89 ±0.68	16.11 ±0.75	16.39 ±0.71	16.46 ±0.79	16.54 ±0.93	16.56 ±0.84	16.60 ±0.92	16.63 ±1.17	

Table 12

Axial length (mm) at the first study visit in children enrolled in the OLSM and CLEERE studies, as a function of age, gender, and ethnicity (mean $\pm$ standard deviation).

Ethnic Group	Age at last birthday (years)									
	6 or younger	7	8	9	10	11	12	13	14 or older	
African American										
Girls	22.36 $\pm$ 0.65	22.36 $\pm$ 0.83	22.81 $\pm$ 0.93	22.82 $\pm$ 0.75	22.75 $\pm$ 0.82	23.15 $\pm$ 0.65	23.17 $\pm$ 1.02	23.20 $\pm$ 0.79	23.10 $\pm$ 0.85	
Boys	22.81 $\pm$ 0.70	22.83 $\pm$ 0.73	23.33 $\pm$ 0.60	23.41 $\pm$ 0.55	23.37 $\pm$ 0.76	23.79 $\pm$ 0.82	23.56 $\pm$ 0.81	23.56 $\pm$ 0.61	23.61 $\pm$ 1.28	
Asian										
Girls	22.37 $\pm$ 0.62	22.58 $\pm$ 0.68	22.79 $\pm$ 0.94	23.26 $\pm$ 1.18	23.40 $\pm$ 0.97	23.66 $\pm$ 0.98	23.54 $\pm$ 0.77	-----	-----	
Boys	22.84 $\pm$ 0.65	23.12 $\pm$ 0.63	23.28 $\pm$ 0.96	23.53 $\pm$ 0.84	23.72 $\pm$ 0.91	23.89 $\pm$ 1.02	23.98 $\pm$ 0.75	-----	-----	
Hispanic										
Girls	22.55 $\pm$ 0.66	22.71 $\pm$ 0.77	22.86 $\pm$ 0.86	23.20 $\pm$ 0.75	23.32 $\pm$ 0.80	23.42 $\pm$ 0.78	23.71 $\pm$ 1.04	23.64 $\pm$ 1.01	23.75 $\pm$ 0.96	
Boys	23.01 $\pm$ 0.64	23.22 $\pm$ 0.63	23.18 $\pm$ 0.80	23.30 $\pm$ 0.76	23.61 $\pm$ 0.90	23.72 $\pm$ 1.03	23.85 $\pm$ 1.01	23.99 $\pm$ 0.90	23.93 $\pm$ 1.30	
Native American										
Girls	22.49 $\pm$ 0.58	22.67 $\pm$ 0.70	23.11 $\pm$ 0.71	23.15 $\pm$ 0.79	23.35 $\pm$ 0.74	23.37 $\pm$ 0.92	23.42 $\pm$ 0.74	-----	23.27 $\pm$ 0.89	
Boys	22.83 $\pm$ 0.75	23.31 $\pm$ 0.59	23.43 $\pm$ 0.74	23.57 $\pm$ 0.76	23.67 $\pm$ 0.76	23.70 $\pm$ 0.94	24.19 $\pm$ 0.91	-----	-----	
White										
Girls	22.17 $\pm$ 0.65	22.19 $\pm$ 0.71	22.52 $\pm$ 0.76	22.74 $\pm$ 0.80	22.84 $\pm$ 0.74	22.93 $\pm$ 0.72	23.03 $\pm$ 0.72	23.10 $\pm$ 0.85	23.99 $\pm$ 1.34	
Boys	22.68 $\pm$ 0.61	22.78 $\pm$ 0.60	22.99 $\pm$ 0.70	23.37 $\pm$ 0.69	23.23 $\pm$ 0.64	23.54 $\pm$ 0.92	23.33 $\pm$ 0.63	23.48 $\pm$ 0.85	-----	
Total										
Girls	22.30 $\pm$ 0.66	22.55 $\pm$ 0.78	22.81 $\pm$ 0.84	23.08 $\pm$ 0.88	23.18 $\pm$ 0.84	23.20 $\pm$ 0.82	23.34 $\pm$ 0.92	23.45 $\pm$ 0.95	23.49 $\pm$ 1.02	
Boys	22.78 $\pm$ 0.65	23.00 $\pm$ 0.67	23.21 $\pm$ 0.77	23.44 $\pm$ 0.74	23.53 $\pm$ 0.82	23.69 $\pm$ 0.95	23.66 $\pm$ 0.86	23.78 $\pm$ 0.90	23.81 $\pm$ 1.27	

Table 13

Statistical analysis of gender and age effects on the ocular components in children enrolled in the OLSM and CLEERE studies (n=4881).

Ocular component	Gender effect?	Age effect?	Ethnic effect?
Refractive error (spherical equivalent in D)	No difference (p = 0.16)	Depends on ethnicity	Depends on age
Corneal curvature (vertical meridian in D)	Girls > Boys (Difference $\approx$ 0.75D, p < 0.001)	Marginal change (p = 0.003)	Asian > Native American (Difference $\approx$ 0.5D, p < 0.0001)
Corneal curvature (horizontal meridian in D)	Girls > Boys (Difference $\approx$ 0.7D, p < 0.001)	No difference (p = 0.22)	Native American < all other ethnic groups (p < 0.0001) White > all other ethnic groups (p < 0.0001)
Corneal toricity	Girls > Boys (Difference $\approx$ 0.1D, p = 0.002)	Depends on ethnicity	Depends on age
Anterior chamber depth (mm)	Boys > Girls (Difference $\approx$ 0.1mm, p < 0.0001)	Depends on ethnicity	Depends on age
Lens thickness (mm)	No difference (p = 0.26)	Depends on ethnicity	Depends on age
Lens refractive index	Girls > Boys (Difference $\approx$ 0.002, p < 0.001)	Depends on ethnicity	Depends on age
Gullstrand lens power	Girls > Boys (Difference $\approx$ 0.3D, p < 0.001)	Lower with age (p < 0.001)	Statistically significant (p < 0.001) but not clinically relevant differences ($\leq$ 0.75D)
Calculated lens power	Girls > Boys (Difference $\approx$ 0.8D, p < 0.001)	Depends on ethnicity	Depends on age
Vitreous chamber depth (mm)	Boys > Girls (Difference $\approx$ 0.4mm, p < 0.001)	Longer with age (p < 0.001)	White < all other ethnic groups (p < 0.0001) Native American > all except Hispanic (p < 0.0001)
Axial length (mm)	Boys > Girls (Difference $\approx$ 0.4mm, p < 0.001)	Longer with age (p < 0.001)	Native American > all except Hispanic (p < 0.0001) Hispanic > African American and White (p < 0.0001)

Comparing the ocular parameters in children enrolled in the OLSM and CLEERE studies among ethnic groups at age 10

Table 14

SPHEQ*	Asian	<	Native American	=	African American	=	Hispanic	=	White
K-Vert	Native American	=	Hispanic	<	Asian	=	White	=	African American
K-Horiz	Native American	<	Hispanic	<	Asian	=	African American	<	White
Torticity	White	<	African American	=	Hispanic	=	Asian	<	Native American
ACD	Native American	=	Asian	=	African American	=	Hispanic	=	White
LT	Native American	=	Hispanic	=	Asian	=	White	=	African American
INDEX	Native American	=	Asian	=	African American	=	Hispanic	=	White
GLP	Hispanic	=	White	<	Asian	=	African American	<	Native American
CLP	Asian	=	Hispanic	=	African American	=	Native American	=	White
VCD	White	<	African American	=	Asian	<	Hispanic	<	Native American
AL	White	<	African American	=	Asian	<	Native American	=	Hispanic

*The < sign conveys a more myopic average refractive error in the Asian children compared to all other ethnic groups.