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Significant Axial Elongation with Minimal Change in Refraction in 3- to 6-Year-Old Chinese Preschoolers

The Shenzhen Kindergarten Eye Study

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Purpose: To document the distribution of ocular biometry and to evaluate its associations with refraction in a group of Chinese preschoolers.

Design: Population-based cross-sectional study.

Participants: A total of 1133 preschoolers 3 to 6 years of age from 8 representative kindergartens.

Methods: Biometric measurements including axial length (AL), anterior chamber depth (ACD), and corneal radius of curvature (CR) were obtained from partial-coherence laser interferometry (IOL Master; Carl Zeiss Meditec, Oberkochen, Germany) before cycloplegia. Lens power (LP) and AL-to-CR ratio were calculated. Cycloplegic refraction (3 drops of 1% cyclopentolate) was measured using an autorefractor (KR8800; Topcon Corp., Tokyo, Japan), and spherical equivalent refraction (SER) was calculated. Biometric and refractive parameters were assessed as a function of age and gender. Multiple regression analysis was performed to explore the associations between refraction and ocular biometry.

Main Outcome Measures: Ocular biometric distributions and their relationships to refraction.

Results: Among the 1127 children (99.5%) with successful cycloplegic refraction, mean SER was 1.37±0.63 diopters (D). Prevalence of myopia increased from 0% at 3 years of age to 3.7% (95% confidence interval, 1.0%−6.5%) at 6 years of age. Biometric parameters followed Gaussian distributions with means of 22.39±0.68 mm for AL, 7.79±0.25 mm for CR, and 24.61±1.42 D for calculated LP; and non-Gaussian distributions with means of 3.34±0.24 mm for ACD and 2.88±0.06 for AL-to-CR ratio. Axial length, ACD, and AL-to-CR ratio increased from 3 to 6 years of age, CR remained stable, whereas LP declined. Overall, SER declined slightly. For the SER variance, AL explained 18.6% and AL-to-CR ratio explained 39.8%, whereas AL, CR, and LP accounted for 80.0% after adjusting for age and gender.

Conclusions: Young Chinese children are predominantly mildly hyperopic, with a low prevalence of myopia by the age of 6 years. An increase of 1 mm in AL was associated with only 0.45 D of myopic change. Decreases in LP reduce the myopic shifts that normally would be associated with increases in AL, and thus play a key role in refractive development in this age group. *Ophthalmology 2017;■:1−13 © 2017 by the American Academy of Ophthalmology*

The process of refractive development during childhood and adolescence often is described as emmetropization.[1,2] On the basis of animal studies, emmetropization often has been conceptualized as resulting from myopic shifts in refraction based on axial elongation driven by hyperopic defocus and slowing of axial elongation driven by exposure to myopic defocus.[3] This model seems to apply well to the first 2 years after birth, when the tight leptokurtic distribution of spherical equivalent refraction (SER) develops. However, the large population-based Refractive Error in School Children study suggests that emmetropia is not the real end point of the process.[4] Instead, in populations where the prevalence of myopia is low, refractions seem to settle at a rather stable state of mild hyperopia (approximately +0.50 to +1.50 diopters [D]), and this state can persist into adult life under appropriate conditions.[5] In contrast, in populations where the prevalence of myopia becomes high, children seem to pass through emmetropia as a rather transient state and continue on to myopia, consistent with the widespread clinical understanding that early-onset emmetropia is a major risk factor for the subsequent development of myopia.[6]

A more complex and detailed picture of normal refractive development currently is emerging. It is clear that neonates are overwhelmingly hyperopic, with a normal distribution of SER centered at approximately +2.00 to +3.00 D.[7] Then, over the first year or two after birth, the distribution of

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SER narrows through a process of matching of the axial length (AL) of the eye to the corneal power or radius of curvature to produce a narrower and more kurtotic distribution, with a mean SER of approximately +0.50 to 1.50 D.[1] After this period, the cornea seems to be quite stable until much later in adult life,[8] but axial elongation and loss of lens power (LP) continue for much longer, extending in some cases into early adult life.[3]

Considerable data on both refraction and ocular biometry are available on children of school age, from 5 to 6 years of age and older, and have confirmed the stability of the cornea, but have documented continuing axial elongation and loss of LP.[9,10] The period of refractive development between 2 to 6 years of age has been studied in preschool-age children, and relatively high myopia prevalence rates have been reported in children from nonwhite ethnic groups.[11−14] However, evidence remains inconclusive.

To understand this period of refractive development, we need more information on the changes in biometry that are taking place, and in particular, how much axial elongation is taking place and the extent to which changes in refraction are limited by the parallel process of loss of LP. In this article, we therefore report on changes in refraction and biometry in a large sample of preschool children from the city of Shenzhen in southern China.

Methods

Study Population

The study population consisted of participants of the Shenzhen Kindergarten Eye Study, a cross-sectional observational study to investigate ocular biometry, refraction, visual acuity, and their associations in a group of preschoolers. Eight first-class kindergartens drawn from different administrative districts of Shenzhen were involved in the study, with high standards of facilities and teaching staff. The project conformed to the tenets of the Declaration of Helsinki and obtained ethical approval from the Institutional Review Board of Zhongshan Ophthalmic Center. After the study purposes and procedures were explained to the parents or legal guardians in detail during a school seminar, written informed consent was obtained.

A total of 1764 preschoolers were enumerated. Of them, 1255 (71.1%) gave informed consent for participation. Only children 3 to 6 years of age were considered eligible; those with successful biometric measurements were included in the biometry analysis (n = 1133), and those with complete cycloplegic refraction were included in the refraction analysis (n = 1127).

Ocular Examinations

Ocular examinations were conducted during school days while classes were in session from April through September 2012. Details of the field examination are described elsewhere.[15] Ocular biometry was measured before pupil dilation with noncontact partial-coherence laser interferometry (IOL Master; Carl Zeiss Meditec, Oberkochen, Germany). All participants were instructed to fixate directly on the alignment beam during the examination by the same operating ophthalmologist (X.D.). The reflection of the alignment light was placed within the sighting circle on the screen to achieve a measurement. Five separate measurements were averaged for AL and the longest and shortest corneal radius (CR) of curvature, whereas 5 measurements of anterior chamber depth (ACD) were generated automatically and averaged. Anterior chamber depth and CR were obtained through image analysis. Anterior chamber depth was measured as the distance between the anterior corneal pole and the anterior lens surface. All data were extracted from the device as a spreadsheet file and matched to the other measurements using the bar code system in which every individual was assigned a unique identification number throughout the study.

Three drops of 1% cyclopentolate were administered to induce cycloplegia; the first 2 were administered 5 minutes apart, and the third was administered 20 minutes later. Cycloplegia and pupil dilation were evaluated after an additional 15 minutes. Cycloplegia was considered complete if a pupillary light reflex was absent and the pupil was dilated to at least 6 mm.[16] Children without complete cycloplegia were not included in the refraction analysis but were retained in the biometric analysis provided they had valid biometric measurements. Participants with complete cycloplegia then underwent refraction using a desktop autorefractor (KR8800; Topcon Corp., Tokyo, Japan). Mean spherical power, cylindrical power, and axis of 3 consecutive measurements were extracted automatically from the device. The anterior segment, including the eyelid, conjunctiva, cornea, iris, and pupil, and the posterior segment, including the fundus, optic disc, and macula, then were evaluated by slit-lamp examination and indirect ophthalmoscopy, performed by an ophthalmologist.

Definitions

Spherical equivalent refraction (SER) was calculated as spherical diopters (D) plus one-half cylindrical diopters using data from the autorefractor. Because of the high correlation between the right and left eyes of the same individual, only data from the right eye were presented. Myopia was defined as SER of −0.50 D or less, emmetropia was defined as -0.50 D $<$ SER $<$ $+0.50$ D, mild hyperopia was defined as $+0.50$ D $\leq$ SER $<$ $+2.00$ D, and hyperopia was defined as SER of +2.00 D or more. Corneal radius was calculated as the mean of the longest CR and shortest CR. Corneal power in diopters was converted from the CR data using the formula corneal power (D) = 0.3375/CR (mm) × 1000; the AL-to-CR ratio was computed as AL in millimeters divided by CR in millimeters. Lens power was calculated using the Bennett-Rabbetts method[17] with unknown lens thickness, using measured values for SER, CR, AL, and ACD.

Statistical Analysis

The ocular characteristics including SER, AL, ACD, CR, AL-to-CR ratio, and calculated LP between the boys and girls were compared using *t* tests. Trend analysis was performed to detect any age differences. Prevalence and its 95% confidence interval were calculated for different refractive categories. Multiple regression analysis was performed to assess the association between SER and ocular biometry using different models. A *P* value of 0.05 or less was considered statistically significant. All analyses were performed using Stata Statistical Software (version 12.0; StataCorp, College Station, TX).

Results

Of the 1255 enrolled children, 118 were out of the age range and another 4 had no successful biometric measurements, leaving a total of 1133 preschoolers (90.3%) 3 to 6 years of age in the study. The study population consisted of 615 boys (54.3%) and 518 girls (45.7%). There were 141 children 3 years of age, 485 children 4 years of age, 319 children 5 years of age, and 188 children 6 years of age. The mean age was 5.0±0.9 years, with no statistically