Two-Year Changes in Refractive Error and Related Biometric Factors in an Adult Chinese Population

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IMPORTANCE This article provides, to our knowledge, the first longitudinal population-based data on refractive error (RE) in Chinese persons.

OBJECTIVE To study cohort effects and changes associated with aging in REs among Chinese adults.

DESIGN, SETTING, AND PARTICIPANTS A 2-year, longitudinal population-based cohort study was conducted in southern China. Participants, identified using cluster random sampling, included residents of Yuexiu District, Guangzhou, China, aged 35 years or older who had undergone no previous eye surgery.

METHODS Participants underwent noncycloplegic automated refraction and keratometry in December 2008 and December 2010; in a random 50% sample of the participants, anterior segment ocular coherence tomography measurement of lens thickness, as well as measurement of axial length and anterior chamber depth by partial coherence laser interferometry, were performed.

MAIN OUTCOMES AND MEASURES Two-year change in spherical equivalent refraction (RE), lens thickness, axial length, and anterior chamber depth in the right eye.

RESULTS A total of 745 individuals underwent biometric testing in both 2008 and 2010 (2008 mean [SD] age, 52.2 [11.5] years; 53.7% women). Mean RE showed a 2-year hyperopic shift from −0.44 (2.21) to −0.31 (2.26) diopters (D) (difference, +0.13; 95% CI, 0.11 to 0.16). A consistent 2-year hyperopic shift of 0.09 to 0.22 D was observed among participants aged 35 to 64 years when stratifying by decade, suggesting that a substantial change in RE with aging may occur during this 30-year period. Cross-sectionally, RE increased only in the cohort younger than 50 years (0.11 D/y; 95% CI, 0.06 to 0.16). In the cross-sectional data, axial length decreased at −0.06 mm/y (95% CI, −0.09 to −0.04), although the 2-year change in axial length was positive and thus could not explain the cross-sectional difference. These latter results suggest a cohort effect, with greater myopia developing among younger persons.

CONCLUSIONS AND RELEVANCE This first Chinese population-based longitudinal study of RE provides evidence for both important longitudinal aging changes and cohort effects, most notably greater myopia prevalence among younger persons.
A feature among Chinese populations is the high prevalence of myopia among school-aged children, combined with a comparatively high prevalence of hyperopia and angle-closure glaucoma among the elderly. This would suggest that the prevalence of conditions such as angle closure, for which a hyperopic refractive error (RE) and associated biometry are important risk factors, might tend to decline in the future if younger Chinese persons remain myopic into older age. It is predicted, based on current trends, that angle-closure glaucoma will blind 5.3 million people by 2020, the large majority of them in China and elsewhere in Asia.

Little is known, however, about how ocular refraction and biometry change with age in Chinese populations. Although modest hyperopic shifts in RE with aging have been identified in longitudinal population studies among persons of European descent, limited cross-sectional studies comparing multiple populations suggest that Chinese and genetically related Inuit populations may have a more rapid rate of aging change in the biometric features that predispose toward angle closure.

Cross-sectional studies cannot distinguish between longitudinal aging and cohort effects, that is, particular effects in a group related by time or common experience. It has been suggested that much of the apparent difference in RE between older and younger Chinese persons may result from cohort effects, with greater recent access to education among Chinese children resulting in additional near work demands and myopia. Older cohorts that have not been exposed to such educational pressure may retain a more hyperopic RE and associated ocular biometric profile. Decreased time spent outdoors among more recent cohorts also may play a role in increasing myopia prevalence.

We are unaware of any longitudinal population-based studies of RE and ocular biometry among Chinese adults. New technologies for imaging the anterior chamber, such as ocular coherence tomography and laser interference biometry, may permit accurate assessment of small changes occurring during relatively short periods. We carried out a 2-year longitudinal study of RE and associated biometric factors in a population-based sample of Chinese adults aged 35 years or older at the start of the study. The aims of the present report are to (1) describe cross-sectional characteristics and 2-year changes in RE and ocular biometry and elucidate cohort and aging effects in this population and (2) model the effect of various potential biometric determinants on change in RE with aging.

Methods

Random cluster sampling was used to identify adults aged 35 years or older residing in the Yuexiu District of Guangzhou, China, in December 2008. Details of the recruitment and examination procedures have been reported elsewhere and are summarized here. During door-to-door household visits, data on all persons aged 35 years or older were collected, including name, sex, and age. A basic examination was carried out in local community facilities, and a random 50% sample of individuals underwent more detailed biometric examination at the Zhongshan Ophthalmic Center.

In 2010, biometric examinations using the identical equipment and protocol and under identical illumination levels were carried out on all available participants from the original 50% subsample. The institutional review board at the Zhongshan Ophthalmic Center in Guangzhou approved the protocol for this study, all participants gave written informed consent, and the study adhered to the tenets of the Declaration of Helsinki. The participants did not receive financial compensation.

Setting and Participants

The Yuexiu District of Guangzhou, located in southern China, has a population of 416,407 individuals living in an area of 9.16 km². Twenty-four of 1575 clusters of 70 to 100 eligible persons were selected at random for a total sample frame of 2280, among whom 1817 individuals (79.7%) completed the basic presbyopia study, including assessment of distance refraction and corneal curvature, and 1141 (50.0% of the original sample frame) were selected at random for biometric testing (Supplement [eFigure 1]). Of the latter sample, 210 individuals (18.4%) were unavailable or unable to complete testing. Testing was carried out on 931 persons (81.6%) in 2008, of whom 47 (5.0%) had a disqualifying history of surgery or media opacities precluding accurate assessment. The remaining 884 (95.0%) eligible participants were available for data analysis in 2008, among whom 763 (86.3%) returned in 2010, 18 (2.4%) of whom had become ineligible because of recent surgery. A total of 745 eligible individuals underwent biometric testing in 2008 and 2010 and provided questionnaire data on age, sex, and educational level (Supplement [eFigure 1]).

Refraction and Biometric Measurements

Automated Refraction (KR-8800; Topcon Corp) without cycloplegia was carried out separately for each eye on all participants in 2008 and 2010. The mean of 5 consecutive measurements was recorded as the final value for each eye. Refractive error was analyzed throughout the study as the spherical equivalent: the spherical power plus one-half of the cylindrical power. The above device also was used to measure corneal refractive power, with 5 readings made for each eye and the mean value recorded.

Axial length (AL) and anterior chamber depth (ACD) were measured separately in each eye using noncontact partial coherence laser interferometry (IOLMaster, version 3.0; Carl Zeiss Meditec) in a dark room (illumination <5 lux). The mean of 5 consecutive measurements was used. Measurements with a ratio of signal to noise less than 2.0 or that differed by more than 0.1 mm from other values were deleted and remeasured.

Anterior segment optical coherence tomography (AS-OCT) imaging (Visante; Carl Zeiss Meditec) was performed under similar dark conditions. One scan, centered over the pupil, was taken on the horizontal meridian (between 0° and 180°). The image of each eye with the best quality (based on visibility of the scleral spur and maximum interference flare) was selected.
Custom software (ZAAP; Zhongshan Angle Assessment Program) was used to perform noise and contrast conditioning on all image files. Algorithms automatically defined the borders of the corneal epithelium and endothelium, anterior and posterior surface of the iris, and anterior surface of the lens. A single observer identified the scleral spur nasally and temporally on each scan, and ZAAP software automatically calculated the following variables: pupil size, corneal thickness, and crystalline lens thickness (LT), defined as the shortest distance between the anterior and posterior poles of the lens. The values for LT measured with AS-OCT are higher than those determined with ultrasound, although the 2 measures are highly correlated. This previously described phenomenon is attributed to the fact that ultrasound estimates distance by the speed of sound, whereas AS-OCT measures distance based on a linear scan.

**Statistical Analysis**

Analyses for right and left eyes produced consistent results, and the right eye was used arbitrarily in all analyses. A 2-tailed paired t test was used to assess the 2-year changes and 95% CI in the various factors among the entire cohort as well as subgroups. Simple linear regression was used to model the effects of ocular biometric variables and demographic factors on RE in 2008 and 2010, as well as on the 2-year change. Multiple regression models were adjusted for age, sex, and biometric variables.

For the association of RE in 2008 and 2010 with its potential determinants and demographic factors, piecewise regressions dividing age into discrete ranges of younger than 50 years and 50 years or older was used because of nonlinearity in RE with age. A similar piecewise regression approach was taken with 2-year change in RE. All analyses were performed using Stata, version 12.0 (StataCorp).

**Results**

A total of 745 persons underwent biometric testing in both 2008 and 2010. The mean (SD) age at baseline was 52.2 (11.5) years, and 53.7% of the participants were female. We previously reported that participants not present for testing in 2010 did not differ significantly from those available with regard to baseline age, sex, weight, height, eyeglass wear, or any of the measured ocular biometric variables. Additionally, there was no significant difference in RE between the 751 individuals who were (mean [SD] RE, −0.45 [2.21]) and the 136 who were not (−0.62 [2.33]) available for follow-up in 2010; the difference (95% CI) was −0.18 (−0.58 to 0.23).

Mean RE for all participants showed a 2-year shift in the hyperopic direction from −0.44 (2.21) to −0.31 (2.26) diopter (D) (difference, +0.13; 95% CI, 0.11 to 0.16) (Table 1). Two-year changes in related biometric factors are summarized in Table 1. Expressed as a proportion of the SD, the largest 2-year changes were observed for LT (11.50% increase), ACD (5.56% decline), and RE (5.88% hyperopic increase).

A 2-year hyperopic shift in RE with aging was observed among participants aged 35 to 44 years (+0.10 D; 95% CI, 0.05 to 0.16), 45 to 54 years (+0.22 D; 95% CI, 0.19 to 0.25), and 55 to 64 years (+0.09 D; 95% CI, 0.03 to 0.15; mean 2-year increase from 35 to 64 years, 0.15 D; 95% CI, 0.12 to 0.18), whereas there was no significant refractive shift for subjects aged 65 years or older (Table 1 and Figure 1). No significant sex differences in longitudinal refractive shift or any of its biometric determinants were observed, although a greater 2-year RE change was observed among participants with higher educational levels (Table 1).

Cross-sectionally, RE also increased (shifted toward hyperopia) with age. For the age groups 35 to 44, 45 to 54, 55 to 64, and older than 65 years, the mean RE in 2008 was −1.43 (2.19), −0.21 (1.83), −0.01 (2.54), and 0.32 (1.95) D, respectively, with similar patterns observed in 2010 (data not shown). The hyperopic shift was most pronounced in the youngest cohorts (Supplement [eFigure 2]): a cross-sectional shift of 0.11 (95% CI, 0.06 to 0.16) D/y was present in the age group 35 to 49 years in 2008 compared with 0.01 (95% CI, −0.01 to 0.03) D/y in the age group 50 years or older.

Two-year change in AL was either negligible or in the positive direction across the study population (Table 1 and Figure 2). However, cross-sectionally, mean axial lengths were greater for younger vs older persons. For the age groups 35 to 44, 45 to 54, 55 to 64, and older than 65 years, mean AL (millimeters) in 2008 was 23.94 (1.19), 23.42 (1.11), 23.53 (1.08), and 23.54 (0.93), respectively (Supplement [eFigure 3]). A cross-sectional shift of −0.06 (95% CI, −0.09 to −0.04) mm/y in the age group 35 to 49 years in 2008 was found, compared with 0.001 (95% CI, −0.009 to 0.001) mm/y in the age group 50 years or older in 2008.

In summary, RE increased both longitudinally over 2 years and cross-sectionally, although the greatest differences cross-sectionally were observed among the youngest cohort (35-44 years), who did not have the greatest 2-year hyperopic shift. Axial length showed no change or a slight increase over 2 years; cross-sectionally, AL decreased in the younger compared with older age groups.

Using the baseline data for 2008, a multiple regression model including sex, height, weight, AL, corneal curvature, ACD, LT, and age could explain 79% of variation in RE. Axial length itself explained 49%, and ACD explained 19% in univariate analyses (Table 2). Similar results were obtained when 2010 data were used (Table 2).

In contrast, multiple regression models for change in RE could explain only 16% of the variation, and change in corneal power and AL explained only 6% and 4% of the variation, respectively, in the univariate analyses, the most of any factor (Table 3). In the multiple regression model, younger age (P < .05), greater decrease in AL, and greater decrease in corneal power (both P < .001) were associated with a greater increase in RE (hyperopic shift) (Table 3).

**Discussion**

In this population of Chinese adults, we found evidence of both important aging changes in RE and also of cohort effects, the latter particularly among younger persons. Regarding the sig-
nificance of aging changes, among participants between the ages of 35 and 64 years, we observed a mean 2-year 0.15-D hyperopic shift, consistent in direction across age groups stratified by decade. This finding suggests that aging changes in the range of 0.075 D/y or 2 D might occur during this 30-year period, similar to the amplitude of the total cross-sectional difference seen between the youngest and oldest age groups in our sample (2.13 D).

### Table 1. Stratified 2-Year Changes in a Population-Based Sample of Chinese Adults With Measurements in 2008 and 2010

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Spherical Equivalent, Mean 2-y Change (95% CI), D</th>
<th>Axial Length, Mean 2-y Change (95% CI), mm</th>
<th>Corneal Power, Mean 2-y Change (95% CI), D</th>
<th>Lens Thickness, Mean 2-y Change (95% CI), mm</th>
<th>Anterior Chamber Depth, Mean 2-y Change (95% CI), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No.</td>
<td>735</td>
<td>738</td>
<td>744</td>
<td>674</td>
<td>732</td>
</tr>
<tr>
<td>2-y Difference, mean (95% CI)</td>
<td>0.13 (0.11 to 0.16)</td>
<td>0.015 (0.009 to 0.021)</td>
<td>0.06 (0.04 to 0.08)</td>
<td>0.06 (0.04 to 0.07)</td>
<td>−0.02 (−0.03 to −0.01)</td>
</tr>
<tr>
<td>2-y Difference, expressed as % of SD in 2008</td>
<td>0.15 (0.15 to 0.16)</td>
<td>0.004 (−0.007 to 0.02)</td>
<td>0.09 (0.05 to 0.13)</td>
<td>0.09 (0.06 to 0.11)</td>
<td>−0.01 (−0.03 to 0.004)</td>
</tr>
<tr>
<td>Age group, y</td>
<td>45-54 (n = 265)</td>
<td>(n = 266)</td>
<td>(n = 266)</td>
<td>(n = 251)</td>
<td>(n = 264)</td>
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<tr>
<td></td>
<td>0.22 (0.19 to 0.25)</td>
<td>0.01 (0.003 to 0.02)</td>
<td>0.06 (0.03 to 0.08)</td>
<td>0.06 (0.04 to 0.08)</td>
<td>−0.02 (−0.03 to −0.001)</td>
</tr>
<tr>
<td></td>
<td>0.09 (0.03 to 0.15)</td>
<td>0.03 (0.01 to 0.04)</td>
<td>0.07 (0.04 to 0.11)</td>
<td>0.03 (−0.01 to 0.06)</td>
<td>−0.02 (−0.04 to −0.006)</td>
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<tr>
<td></td>
<td>(n = 153)</td>
<td>(n = 152)</td>
<td>(n = 153)</td>
<td>(n = 139)</td>
<td>(n = 151)</td>
</tr>
<tr>
<td>≥65 (n = 107)</td>
<td>(n = 111)</td>
<td>(n = 114)</td>
<td>(n = 105)</td>
<td>(n = 109)</td>
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<tr>
<td></td>
<td>0.03 (−0.06 to 0.12)</td>
<td>0.02 (0.008 to 0.04)</td>
<td>−0.02 (−0.08 to 0.05)</td>
<td>0.04 (0.003 to 0.08)</td>
<td>−0.04 (−0.07 to −0.02)</td>
</tr>
<tr>
<td>Total No.</td>
<td>735</td>
<td>738</td>
<td>744</td>
<td>674</td>
<td>732</td>
</tr>
<tr>
<td>Mean difference (95% CI)</td>
<td>0.02 (−0.03 to 0.08)</td>
<td>−0.004 (−0.02 to 0.008)</td>
<td>−0.002 (−0.04 to 0.04)</td>
<td>0.0009 (−0.03 to 0.03)</td>
<td>−0.009 (−0.03 to 0.008)</td>
</tr>
<tr>
<td>Educational level</td>
<td>Less than high school (n = 240)</td>
<td>(n = 245)</td>
<td>(n = 246)</td>
<td>(n = 231)</td>
<td>(n = 243)</td>
</tr>
<tr>
<td></td>
<td>0.15 (0.11 to 0.18)</td>
<td>0.01 (0.005 to 0.02)</td>
<td>0.06 (0.02 to 0.09)</td>
<td>0.06 (0.04 to 0.08)</td>
<td>−0.03 (−0.04 to −0.01)</td>
</tr>
<tr>
<td></td>
<td>(n = 397)</td>
<td>(n = 399)</td>
<td>(n = 400)</td>
<td>(n = 361)</td>
<td>(n = 396)</td>
</tr>
<tr>
<td>High school or above (n = 454)</td>
<td>(n = 453)</td>
<td>(n = 457)</td>
<td>(n = 415)</td>
<td>(n = 449)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.12 (0.08 to 0.16)</td>
<td>0.02 (0.008 to 0.03)</td>
<td>0.06 (0.04 to 0.08)</td>
<td>0.06 (0.04 to 0.07)</td>
<td>−0.02 (−0.03 to −0.006)</td>
</tr>
<tr>
<td>Total No.</td>
<td>694</td>
<td>698</td>
<td>703</td>
<td>646</td>
<td>692</td>
</tr>
<tr>
<td>Mean difference (95% CI)</td>
<td>−0.06 (−0.12 to −0.006)</td>
<td>0.01 (0.00005 to 0.03)</td>
<td>−0.05 (−0.09 to −0.008)</td>
<td>−0.02 (−0.05 to 0.004)</td>
<td>−0.02 (−0.03 to 0.002)</td>
</tr>
<tr>
<td>Baseline spherical equivalent</td>
<td>First quartile (&lt;−0.875 D) (n = 186)</td>
<td>(n = 189)</td>
<td>(n = 191)</td>
<td>(n = 166)</td>
<td>(n = 186)</td>
</tr>
<tr>
<td></td>
<td>0.11 (0.04 to 0.18)</td>
<td>0.02 (0.01 to 0.04)</td>
<td>0.09 (0.05 to 0.14)</td>
<td>0.07 (0.05 to 0.09)</td>
<td>−0.01 (−0.03 to 0.004)</td>
</tr>
<tr>
<td></td>
<td>(n = 195)</td>
<td>(n = 193)</td>
<td>(n = 195)</td>
<td>(n = 177)</td>
<td>(n = 192)</td>
</tr>
<tr>
<td>Second quartile (−0.875 to 0 D) (n = 174)</td>
<td>(n = 172)</td>
<td>(n = 174)</td>
<td>(n = 159)</td>
<td>(n = 170)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.12 (0.07 to 0.17)</td>
<td>0.01 (−0.003 to 0.03)</td>
<td>0.05 (0.01 to 0.09)</td>
<td>0.07 (0.04 to 0.10)</td>
<td>−0.02 (−0.04 to −0.007)</td>
</tr>
<tr>
<td>Third quartile (0 to +0.625 D) (n = 180)</td>
<td>(n = 180)</td>
<td>(n = 181)</td>
<td>(n = 168)</td>
<td>(n = 180)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.17 (0.13 to 0.20)</td>
<td>0.01 (0.003 to 0.02)</td>
<td>0.06 (0.03 to 0.09)</td>
<td>0.06 (0.04 to 0.09)</td>
<td>−0.008 (−0.02 to 0.007)</td>
</tr>
<tr>
<td>Fourth quartile (+0.625 D) (n = 180)</td>
<td>(n = 180)</td>
<td>(n = 181)</td>
<td>(n = 168)</td>
<td>(n = 180)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.14 (0.09 to 0.19)</td>
<td>0.01 (0.006 to 0.02)</td>
<td>0.03 (−0.009 to 0.07)</td>
<td>0.03 (0.002 to 0.06)</td>
<td>−0.04 (−0.06 to −0.01)</td>
</tr>
<tr>
<td>Total No.</td>
<td>735</td>
<td>734</td>
<td>741</td>
<td>670</td>
<td>728</td>
</tr>
<tr>
<td>Change in 2-y difference per 1-U increase in RE (95% CI)</td>
<td>0.01 (−0.001 to 0.02)</td>
<td>−0.005 (−0.008 to −0.002)</td>
<td>−0.009 (−0.02 to −0.0007)</td>
<td>−0.004 (−0.01 to 0.002)</td>
<td>−0.004 (−0.008 to −0.0002)</td>
</tr>
</tbody>
</table>

Abbreviations: D, diopter; RE, refractive error.

*All values are for the right eye.

*P < .01.

*P < .05.

*P < .001.
However, evidence of cohort effects was present as well. Refractive error was most myopic among the youngest cohort (35-44 years); thus, cross-sectional differences between this and the older groups were the greatest. However, this group of individuals aged 35 to 44 years did not have the greatest 2-year hyperopic shift (0.10 D for those aged 35-44 years vs 0.22 D for those aged 45-54 years) (Table 1 and Figure 2). This finding is consistent with cohort effects explaining part of the more myopic RE observed among younger persons.

Axial length data are also consistent with cohort effects occurring among the younger participants (35-44 years). Although AL was greater among these younger persons compared with those aged 45 to 64 years, we found no evidence for any decline in AL with age that might explain this finding (Figure 2). In fact, the 2-year change in AL was either small or in the positive direction among all age groups (Supplement eFigure 3). It may be that these younger individuals were subjected to greater educational pressures than those born earlier, leading to greater myopia and longer AL. Our educational data are consistent with this hypothesis: high school completion rates declined from 80% among those aged 35-44 years to 32% among those aged 65 years or older (P < .001). We cannot exclude the possibility of similar or greater cohort effects among persons younger than the youngest participants in our study. Few data are available, and none of which we are aware in China, to quantify population changes in RE in people aged 16 to 35 years. Educational level was associated with RE in 2008 and 2010, but after adjusting for biometric variables, this association disappeared, suggesting that any effect of educational level on RE is mediated through these biometric factors.

The small longitudinal increase in AL in this population could not explain the 2-year hyperopic shift recorded. The observed 2-year increase in corneal power and LT and the decrease in ACD (assuming this represents forward movement of the lens), would also be expected to lead to increasing myopia rather than hyperopia. Increasing hyperopia despite an increase in LT has been described as the “lens paradox,” apparently because of the lens losing power despite growing thicker owing to age-related reduction in the gradient of refractive index.

Multiple regression models (Table 2) could explain 80% of the cross-sectional variation in RE, with approximately half of the variability in the 2008 and 2010 data sets being explained by AL. However, only approximately 15% of the variation in the change in RE could be explained by similar models (Table 3). Thus, the variables that influence change in RE with aging among Chinese populations are still not well understood. It is possible that including lens power in our analysis would have improved predictive power, a point that should be addressed in future research.

We are unaware of other longitudinal population-based studies of RE and biometry among ethnic Chinese people. The refractive changes we observed (0.075 D/y) are similar to or slightly greater than those reported for persons of European descent (0.05 D/y in the Beaver Dam study and 0.04 D/y in the Blue Mountains studies), although the youngest participants in our study were 8 to 14 years younger at baseline than the youngest individuals in these studies. Our findings are consistent with those of previous reports in that hyperopic shifts were more prominent in younger age groups, perhaps being partly offset by myopic shift from nuclear cataract among older subjects.

If cohort effects explain much or all of the refractive difference observed between younger and older adults in this population, 2 D in the present study, an implication may be that the prevalence of angle-closure glaucoma will decline in China as these younger myopic cohorts replace more hyperopic ones. Alternatively, if aging changes in RE may be sufficient to explain much of the observed difference between persons in their 30s and their 60s in this population, younger myopic cohorts might resemble older cohorts more closely over time with regard to their refractive distribution and, by implication, possibly their angle-closure risk. More longitudinal studies including younger cohorts are needed to better understand this potentially important question of future angle-closure risk in China.
Strengths of this study include its population-based design and the use of noncontact technologies for most measurements. Rates of follow-up and completion of testing were also generally high. The age range of participants available for testing was wide, beginning with participants in their 30s and extending into the 80s.

Limitations include the fact that cycloplegia was not used for refraction, raising the possibility that some of the cross-sectional differences in RE observed between younger and older persons might have been the result of loss of accommodation, although a hyperopic shift in the age range 35 to 64 years has previously been observed when using cycloplegia. Similarly, some of the measured increase in hyperopia over 2 years might have been the result of loss of accommodative power, resulting in a less myopic RE at follow-up.

The relatively small refractive shift of 0.075 D/y is a point estimate based on 2 years of observation. Although this figure remains consistent in direction between ages 35 and 65 years (Figure 1), the estimation of a total age-related change of 2 D over 30 years is imprecise. The 2-year follow-up period was short, although it was adequate to observe changes in several of the factors we studied, all of which were in the expected direction (hyperopic change in RE,8,9 increase in LT,5 and decrease in ACD9). However, further follow-up would be beneficial.

**Conclusions**

To our knowledge, this study is the first to report longitudinal refraction data for Chinese individuals on a population basis and as such can be helpful in better understanding how changes in refraction may affect the distribution of RE and related eye diseases in the future in this large population.
Research  Original Investigation  

Refractive error and visual impairment in urban populations: Evidence from China and the United States

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Study concept and design: He, Kong, Morgan, Congdon.
Acquisition, analysis, or interpretation of data: Chen, Zeng, Huang, Zhang, Meltzer, Jin, Congdon.
Drafting of the manuscript: He, Zeng, Meltzer, Jin, Congdon.
Critical revision of the manuscript for important intellectual content: Kong, Chen, Zeng, Huang, Morgan, Congdon.
Statistical analysis: He, Zeng, Morgan, Meltzer, Jin, Congdon.
Obtained funding: He, Morgan, Congdon.
Administrative, technical, or material support: He, Kong, Chen, Zeng, Huang, Morgan, Congdon.
Study supervision: He, Congdon.

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REFERENCES