Changes in Refraction over 10 Years in an Adult Population: The Beaver Dam Eye Study

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Purpose. To quantify the 10-year change in refraction in persons more than 40 years of age.

Methods. All people 43 to 84 years of age and living in Beaver Dam, Wisconsin, in 1988 were invited for a baseline examination (1988–1990), a 5-year follow-up examination (1993–1995), and a 10-year follow-up examination (1998–2000). Refractions were determined according to the same protocol at all examinations. Aphakic and pseudophakic eyes and eyes with best corrected visual acuity of 20/200 or worse were excluded. After exclusions, refraction data were available on 2362 right eyes of the 2937 people examined at baseline and 10-year follow-up.

Results. Age was related to the direction and amount of change in refraction. Spherical equivalent became more positive in the youngest subjects and more negative in the oldest. After adjustment for the severity of nuclear sclerosis and other factors, the 10-year change in refraction was +0.48, +0.03, and −0.19 D for persons 43 to 59, 60 to 69 and 70+ years of age at the baseline examination, respectively. Severity of nuclear sclerosis was also strongly related to amount of change. Those with mild nuclear sclerosis at baseline had a change of +0.35 D, whereas those with severe nuclear sclerosis had a change of −0.53 D. The amount of change was also related to diabetes and weakly related to baseline refractive error, but was unrelated to gender and education. In addition to the longitudinal changes observed, there was a birth cohort effect. In comparing people of the same age across examinations, those born in more recent years had more myopia than those born in earlier years.

Conclusions. Significant changes in spherical equivalent in adults occur over a 10-year period. Younger people became more hyperopic, whereas older people became more myopic. These data provide evidence of a longitudinal change in refraction in adults, which may explain the refractive patterns observed in cross-sectional studies. (*Invest Ophthalmol Vis Sci.* 2002;43:2566–2571)

Refractive error is a common condition worldwide. In recent years, several population-based studies have begun to examine the prevalence of myopia and hyperopia in adults.[1–10] Data from these studies show that the prevalence of myopia declines with age. For example, in the Beaver Dam Eye Study, prevalence of myopia decreased from 42% in those 43 to 54 years of age to 14% in those 75 and older.[1] The Baltimore Eye Survey and the Blue Mountains Eye Study found similar decreases in prevalence of myopia with age.[2,3] Some studies have found the prevalence of myopia to increase again after the age of 60 or 70. The Visual Impairment Project (VIP) in Australia found prevalence of myopia to be 24% in those 40 to 49 years of age, declining to 12% in those 70 to 79, and increasing to 17% in those 80+.[4] Studies in nonwhite populations show similar prevalence patterns.[2,5,6] Studies that report the mean refraction show similar trends of more myopic refraction among people in their 40s, more hyperopic refraction until the age of 60 or 70, then more myopic refraction again.[7–10]

The reasons for these cross-sectional patterns are unclear. Education is strongly associated with prevalence of myopia.[1–4,7,11] The higher prevalence of myopia in younger ages has been hypothesized to be due to differences between birth cohorts that may have had different exposures to education. In an Eskimo population, noticeable increases in the prevalence of myopia coincided with the introduction of mandatory education.[12]

Others, however, have hypothesized that these patterns reflect age-related changes within a person. Data from studies that compared the prevalence results of studies that were conducted during different decades suggested a longitudinal change with age, instead of a cohort effect.[13,14] Another study that examined medical records of a clinic-based population over time found people in their 20s and 30s had refractive changes toward myopia, whereas people in their 50s and 60s had changes toward hyperopia over 10 years of follow-up.[15] To our knowledge, the Beaver Dam Eye Study is the only population-based study that has examined changes in refraction over a long period in adults. Observations during a 5-year period showed a shift toward hyperopia occurred among all ages while accounting for degree of nuclear sclerosis.[16] This population has now been observed for 10 years, permitting us to examine whether the shift toward hyperopia persists and to examine possible cohort effects in this population.

Methods

Population

Methods used to identify the population and description of participants and nonparticipants appear in previous reports.[17–19] Briefly, a private census of the population of Beaver Dam, Wisconsin, was performed from fall 1987 through spring 1988. All 5925 people identified as living within the township of Beaver Dam and aged 43 to 84 years were eligible for participation and were invited for baseline examinations from March 1988 through September 1990. All people participating in the baseline examination and surviving until March 1993 (n = 4541) were invited to return for follow-up examinations from March 1993 through June 1995. A total of 3684 returned for the second examination phase. All participants at the baseline examination were also invited to return for the second follow-up examination from March 1998 through June 2000. A total of 2937 people who had participated at the baseline examination returned for this examination (2764 people participated in all three examinations).

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Procedures

Similar procedures were used at each examination phase. Tenets of the Declaration of Helsinki were observed. Informed consent was obtained from each subject, and institutional human experimentation committee approval was granted. Measurement of the refractive correction in each participant's current prescription (if available) was made, followed by a single standardized noncycloplegic refraction with an automated refractor (model 530; Humphrey Instruments, San Leandro, CA). The refraction was refined according to a modification of The Early Treatment Diabetic Retinopathy Study (ETDRS) protocol[20] to obtain the best corrected visual acuity when the automated refraction yielded visual acuity of 20/40 or worse. Inter- and intraexaminer comparisons showed no significant differences in the refractions, over time or among examiners. Examiners' reliability measured within 0.25 D.

Blood pressure was measured according to the Hypertension Detection and Follow-up Program protocol.[21] Pupils were pharmacologically dilated with 2.5% phenylephrine and 1% tropicamide. A scheduled interview was administered. During the interview, participants were asked about years of education completed; income; and history of diabetes, cardiovascular diseases (myocardial infarction, angina, and stroke), and cigarette and alcohol consumption. Specifically, the years and number of cigarettes smoked and number of 12-oz bottles of beer, 4-oz glasses of wine, and 1.5-oz glasses of liquor consumed per average week were recorded. After pupil dilation, slit lamp examination of the lens was performed. Photographs were then taken of the lens of each eye with modified cameras. Slit lamp photographs were subsequently graded for lens status and severity of nuclear sclerosis.[22] Nuclear sclerosis was graded on a five-level scale by comparing the slit lamp photographs to a set of standards. Serum glucose and glycosylated hemoglobin from a casual blood specimen were measured for each subject.[23,24]

Definitions

The spherical equivalent (defined as sum of spherical power and half-cylinder power, in diopters) was calculated from one of three possible methods of refraction. The results of the Humphrey refraction were used in the analyses for the majority of the population (97% at baseline, 94% at 5-year follow-up, and 93% at 10-year follow-up). When ETDRS refraction (as modified for this study and described herein) was performed, that refraction was used in the analyses (3% at baseline, 4% at 5-year follow-up and 3% at 10-year follow-up). In the remaining people, refraction from the current prescription was used. Eyes without a lens or with an intraocular lens were excluded. In addition, eyes with best corrected visual acuity of 20/200 or worse were excluded from these analyses because of diminished reliability of refractions and increased variability of refractions. No person in the study had undergone refractive surgery.

Change in refraction was defined as the refraction at the baseline examination subtracted from the refraction at the 10-year examination. Myopia was defined as a spherical equivalent more myopic than −0.5 D. Hyperopia was defined as a spherical equivalent more hyperopic than +0.5 D. Incident myopia was defined as a change from −0.5 D and more hyperopic to more myopic than −0.5 D. Similarly, incident hyperopia was defined as a change from +0.5 D and more myopic to more hyperopic than +0.5 D. Change in spherical equivalent over time resulting in a positive change was defined as a shift toward hyperopia, whereas that resulting in a negative change was defined as a shift toward myopia.

A person was considered to have diabetes if there was a self-report of diabetes accompanied by treatment (insulin or diet) or elevated glucose or glycosylated hemoglobin. Age was defined by the baseline value. Education level was categorized as fewer than 12 years, 12 years, 13 to 15 years, and 16 or more years. Pack-years was defined as the number of packs smoked per day times the number of years smoked. The number of glasses of beer, wine, and hard liquor were converted to grams of ethanol (12.96 g for beer, 11.48 g for wine, and 14.0 g for hard liquor) and totaled. Nuclear sclerosis was graded as no nuclear sclerosis (grades 1 and 2), mild (grade 3), and severe (grades 4 and 5).

Statistical Methods

Analyses were performed using SAS[25] and were performed separately on data from the right and left eyes. The mean amount of change was calculated for each level of a categorical risk factor, such as age or gender. Significance of differences in means was assessed through analysis of variance. When multiple risk factors were included in the model, type III sums of squares (SS) were examined.[26] To compute the estimated change after adjusting for other factors, the multivariate model was evaluated with the appropriate population percentage used for each category for each risk factor. The amount of change was also categorized and compared between ages and genders with the Mantel-Haenszel test. Cumulative 10-year incidences of myopia and hyperopia (as categorical measures) were assessed through the discrete linear logistic model. Differences between age and gender groups were assessed with log rank statistics. Cohort effects were examined visually by treating the refractions observed at each examination of a person as independent observations and plotting those by age (at the corresponding examination) and year of birth.

Results

Changes in spherical equivalent were analyzed for the 2362 right eyes with refraction, after exclusions, at the baseline and 10-year follow-up examinations. The exclusions were: 205 with refractions not measured, 324 with cataract extractions, and 46 with visual acuity of 20/200 or worse. After similar exclusions, 2393 left eyes were available for analyses. Because results from right and left eyes were similar, only the results from the right eyes are presented. Comparisons of various characteristics among those included for analyses and those excluded are shown in Table 1. Those excluded tended to be older, female, and shorter and to have lower income, severe nuclear sclerosis, diabetes, and more pack-years smoked. There were no differences in refractive error at the baseline examination.

The distribution of the 10-year change in spherical equivalent by age and gender is shown in Table 2. There were no differences between genders, but there were significant differences among the age groups. Those in the youngest age group (43–59 years at baseline) showed an average shift toward hyperopia of +0.54 D (95% confidence interval [CI]: +0.50 to +0.58). Those in the middle age group (60–69 years) had a 10-year change of −0.03 D (95% CI: −0.13 to +0.07). Those in the oldest age group (70 years and older) had an overall shift toward myopia of −0.41 D (95% CI: −0.57 and −0.25). Over the 10-year interval, the entire population experienced a shift toward hyperopia of +0.28 D (95% CI: +0.24 and +0.32).

To evaluate the pattern of change over the 10-year period, we examined the subgroup of 2235 people with refraction data at all three examinations (Fig. 1). The shift toward hyperopia observed in the youngest group was nearly linear over time. The overall 10-year change in refraction in the middle group (60–69 years) resulted from an initial shift toward hyperopia between the baseline and 5-year examinations, followed by a shift in myopia between the 5- and 10-year examinations. The overall 10-year shift toward myopia in the oldest group (70 years and older) resulted from a small shift toward myopia between baseline and the 5-year examinations followed by a larger shift between the 5- and 10-year examinations.

Nearly 50% of the population under the age of 60 years had a shift toward hyperopia greater than 0.5 D, whereas only 4% had a shift toward myopia more than −0.5 D (Table 2). Among those 70 years of age and older, the trend was reversed, with

Table 1. Comparison of Participant Characteristics by Inclusion for Analyses, Right Eyes

Characteristic	Included *n*	Included Mean	Included SD	Excluded *n*	Excluded Mean	Excluded SD	*P**
Age (y)	2362	57.2	9.2	575	65.6	9.8	<0.001
Systolic blood pressure (mm Hg)	2362	128.2	18.2	575	133.5	20.3	0.07
Diastolic blood pressure (mm Hg)	2362	78.5	10.3	575	76.0	10.5	0.06
Education (y)	2360	12.6	2.7	575	12.1	2.9	0.19
Height (in.)	2360	65.8	3.6	573	64.7	3.6	0.02
Pack-years smoked	2353	14.6	22.0	572	16.4	27.7	0.02
Alcohol (g ethanol)	2353	57.1	107.2	575	49.1	137.4	0.98
	n	%		*n*	%		*P**
Gender (female)	2362	56.2		575	66.4		0.005
Income (US$)	2301			547			
<10,000		8.1			19.9		
10,000–19,000		22.3			33.3		
20,000–29,000		22.3			17.0		
30,000–44,000		25.9			16.1		
≥45,000		21.4			13.7		0.02
Diabetes (yes)	2324	5.7		563	11.4		<0.001
Cardiovascular disease history (yes)	2341	8.7		563	13.5		0.78
Refractive error	2362			465			
Myope		31.3			28.2		
Hyperope		40.9			51.8		0.68
Severe nuclear sclerosis (grades 4, 5)	2335	4.0		469	29.4		<0.001

* Age-adjusted.

33% having a shift toward myopia and only 15% having a shift toward hyperopia. The cumulative 10-year incidence of myopia was higher in the older age groups. The cumulative 10-year incidence of hyperopia was similar among all ages; however, there are not many people 70 years and older at baseline who were at risk for incident hyperopia.

We considered whether other characteristics might be related to changes in refraction. First, age-adjusted change associated with these factors was examined one at a time. A multivariate model with all these factors was then fit and the amount of change after adjustment for all the other factors was estimated (Table 3). The results of the multivariate model did not differ substantially from the age-adjusted model. Degree of nuclear sclerosis, presence of diabetes, and baseline refractive error were all significantly related to the amount of 10-year change observed. Gender and education were not related to change in refraction. After adjusting for age and all other factors, those with moderate nuclear sclerosis (level 3) at baseline had a shift toward hyperopia over the 10 years of +0.21 D, whereas those with severe nuclear sclerosis (levels 4, 5) at baseline had a shift toward myopia of −0.53 D. Those with diabetes had a greater shift toward hyperopia than those without. People who had hyperopia or myopia at baseline had slightly smaller shifts

Table 2. Age and Gender Distribution of 10-Year Changes in Refraction (Spherical Equivalent) in the Right Eye of Participants in the Beaver Dam Eye Study

Gender	Baseline Age (y)	10-Year Change in Spherical Equivalent *n*	Change (D)	95% CI	Percent with 10-Year Change < −0.5 D	> +0.5 D	Cumulative 10-Year Incidence: Myopia *n*	Myopia %	Hyperopia *n*	Hyperopia %
Female	43–59	802	+0.56	+0.50 to +0.62	4.5	49.4	423	3.3	556	25.5
	60–69	358	−0.08	−0.22 to +0.06	24.3	32.4	263	9.5	138	21.0
	70+	167	−0.41	−0.61 to −0.21	33.5	15.0	136	14.0	44	15.9
	Total	1327	+0.27	+0.21 to +0.33	13.5	40.5	822	7.1	738	24.1
Age trend			$P < 0.001$		$P < 0.001$		$P < 0.001$		$P = 0.24$	
Male	43–59	654	+0.51	+0.45 to +0.57	2.6	41.1	397	4.5	450	24.2
	60–69	284	+0.03	−0.11 to +0.17	18.7	30.6	229	9.6	111	32.4
	70+	97	−0.41	−0.65 to −0.17	33.0	16.5	84	15.5	23	8.7
	Total	1035	+0.29	+0.23 to +0.35	9.9	35.9	710	7.5	584	25.2
Age trend			$P < 0.001$		$P < 0.001$		$P < 0.001$		$P = 0.04$	
Female vs male (unadjusted)			$P = 0.57$		$P = 0.74$		$P = 0.76$		$P = 0.70$	
Total	43–59	1456	+0.54	+0.50 to +0.58	3.6	45.7	820	3.9	1006	25.0
	60–69	642	−0.03	−0.13 to +0.07	21.8	31.6	492	9.6	249	26.1
	70+	264	−0.41	−0.57 to −0.25	33.3	15.5	220	14.5	67	13.4
	Total	2362	+0.28	+0.24 to +0.32	11.9	38.5	1532	7.2	1322	24.6
Age trend			$P < 0.001$		$P < 0.001$		$P < 0.001$		$P = 0.11$	

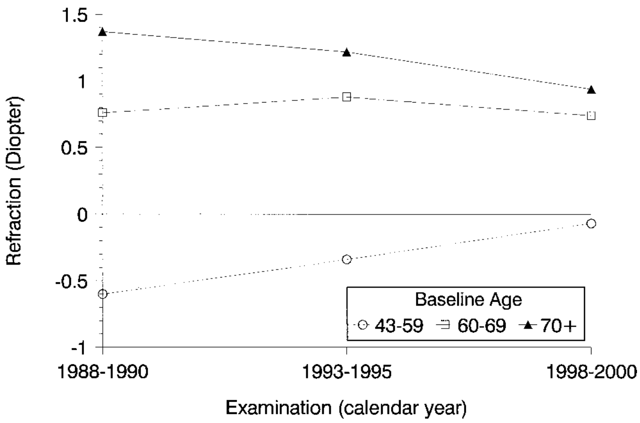

FIGURE 1. Refraction (spherical equivalent, right eye) at each examination by age for in The Beaver Dam Eye Study.

toward hyperopia (+0.24 D and +0.25 D, respectively) than did emmetropes at baseline (+0.38 D).

We further explored the relationship of refraction with nuclear sclerosis and age. To account for the direct effect of nuclear sclerosis on refraction we normalized refraction at each visit to the nuclear sclerosis amount at that visit, as follows. The mean and SD of refraction in the population for each level of nuclear sclerosis were determined and then subtracted from each person's refraction. This difference was then divided by the SD. These calculations were performed at each visit separately. Once each person's refraction was normalized, the 10-year change was calculated and analyzed (Table 4). Although the estimates changed from those in Table 3, the relative differences and conclusions changed very little.

Finally, the relative effects of age and year of birth (birth cohort) on the refractive changes were examined (Fig. 2). Each person may contribute information for multiple points on the figure and all people born in the same time interval, as defined on the figure, are connected with a line. For example, a person born in 1930 would have been 58 at the baseline examination, 63 at the 5-year examination, and 68 at the 10-year examination, thus contributing data to three points on the figure. We plotted only the points with at least 200 observations. The shift toward hyperopia observed in the younger participants and the shift toward myopia in the older participants were evident (Fig. 2). In addition, a birth cohort effect was evident. The refraction in people the same age at the various examinations was more myopic in persons born in more recent years. For example, the average refractions in persons 55 to 59 years at an examination were +0.20 D (n = 405), −0.13 D (n = 516), and −0.50 D (n = 506), for those born in 1928 to 1932, 1933 to 1937, and 1938 to 1942, respectively. The confidence intervals for these points do not overlap, which indicates a statistically significant birth cohort effect. In other age groups, the differences by birth year are not as distinct, but the trends still exist.

DISCUSSION

The variation in refractive error in adults has been described in several population-based cross-sectional studies. Although there are some small differences in techniques and definitions, these studies have shown increasing prevalence of hyperopia with increasing age after the age of 40 years.[1–4,11] After 70 years of age, some studies have found that the prevalence of myopia starts to increase.[4–10] The explanation for these observed prevalence patterns is not clear but has been hypothesized to be due to either a birth cohort effect or to actual longitudinal changes in refractive error with age.[13,14] These cross-sectional studies are limited in their ability to distinguish these effects. Our study provides prospective evidence that both effects appear important in explaining the refractive pat-

TABLE 3. Estimated Effects for Various Factors for 10-Year Change in Refraction (Spherical Equivalent) in the Right Eye, Adjusting for Age Alone, Then Adjusting for Other Factors in The Beaver Dam Eye Study

Factor	n	10-Year Change in Spherical Equivalent (D)	Age-adjusted Model: Estimated Change (diopters)	Age-adjusted Model: P	Multivariate Model*: Estimated Change† (D)	Multivariate Model*: 95% CI	Multivariate Model*: P
Age at baseline (years)							
43–59					0.48	0.42 to 0.53	—
60–69					0.03	−0.05 to 0.11	<0.001
70+					−0.19	−0.32 to −0.06	<0.001
Gender							
Female	1327	0.27	0.28	—	0.30	0.25 to 0.36	—
Male	1035	0.29	0.28	0.93	0.25	0.19 to 0.31	0.22
Education (y)							
<12	427	0.01	0.22	—	0.23	0.14 to 0.33	—
12	1150	0.30	0.27	0.37	0.27	0.21 to 0.32	0.53
13–15	375	0.39	0.32	0.15	0.34	0.24 to 0.44	0.14
16+	408	0.40	0.33	0.12	0.32	0.22 to 0.41	0.23
Nuclear sclerosis (grade)							
None (1, 2)	1656	0.44	0.35	—	0.35	0.31 to 0.40	—
Moderate (3)	585	0.04	0.21	0.004	0.21	0.12 to 0.29	0.004
Severe (4, 5)	94	−0.83	−0.46	<0.001	−0.53	−0.73 to −0.32	<0.001
Diabetes status							
No	2191	0.27	0.26	—	0.27	0.23 to 0.31	—
Yes	133	0.42	0.49	0.008	0.52	0.36 to 0.68	0.003
Baseline refractive error							
Emmetrope	656	0.47	0.39	—	0.38	0.30 to 0.45	—
Myope	739	0.37	0.25	0.007	0.24	0.16 to 0.31	0.006
Hyperope	967	0.08	0.22	<0.001	0.25	0.19 to 0.32	0.01

* Model contains all factors in the table.
† Change estimated for the factor after adjustment for other factors in the model.

TABLE 4. Estimated Effects for Various Factors with Amount of Change after Normalizing Refraction for Degree of Nuclear Sclerosis

	Multivariate Model (adjusted for all other factors)			
Factor	**Estimated Change in Spherical Equivalent (D)**	**95% CI**	***P***	**F**
Age (y)				
43–59	0.11	0.08 to 0.14	—	—
60–69	−0.09	−0.13 to −0.05	<0.001	66.20
70+	−0.10	−0.17 to −0.03	<0.001	32.18
Gender				
Female	0.05	0.02 to 0.07	—	—
Male	0.02	−0.01 to 0.05	0.26	1.25
Education (y)				
<12	0.01	−0.04 to 0.06	—	—
12	0.03	0.00 to 0.06	0.45	0.58
13–15	0.06	0.01 to 0.11	0.15	2.10
16+	0.06	0.01 to 0.11	0.16	2.01
Diabetes				
No	0.03	0.01 to 0.05	—	—
Yes	0.16	0.08 to 0.25	0.003	8.77
Baseline refractive error				
Emmetrope	0.07	0.03 to 0.11	—	—
Myope	0.05	0.02 to 0.09	0.53	0.40
Hyperope	−0.01	−0.04 to 0.03	0.004	8.45

terns in adults. First, we found that younger people tended to shift more toward hyperopia, whereas older people shifted toward myopia during the 10-year interval. In persons aged 43 to 59 years, the average 10-year change in refraction was +0.54 D, whereas in those 70 years and older, the average change was −0.41 D. This is consistent with our 5-year data that showed that persons aged 55 to 64 had a change of +0.21 D, whereas those 75 years and older had a change of −0.30 D.[16] Second, we found that when people of the same age were compared, those born in more recent years had higher myopia than those born earlier, which supports a birth cohort effect. The birth cohort effect was strongest in the younger participants.

The shift toward myopia in the oldest age group may be attributable to advancing nuclear sclerosis. Nuclear sclerosis, age, and refraction appear to be closely linked.[4,10,27,28] We used two different models to account for the effect of nuclear sclerosis. Conclusions from each model were similar to each other and to models adjusting for age only. The main effect of adjustment for nuclear cataract was an attenuation of the shift

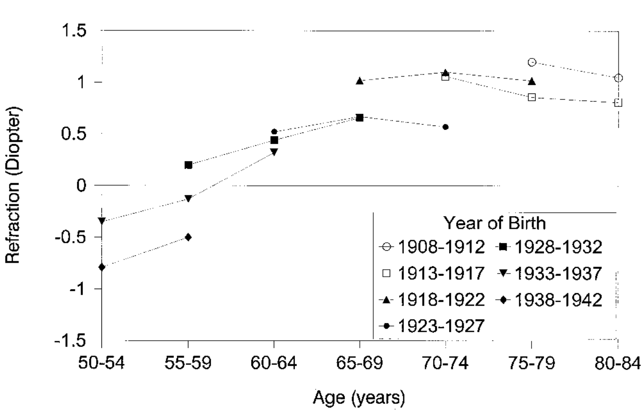

FIGURE 2. Refraction (spherical equivalent, right eye) at each examination by year of birth and corresponding age in The Beaver Dam Eye Study.

in myopia in the oldest age group. Thus, although nuclear sclerosis was an important factor in the amount of change in refraction, age was still an important factor. Nuclear sclerosis was also important because those with nuclear sclerosis at baseline may have been excluded from these analyses due to extraction of cataract or poor visual acuity.

In addition, other lenticular changes may occur. Studies examining the components of refraction have found that the lens gets thicker and more steeply curved with age.[10,29,30] In compensation for these effects, the gradient in the refractive index also changes.[29,31,32] Recent work by Glasser and Campbell[30] has shown that the focal length of the lens increases up to age 65 years and then begins to decrease. These changes may explain some of the shifts observed in this study as well as the cross-sectional results.

In addition to lenticular changes, some studies have shown that the axial length continues to change in adults. Studies in young adults have shown that education and near work appear to cause increases in axial length and shifts toward more myopia.[33–35] In an adult population in Singapore, the amount of myopia and hyperopia was most strongly related to axial length after adjustment for age and gender.[10] We cannot evaluate these relationships, because we do not have measurements of axial length or near work in our study subjects.

Other factors examined did not have a strong effect on the refraction changes. Gender and education had no effect, whereas the presence of diabetes tended to cause a larger shift toward hyperopia. Although there were some significant differences in the amount of change by baseline refractive error, these differences were relatively small. Studies in young adults have also found that the amount of change differed little by initial refractive error.[33,34,36]

Education had no effect on the longitudinal changes, but may help explain the cohort effect. Several prevalence studies have shown higher rates of myopia among those with more education.[1–5] Both the Framingham and the Beaver Dam Eye Studies have also shown higher education levels attained in the younger subjects.[1,11] Differing patterns of education may be one explanation for the observed cohort effect.

In summary, we have documented 10-year changes in refraction in a population more than 40 years old at the baseline examination. These changes appeared to occur regardless of gender, education, or refractive status (i.e., no difference in amount of change in persons who are myopes, emmetropes, or hyperopes), but are highly dependent on age and degree of nuclear sclerosis. Younger participants had a shift toward hyperopia, whereas older participants and those with severe nuclear sclerosis had a shift toward myopia. These data provide further evidence that the eye undergoes refractive changes, even at older ages. We have also shown a cohort effect, in that people born in more recent years tended to have more myopia. The changes we observe may be noticeable to people and may require use of glasses in people who have never needed them before or may necessitate changes in current glasses. The changes are not monotonic. The changes should be recognized, especially by refractive surgeons whose are seeking to reduce refractive error at the time of surgery, but who may not be able to predict or tailor the surgery for changes in refraction that are likely to occur in their patients.

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