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Original Article

Changes in refractive status in an elderly Chinese population in a 7-year follow-up: The Shihpai Eye Study

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Abstract

Background: Refractive error is the major cause of moderate and severe visual impairment. Visual impairment limits people's ability to perform daily tasks and affects their quality of life. Longitudinal data on the refractive status of the elderly was available only for whites and Africans. The purpose of this study was to report the 7-year incidence of myopia, hyperopia and refractive error change as well as their associated risk factors in a metropolitan elderly Chinese population.

Methods: The Shihpai Eye Study 2006 included 460/824 (55.8%) subjects (age range 72−94 years old) of 1361 participants in the 1999 baseline survey for a follow-up eye examination. Incidences were calculated for those who had emmetropia (−0.50D < spherical equivalent (SE) <+0.50D) at baseline. Refractive error change at 7 year was defined as (SE at the 7-year visit − SE at baseline).

Results: 90 (26.4%) subjects were emmetropic, 61 (17.9%) were myopic and 190 (55.7%) hyperopic. The mean refractive error was 0.49 ± 2.19 D and the average change in refractive error was −0.13 ± 1.03 D. The incidence of myopia at seven-year was 26.8 % [95% Confidence interval (C.I.): 22.8%−30.9%] and the incidence of hyperopia was 19.7% (95% C.I.: 16.1%−23.3%). Nuclear sclerosis (>Grade 2 vs. ≤Grade 2) [$p < 0.0001$; relative risk (RR): 8.94; 95% C.I.: 4.40−18.2], anterior chamber depth (mm) [$p = 0.05$; RR: 0.43; 95% C.I.: 0.18−1.01] and lens thickness (mm) [$p < 0.01$; RR: 2.35; 95% C.I.: 1.17−2.73] were significantly associated with myopic shift. On the other hand, hyperopic shift was significantly associated with cortical opacity (>Grade 2 vs. ≤Grade 2) ($p = 0.02$; RR: 1.21; 95% C.I.: 1.02−3.54).

Conclusion: In this elderly Asian population, there was on average a slight myopic shift. The incidence of myopia was comparable to population-based studies of other ethnic groups, whereas the incidence of hyperopia was substantially higher.

Keywords: Cohort; Elderly; Incidence; Population-based; Refractive error

1. Introduction

It is estimated that 285 million people are visually impaired globally. According to the World Health Organization, refractive error is the major cause of moderate and severe visual impairment. Visual impairment limits people's ability to perform daily tasks[1,2] and affects their quality of life.[3−5] Most studies on refractive error have focused on school-aged children[6,7] or young and middle-aged adults.[8,9] With increased longevity, the public health costs of refractive error-imposed morbidity such as a compromised physical functioning dimension are expected to increase.[10]

There was little data on the refractive status of the elderly in the Asian populations,[11−14] and longitudinal data was

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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available only for whites[15–19] and Africans.[20] Further, ocular biometric risk factors were not assessed in most studies. The purpose of this study was to investigate the refractive error change as well as the incidence of myopia and hyperopia in a metropolitan elderly Asian population at seven-year follow-up and their associated risk factors.

2. Methods

The Shihpai Eye Study[21] was a community-based, cross-sectional survey of vision and eye diseases among non-institutionalized subjects 65 years of age and older in Shihpai, Taipei, Taiwan. Residents 65 years of age and older were identified using the household registration system. This system officially registers personal information such as date of birth, sex, and home address, as well as family members and relations. According to the official household registration in 1999, the total number of residents 65 years and older in Shihpai was 4750; 3746 persons were eligible, and 2045 of these were randomly selected to be invited to participate in the study. Of the 2045 subjects, 1361 (66.6%) participated in both the questionnaire and eye examination. The baseline examination was conducted between July 1, 1999, and December 31, 2000. Follow-up examination of the eye condition of the fixed cohort was conducted from 25 March, 2006, and ended 31 December, 2007. We planned to invite the 1361 participants in the baseline examination for the follow-up study. A structured questionnaire similar to the baseline survey[21] was conducted by intensively trained interviewers. The questionnaire obtained information on demographics (age, sex, locality, marital status, and education). Height and weight were measured and body mass index was calculated by the formula weight in kilograms divided by the square of the height in meters (kg/m^2). Personal medical history was assessed by a checklist. Participants were asked whether they had been diagnosed with a chronic disease such as diabetes (yes/no) by a physician. Cigarette smoking history was scored as smoker, passive smoker, ex-smoker, or never-smoker. Alcohol consumption was limited to wine and hard alcohol and was scored as no consumption (or frequency of alcohol consumption only once a week) or habit of alcohol consumption (frequency of alcohol consumption more than once a week). Subjects who were interviewed were invited to participate in a comprehensive ophthalmic examination conducted at the Taipei Veterans General Hospital. Ophthalmologists conducted the examinations according to a standardized protocol. Informed consent was obtained from each subject after explaining to them the purpose and procedure of the study. The survey followed the tenets of the Declaration of Helsinki.

This study was approved by the Institutional Review Board of the Taipei Veterans General Hospital.

2.1. Definitions

Spherical equivalent (SE) was used to calculate refractive error and was defined as (spherical power+ 1/2 cylinder power). Emmetropia was defined as SE $\geqq -0.5$ D and $\leqq +0.5$ D. Myopia was defined as SE <-0.5 D and hyperopia $>+0.5$ D.

Incidence of myopia and hyperopia were defined as development of myopia or hyperopia at the 7-year follow-up visit when baseline refraction was emmetropic.

Change in refraction at 7 years was defined as (SE at the 7-year visit − SE at baseline). A refractive change of >-0.5 D was considered myopic shift. A refractive change of $>+0.5$ D was considered hyperopic shift.

Three major types of age-related cataracts (nuclear, cortical, and posterior subcapsular) were assessed based on the Lens Opacity Classification system III (LOCS III) by one ophthalmologist at the slit-lamp under maximum dilatation with tropicamide. Subjects were categorized as having an age-related cataract if any type of opacity with an LOCS III grade >2 was present in one or both eyes. We chose grade >2 as the cutoff, because this grade was used in our prevalence[21] and incidence[22] analysis. Anterior chamber depth, lens thickness and axial length were measured by A-scan; central corneal thickness was measured using ultrasound pachymetry.

2.2. Statistical analysis

Dependent variables in the analysis were changes in refractive status (myopic shift and hyperopic shift). Independent variables tested were age ($\geq$80 years vs. 72–79 years), sex (male vs. female), education (high school and above vs. secondary school and below), marital status (with spouse vs. single, separated, divorced or widowed), body mass index ($\geqq$25 vs. $<$25), history of hypertension (yes vs. no), diabetes (yes vs. no), cardiovascular disease (yes vs. no), stroke (yes vs. no), history of smoking (yes vs. never; quitted vs. never) and alcohol drinking (yes vs. no). Ocular variables evaluated included nuclear sclerosis (>2 vs. $\leqq 2$), cortical opacity (>2 vs. ≤ 2), posterior subcapsular opacity (>2 vs. $\leqq 2$), anterior chamber depth (mm), lens thickness (mm), central corneal thickness (um) and axial length (mm). Univariate analysis was performed to test for an association between each independent variable and dependent variable by chi-square analysis for categorical variables and Student's t-test for continuous variables. Generalized estimating equations were used to fit the best model for independent variables. Gender, age, and other independent variables were analyzed in the multivariate models. A P value of <0.05 was considered to be statistically significant in the multivariate model. Since the correlation between the left and the right eye showed similar results ($r = 0.82$), only the results from the right eye was reported. Statistical analysis was performed by the Statistical Analysis System (SAS 6.12; SAS Institute, Cary, NC) software.

3. Results

Of the 1361 participants who attended the baseline examination in the 1999 study, 205 (15.1%) were dead before the follow-up study began, 301 (22.1%) had moved away, and

31 (2.3%) were institutionalized. In total, 824 (60.5%) subjects were thus eligible for the study, and 725 (87.4%) agreed to be interviewed for the questionnaire. Among those interviewed, 460 (55.8% of those eligible or 39.8% of the survivors) participated in the ophthalmic examination (Fig. 1). Comparisons of the demographics and some of the variables between the subjects who did and did not undergo the eye examination are shown in Table 1. The participants were younger (78.1 ± 4.1 years vs 80.4 ± 5.4 years, $p < 0.001$), more likely to be male ($p < 0.001$), and were more highly educated ($p < 0.001$).

After excluding participants who were pseudophakic, aphakic and participants whose refractive error were unable to be measured, the number of participants with both baseline and follow-up refraction were 341.

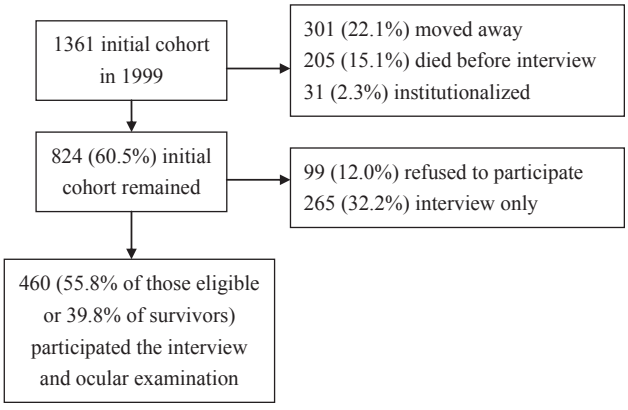

Fig. 1. Results of recruitment of the Shihpai Follow-up Study.

The distribution of refractive error in 1999 and the 7-year follow-up was similar as shown in Fig. 2. The mean 7-year refractive error of the right eye was 0.49 ± 2.19 D. The distribution showed a skew towards myopia. At baseline, the mean refractive error was 0.60 ± 1.89 D. At the 7-year follow-up, 61 (17.9%) were myopic (6.2% < −3.0 D; 2.4% < −6.0 D) and 190 (55.7%) were hyperopic as compared to 56 (16.4%) myopia and 213 (62.4%) hyperopia at baseline. 72 (21.2%) of the persons were emmetropic at baseline visit as compared to 90 (26.4%) in the follow-up visit.

The incidence of myopia at the 7-year follow-up was 26.8% (95% Confidence interval (C.I.): 22.8%–30.9%). The 7-year incidence of hyperopia was 19.7% (95% C.I.: 16.1%–23.3%).

The average change in refractive error was a slight shift towards myopia (−0.13 ± 1.03 D). 52.8% (95% C.I.: 47.5%–58.2%) of participants remained emmetropic, 26.0% (95% C.I.: 21.9%–30.7%) had myopic shift and 21.2% (95% C.I.: 16.8% %–25.6%) had hyperopic shift.

At univariate analysis, myopic shift was significantly associated with education level ($p = 0.02$), nuclear sclerosis ($p < 0.0001$), cortical opacity ($p = 0.05$) as well as lens thickness ($p < 0.01$). Under multivariate analysis controlling for confounding factors, myopic shift was significantly related to nuclear opacity ($p < 0.0001$; RR: 8.94; 95% C.I.: 4.40 −18.2), anterior chamber depth ($p = 0.05$; RR: 0.43; 95% C.I.: 0.18–1.01) and lens thickness ($p < 0.01$; RR: 2.35; 95% C.I.: 1.17–2.73) (Table 2).

Table 1
Descriptive characteristics of participants in Shihpai, Taipei, Taiwan, 2006–2007.

Characteristic		Participants (n = 460) (%)	Non-participants (n = 265) (%)	p
Age, y	72–79 y	333 (72.4)	150 (56.6)	<0.001*
	≥80 y	127 (27.6)	115 (43.4)	
Sex	Male	304 (66.1)	128 (48.3)	<0.001*
	Female	156 (33.9)	137 (51.7)	
Education	≤Secondary education	251 (54.6)	191 (72.1)	<0.001*
	≥High school	209 (45.4)	74 (27.9)	
Marital status	With spouse	365 (79.3)	191 (72.1)	0.03
	Without spouse[a]	95 (20.7)	74 (27.9)	
Body mass index, kg/m^2	<25	292 (63.5)	158 (59.6)	0.30
	≥25	168 (36.5)	107 (40.4)	
History of hypertension	Yes	213 (46.3)	138 (52.0)	0.53
	No	208 (45.2)	122 (46.0)	
History of diabetes	Yes	85 (18.5)	53 (20.0)	0.99
	No	331 (72.0)	206 (77.7)	
History of cardiovascular disease	Yes	167 (36.3)	85 (32.1)	0.06
	No	249 (54.1)	173 (65.3)	
History of stroke	Yes	14 (3.0)	18 (6.8)	0.03
	No	407 (88.5)	241 (90.0)	
Smoking (current vs. never)	Yes	43 (9.3)	14 (5.3)	0.03
	No	335 (72.8)	218 (82.6)	
Ex-smoking (quit vs. never)	Yes	46 (10.0)	29 (10.9)	0.90
	No	335 (72.8)	218 (82.3)	
Alcohol	Yes	20 (4.3)	7 (2.6)	0.10
	No	322 (70.0)	233 (87.9)	

*$p < 0.004$ (with Bonferroni adjustment).
[a] With spouse included participants who were married and living with spouse, without spouse included participants who were single, separated, divorced or widowed.

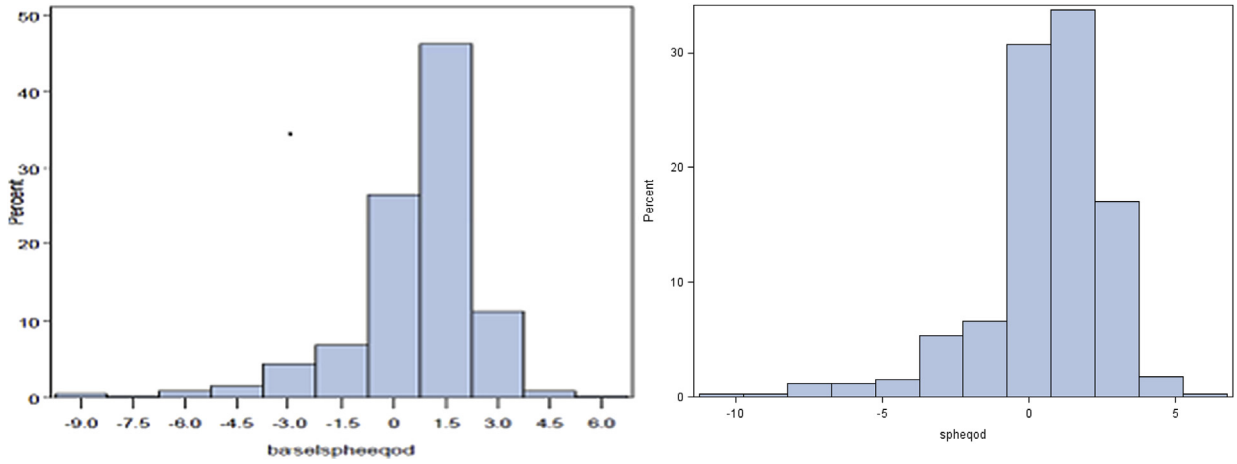

Fig. 2. The distribution of refractive error of the right eyes of participants in Shihpai, Taipei, Taiwan 1999 (left) and 2006 (right). *Percent: percentage. baselspheeqod: baseline spherical equivalent of right eye (1999). spheqod: spherical equivalent of right eye in the follow-up study (2006).

Table 2
Multivariate analysis on myopic shift among participants in Shihpai, Taipei, Taiwan, 2006–2007.

Variable	RR (95% confidence interval)	P
Age (years) (80–93 y vs. 72–79 y)	0.59 (0.25–1.43)	0.24
Gender (male vs. female)	0.77 (0.36–1.68)	0.52
Education (≧high school vs. ≦secondary)	0.53 (0.25–1.09)	0.08
Marital status (with spouse vs. single, separated, divorced or widowed)	0.42 (0.38–4.53)	0.50
Body mass index (≧25 vs. <25)	0.31 (0.18–1.06)	0.12
History of hypertension (yes vs. no)	0.32 (0.21–1.10)	0.18
History of diabetes (yes vs. no)	0.61 (0.55–4.35)	0.42
History of cardiovascular disease (yes vs. no)	0.45 (0.32–2.18)	0.45
History of stroke (yes vs. no)	0.24 (0.05–1.96)	0.24
Smoking (current and quit vs. no)	0.55 (0.44–3.40)	0.55
Alcohol drinking (yes vs. no)	0.41 (0.44–0.51)	0.41
Nuclear opacity (>2 vs. ≦2)	8.94 (4.40–18.2)	<0.0001*
Cortical opacity (>2 vs. ≦2)	0.66 (0.33–1.32)	0.24
Posterior subcapsular opacity (>2 vs. ≦2)	1.59 (0.42–6.09)	0.50
Anterior chamber (mm)	0.43 (0.18–1.01)	0.05*
Lens thickness (mm)	2.35 (1.17–2.73)	<0.01*
Pachymetry (um)	0.99 (0.97–1.01)	0.44
Axial length (mm)	1.25 (0.86–1.81)	0.25

*P < 0.05.

Table 3
Multivariate analysis on hyperopic shift among participants in Shihpai, Taipei, Taiwan, 2006–2007.

Variable	RR (95% confidence interval)	P
Age (years) (80–93 y vs. 72–79 y)	1.36 (0.35–3.06)	0.12
Gender (male vs. female)	2.26 (0.18–28.5)	0.53
Education (≧high school vs. ≦secondary)	1.47 (0.40–5.39)	0.56
Marital status (with spouse vs. single, separated, divorced or widowed)	0.52 (0.45–3.16)	0.88
Body mass index (≧25 vs. <25)	0.47 (0.32–2.45)	0.90
History of hypertension (yes vs. no)	0.48 (0.44–2.01)	0.88
History of diabetes (yes vs. no)	0.49 (0.32–2.82)	0.92
History of cardiovascular disease (yes vs. no)	0.40 (0.31–1.47)	0.32
History of stroke (yes vs. no)	0.41(0.12–3.89)	0.67
Smoking (current and quit vs. no)	0.56 (0.53–3.04)	0.59
Alcohol drinking (yes vs. no)	0.54(0.47–2.94)	0.73
Nuclear opacity (>2 vs. ≦2)	0.68 (0.11–4.35)	0.68
Cortical opacity (>2 vs. ≦2)	1.21 (1.02–3.54)	0.02*
Posterior subcapsular opacity (>2 vs. ≦2)	0.92 (0.17–4.89)	0.93
Anterior chamber (mm)	0.28 (0.04–1.85)	0.19
Lens thickness (mm)	1.30 (0.23–7.23)	0.77
Pachymetry (um)	0.99 (0.97–1.02)	0.55
Axial length (mm)	1.27 (0.91–1.78)	0.16

*P < 0.05.

On the other hand, hyperopic shift was significantly related to nuclear sclerosis ($p = 0.05$), cortical opacity ($p = 0.02$), central corneal thickness ($p = 0.04$) and axial length ($p = 0.05$) on univariate analysis. Under multivariate analyses, hyperopic shift was only significantly associated with cortical opacity ($p = 0.02$; RR: 1.21; 95% C.I. 1.02–3.54) (Table 3).

4. Discussion

To our knowledge, this is the first longitudinal population-based data on the refractive error change in a metropolitan elderly Asian population. Furthermore, we also included ocular biometric factors which were usually not available in other population-based studies.[17–20]

The distribution of refractive error in the 7-year follow-up was very similar to our baseline survey[11]; with a skew towards myopia. 17.9% of participants were myopic in the follow-up study as compared to 19.4% in the prevalence study. 55.7% of participants were hyperopic in the follow-up study, this was in concordance with 59.0% in the prevalence study. The proportion of elderly with high myopia (SE < −6.0 D) was 2.4% in both the baseline survey and the follow-up study. This contrasted sharply with the high prevalence and incidence of myopia among the younger generations in Taiwan[23] and other Asian countries,[9,24] and confirmed the age-related trends and the cohort effect of myopia.

As compared to other population-based studies that targeted the refractive change of the elderly, our study concurred

with their findings that the mean overall change is very small but in the direction of myopic shift. The mean refractive error change in our participants was −0.13 ± 1.03 D, which was comparable to that in the 9-year follow-up of the Barbados Eye Study[20] of similar age group (−0.78 ± 1.22 D) as well as the 5-year[15] (−0.22 D in participants 75 years and above) and 10-year follow-ups[16] (−0.61 D) of the Blue Mountains Eye Study. This also concurred with the findings of 5-year (−0.30 D for those 75 years and older) as well as the 10-year follow-up of the Beaver Dam Eye Study[18] (−0.41 D shift in those 70 years and older). The five-year follow-up of the Reykjavik Eye Study also had consistent findings of −0.02 D myopic shift for subjects 70 years of age and older at baseline.

The 9-year incidence of myopia (28.4%) in the Barbados Eye study[20] was also comparable to that in our findings (26.8%), whereas the incidence of hyperopia (19.7%) was substantially higher in our participants (Barbados Eye study 9.6%). This contrasted sharply with the 10-year follow-up of the Beaver Dam Eye Study, which noted 14.5% of myopic incidence and 13.4% of hyperopic incidence for those 70 years and above.

The 10-year follow-up of the Beaver Dam Eye Study noted 33.3% of those 70 years and above had myopic shifts of more than −0.5 D and 15.5% with hyperopic shift of more than +0.5 D in 10 years as compared to 26.8% and 19.7%, respectively in our study. The Barbados Eye study showed that 54.6% had myopic shift whereas 13.5% had hyperopic shift. It was speculated that a significantly smaller number of participants received cataract operation in the Barbados participants and contributed to the larger proportion of participants with myopic shift.

Our finding that myopic shift was largely due to nuclear sclerotic change of lens is consistent with those of most population-based studies.[15–20,25] We further evaluated other ocular biometric factors and noted that a shallower anterior chamber depth and a thicker lens are more prone to myopic shift. However, the impact was not as great as that of the nuclear sclerosis grading.

Multivariate analysis showed that cortical opacity was the only risk factor related to hyperopic shift. The reason why cortical opacity of the lens was associated with hyperopic shift in this elderly population is not well understood. In the literature, the underlying cause for hyperopic shift in the elderly is not well established. Other population-based studies noted that axial length and vitreous chamber depths were associated with hyperopic shift. It was speculated that cortical opacity may affect the penetration of ultrasound and hence the measurement of axial length and vitreous depth. Another plausible explanation is that cortical opacity affects the autorefractor measurement. This aspect requires further evaluation. On the other hand, we found no significant difference in refractive shift between people with and without diabetes. Educational level which was statistically significant under univariate analysis was insignificant after adjusting for confounding factors. Other systemic factors such as body mass index, history of hypertension, cardiovascular disease, and stroke as well as smoking and alcohol intake were not predictive of refractive change in the elderly.

The findings of this study are strengthened by its prospective design and comprehensive set of systemic and ocular variables considered for risk adjustment. Moreover, our survey was conducted in a medical center by professionally trained ophthalmologists according to a standardized protocol.

There are some limitations to our study. The response rate was relatively low (55.8% of those eligible). Obtaining population-based prevalence estimates of eye disease among elderly persons is challenging because this group of individuals is less likely to participate in research studies.[26] The inclusion rate in the Rotterdam Study[27] ranged from 59% in the 75- to 84-year group to 28% in the group of that was 85 years old and older. Similarly, in the Baltimore Study,[28] the inclusion rates were 48% in the 70- to 79-year group and 21% in the group that was 80 years old and older. Another potential reason for the low participation rate is that the lack of the utilization of ophthalmologic care, prevention and treatment has created the impression that loss of vision is expected in senior life and the idea that nothing can be done to improve the situation among elderly people, particularly among less-educated elderly people.[21]

The unexamined subjects remain a potential source of bias. Our study population was composed of non-institutionalized survivors and excluded those who were inpatients or had paralysis or disability, which likely removed a disproportionate number of potential participants with functional or physical impairments and/or declining health-related quality of life and thus might have biased the results of the study. Second, the assessments of co-morbidities via dichotomized classifications were simplistic. Third, the possibilities of chance findings cannot be completely excluded.

In conclusion, our study noted that refractive shifts continue in older age in the Asian population. On average, there was a slight myopic shift in the elderly. The incidence of myopia was comparable to those found in population-based studies of other races, whereas the incidence of hyperopia was substantially higher. The underlying cause of hyperopic shift is mostly due to cortical opacity, and myopic shift is mainly caused by nuclear cataract.

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