Refractive Errors and Factors Associated with Myopia in an Adult Japanese Population

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Purpose: To investigate the refractive status and factors associated with myopia by a population-based survey of Japanese adults.

Methods: A total of 2168 subjects aged 40 to 79 years, randomly selected from a local community, were assessed in a cross-sectional study. The spherical equivalent of the refractive error was calculated and used in a multiple logistic regression analysis to evaluate the relationships between myopia and possible related factors.

Results: The mean (± SD) of the spherical equivalent was −0.70 ± 1.40 diopters (D) in men, and −0.50 ± 1.44 D in women. Based on ± 0.5 D cutoff points, the prevalence of myopia, emmetropia, and hypermetropia were 45.7%, 40.8%, and 13.5% in men, and 38.3%, 43.1%, and 18.6% in women, respectively. A 10-year increase in age was associated with reduced risk of myopia [men: odds ratio (OR) = 0.53, 95% confidence interval (CI): 0.44–0.62; women: OR = 0.65, 95% CI: 0.54–0.78]. In men, myopia was significantly associated with higher education (high school: OR = 1.6, 95% CI: 1.1–2.3; college: OR = 2.0, 95% CI: 1.3–3.1) and management occupations (OR = 1.6, 95% CI: 1.0–2.4). For women, high income (OR = 1.5, 95% CI: 1.1–2.2), and clerical (OR = 1.5, 95% CI: 1.0–2.4) and sales/service occupations (OR = 1.7, 95% CI: 1.1–2.6) were also associated with myopia.

Conclusions: The prevalence of myopia in a Japanese population was similar to that in other Asian surveys but higher than in black or white populations. Our study confirmed a higher prevalence of myopia among younger vs. older populations, and a significant association with education levels and socioeconomic factors. **Jpn J Ophthalmol 2003;47:6–12** © 2003 Japanese Ophthalmological Society

Key Words: Age, education level, myopia, refractive error, socioeconomic factors.

Introduction

Earlier studies have shown that the prevalence of myopia is higher in the Asian population than in black and white populations,[1] and several epidemiological studies have shown that both genetic factors, such as race[2] and family history,[2–5] and environmental factors, such as education level[6–8] and socioeconomic status,[9–11] are important risk factors for myopia. The prevalence of myopia seems to be increasing worldwide.[1,12] In particular, the incidence of myopia has increased rapidly in younger generations over the past few decades,[13–15] and the concurrent increase in formal education and white-collar occupations may be a reason for this increase.[1]

In Japan, however, there has been no population-based survey investigating the refractive status in an adult population. Although a nationwide glaucoma survey[16] showed the prevalence of refractive errors by age, other factors related to myopia have not yet been analyzed.

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In the present study, we investigated the refractive status of middle-aged to elderly populations living in two communities in Aichi prefecture, Japan. In addition, the relationships between myopia and several other factors, such as age, physique, education level, and socioeconomic status, were examined.

Materials and Methods

Data for the present report were obtained from a population-based survey of aging conducted in Obushi and Higashiura-cho, Aichi prefecture, Japan, by the National Institute for Longevity Sciences—the Longitudinal Study of Aging (NILS-LSA). Random sampling from the municipal register, which was stratified by age and sex, identified eligible subjects of the same racial and ethnic origin, aged from 40 to 79 years.

A detailed description of this study design has been reported elsewhere.[17] In brief, the NILS-LSA consists of clinical evaluations, body composition and anthropometry, physical functions, nutritional analysis, and psychological tests. Participants were interviewed at the research center on demographic characteristics, medical and ophthalmologic history, and self-reported vision problems. The Ethical Committee of the Chubu National Hospital reviewed and approved all procedures for the study, and a written informed consent was obtained from all subjects.

We analyzed the baseline data of NILS-LSA obtained between March 1997 and Apri1 2000. During this period, 2267 people (1136 men and 1131 women)

Table 1. Characteristics of Participants

	Men (n = 1087)		Women (n = 1081)	
Characteristics	Mean	SD*	Mean	SD*
Age (years)	58.7	10.8	58.7	10.8
Height (cm)	164.7	6.3	151.5	6.0
Weight (kg)	62.3	9.1	52.6	8.3
Smoking (pack-years)	24.6	22.5	1.6	6.6
Refractive error of the right eye (spherical equivalent)				
40–49 years	−1.35	1.37	−1.22	1.37
50–59 years	−1.03	1.43	−0.67	1.33
60–69 years	−0.22	1.17	−0.09	1.37
70–79 years	−0.09	1.20	0.04	1.31
Total	−0.70	1.40	−0.50	1.44
	n	%	n	%
History of				
Hypertension	262	24.1	284	26.3
Diabetes	106	9.8	58	5.4
Household income (Yen)				
<6.5 million	412	37.9	448	41.4
6.5–10 million	376	34.6	290	26.8
>10 million	291	26.8	275	25.4
Education level				
Elementary school or junior high school	314	28.9	393	36.4
High school	438	40.3	430	39.8
College or university or higher	332	30.5	253	23.4
Occupation				
Expert	135	12.4	89	8.2
Management	204	18.8	6	0.6
Clerical	127	11.7	245	22.7
Sales, service	51	4.7	171	15.8
Physical labor	358	32.9	227	21.0
Security guard	24	2.2	0	0.0
Agriculture, forestry, fishery	47	4.3	62	5.7
Business on one's own	78	7.2	57	5.3
Housework	0	0.0	108	10.0
Unclassified	40	3.7	80	7.4

*SD: standard deviation.

participated in the NILS-LSA. We excluded participants with a previous history of cataract surgery and those without refractive error data, so that 2168 people (1087 men and 1081 women) were included in the present study.

As part of our standardized examination, an automated objective refraction test was performed on each participant with an AutoRefractor & Keratometer (ARK700A, NIDEK, Gamagori). Visual acuity was then measured with Landolt broken rings at 5 meters under standard lighting conditions, and measured initially using any corrective devices the participants were currently using. If the participant was unable to read the 1.0 equivalent line, refraction was performed using the results of the objective refraction as a starting point. The best-corrected visual acuity was found, and both the derived refractive data and the visual acuity were recorded. When the presenting acuity of the participant was 1.0 or better, the initial objective refraction was recorded as the subject's refractive data. The spherical equivalent (sphere + 1/2 cylinder) was used to calculate the refractive error. Because of the age of our study population, cycloplegia was not used.

Information on smoking habits, household income, education level, and lifetime occupation was obtained from the questionnaires filled out by the participants. Total pack-years smoked was defined as the number of cigarettes smoked per day divided by 20, multiplied by the number of years smoked. Any history of hypertension and diabetes was also recorded.

Myopia was defined as the spherical equivalent of ≤ -0.5 diopters (D). We further categorized the myopia as mild myopia (> -0.5 D to -3.0 D), moderate myopia (> -3.0 D to -6.0 D) and high myopia (≥ -6.0 D). Hypermetropia was defined as the spherical equivalent of more than +0.5 D, and emmetropia was defined as the spherical equivalent of +0.5 D or less but > -0.5 D. Because the spherical equivalents in the right and left eyes were highly correlated (Pearson's correlation: $r = 0.91$, $P < .0001$ in men; $r = 0.88$, $P < .0001$ in women), we present the data for only the right eye.

To estimate how other factors may be associated with refractive errors, we grouped household income and education level into three categories each, and occupation into 10 categories (Table 1).

For analysis, the values for the spherical equivalent of refractive errors, age, height, weight, and pack-years smoked were entered as continuous variables. The relationships among these variables were assessed using the Spearman correlation analysis. We used the Student t-test, analysis of variance, the Cochran-Mantel-Haenszel χ^2, and general linear regression (including trend tests) to assess the relationships between the spherical equivalent and other potential risk factors. Multiple logistic regression was used to determine whether these variables affected the risk of myopia. All statistical analyses were performed by sex because there were large differences between the sexes in several factors (eg, smoking habit or occupation). Data were analyzed using the Statistical Analysis System (SAS) release 6.12.[18]

Results

The characteristics of the study population are presented in Table 1. The mean age was 58.7 years for each sex. The mean (± SD) spherical equivalent of the refractive error was -0.70 ± 1.40 D in men and -0.50 ± 1.44 D in women. This constituted a significant difference between the sexes (t-test, $P = .001$). The older age groups had more hypermetropic refractive errors in both sexes ($P < .0001$ for trend).

The mean value for pack-years smoked was significantly greater for men than for women (t-test, $P < .0001$), and there were also significant differences in occupations between sexes ($\chi^2 = 478.3$, $P < .0001$). In particular, men did not list housework and women did not list guard work as lifetime occupations.

The distribution of the spherical equivalent of refractive error is shown in Figure 1. Based on the ± 0.5 D cutoff points, the prevalence of myopia, emmetropia, and hypermetropia were 45.7%, 40.8%, and 13.5% in men, and 38.3%, 43.1%, and 18.6% in women, respectively. This difference in distribution between sexes was also highly significant ($\chi^2 = 16.5$, $P = .0003$). The incidence of mild myopia was 37.9% in men and 30.5% in women, moderate myopia was

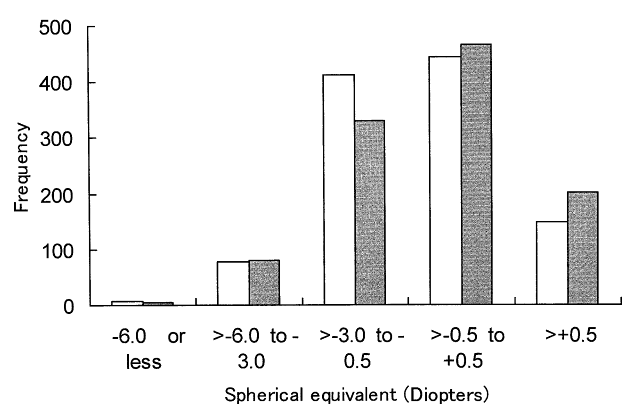

Figure 1. Distribution of refractive errors by sex. □ men women, ■.

7.2% and 7.3%, respectively, and high myopia was 0.6% and 0.5%, respectively.

The distribution of spherical equivalent by age groups and sex is shown in Figure 2. The prevalence of hypermetropia increased with age in both men (Cochran-Mantel-Haenszel χ^2 = 108.6, P < .001) and women (Cochran-Mantel-Haenszel χ^2 = 149.0, P < .001). For participants in their 40s, 1.4% of men and 1.1% of women showed hypermetropia, while the figures were 27.8% and 38.1% when they reached their 70s. Although the prevalence of hypermetropia was higher in women than in men in all age groups except for the 40–49-year group, the differences in data were not significant between sexes. The prevalence of myopia (spherical equivalent ≤ −0.5 D) decreased with advancing age in both men (Cochran-Mantel-Haenszel χ^2 = 118.3, P < .00l) and women (Cochran-Mantel-Haenszel χ^2 = 87.6, P < .00l). In the 40–49-year age group, 69.4% of the men and 60.2% of the women were myopic, while in the 70–79-year age group, only 28.6% of the men and 25.4% of the women were myopic.

A simple correlation analysis showed a significant positive association between age and the spherical equivalent of refractive errors for both sexes (P < .000l). Conversely, height and weight had a significant inverse association with the spherical equivalent for both sexes (P < .000l), and pack-years smoked was positively correlated with the spherical equivalent in men (P = .004), but inversely in women (P = .00l). However, these significant associations, except for height in women, were not found when adjustments were made for age.

In the categorical variables, the participants with a history of hypertension had a lower mean spherical equivalent value than those without a history of hypertension (t-test, men: P = .017, women: P = .001). However, a history of diabetes had no significant influence on the mean spherical equivalent in either sex. A significant relationship between the spherical equivalent and household income was found (men: F = 29.0, P < .000l, women: F = 21.5, P < .000l), with the spherical equivalent decreasing as the household income increased (P < .0001 for trend). Similarly, a higher education level was associated with greater myopia in both sexes (men: F = 45.4, P < .000l, P < .0001 for trend; women: F = 22.3, P < .000l, P < .0001 for trend). There were also significant associations between the spherical equivalent and lifetime occupations (men: F = 7.7, P < .000l, women: F = 4.7, P < .000l).

Finally, multiple logistic regression analysis for the risk of myopia (spherical equivalent ≤ −0.5 D) using all variables was performed (Table 2). An increase in age of 10 years was associated with a 0.53 [95% confidence interval (CI): 0.44–0.62] and 0.65 (95% CI: 0.54–0.78) lower probability of having myopia in men and women, respectively. Men with a higher education were at higher risk for myopia: high school, odds ratio (OR) = 1.59, 95% CI: 1.10–2.29; college or higher, OR = 2.05, 95% CI: 1.33–3.14. In women, the highest income group was associated with a higher incidence of myopia (OR = 1.52, 95% CI: 1.05–2.18) compared with the lowest income group.

To assess the effect of occupation, we considered persons in the physical labor category as a reference group because this was the most frequent occupation in the present study (27.0% of the participants). The presence of myopia was associated with management occupations (OR = 1.55, 95% CI: 1.01–2.39) in men, and with clerical (OR = 1.54, 95% CI: 1.01–2.36) and sales/service (OR = 1.66, 95% CI: 1.06–2.61) occupations in women. No association was found in either sex between pack-years smoked, hypertension, or diabetes and the presence of myopia.

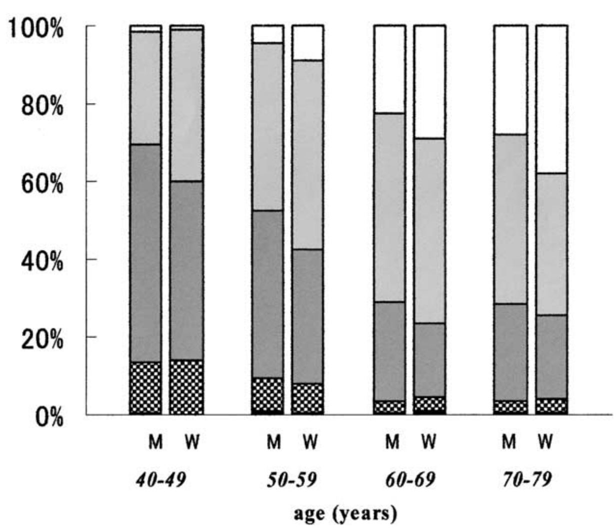

Figure 2. Refractive status, stratified by age and sex. Refractive status, spherical equivalent, are defined as: hypermetropia (> +0.5 diopters [D]), emmetropia (> −0.5 to +0.5 D), mild myopia (> −3.0 to −0.5 D), moderate myopia (> −6.0 to −3.0 D), high myopia (≤ −6.0 D). M: men, W: women. □: hypermetropia, □: emmetropia, ▢: mild myopia, ▩: moderate myopia, ■: high myopia, in descending order from top to bottom of each column.

Discussion

The main findings of this investigation in a large Japanese population are that the prevalence of myopia was 45.7% in men and 38.3% in women, and that there are significant independent associations be-

Jpn J Ophthalmol
Vol 47: 6–12, 2003

Table 2. Results of Multiple Logistic Regression for Risk of Myopia

	Men		Women	
Variables	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
Age (10 years)	0.53	0.44–0.62	0.65	0.54–0.78
Height (10 cm)	1.24	0.93–1.65	1.14	0.85–1.53
Weight (10 kg)	0.82	0.68–0.98	0.98	0.81–1.18
Education level				
Elementary school or junior high school (reference)	1		1	
High school	1.59	1.10–2.29	1.21	0.85–1.71
College or university or higher	2.05	1.33–3.14	1.27	0.84–1.93
Household income (Yen)				
<6.5 million (reference)	1		1	
6.5–10 million	0.89	0.62–1.26	1.12	0.79–1.60
>10 million	1.04	0.72–1.51	1.52	1.05–2.18
Occupation				
Expert	1.48	0.91–2.41	0.68	0.38–1.22
Management	1.55	1.01–2.39	1.12	0.17–7.40
Clerical	1.52	0.95–2.42	1.54	1.01–2.36
Sales, service	1.56	0.81–3.01	1.66	1.06–2.61
Physical labor (reference)	1		1	
Security guard	1.08	0.42–2.81	N/A*	
Agriculture, forestry, fishery	1.70	0.83–3.45	1.07	0.52–2.17
Business on one's own	0.58	0.32–1.05	1.12	0.57–2.18
Housework	N/A*		0.78	0.45–1.38
Unclassified	1.78	0.84–3.77	1.00	0.56–1.79
Smoking (per 10-pack–years)	1.00	0.94–1.06	1.07	0.87–1.31
History of				
Hypertension	1.15	0.82–1.61	0.88	0.62–1.26
Diabetes	1.15	0.72–1.84	1.63	0.83–3.18

*N/A: not applicable

tween the presence of myopia and several socioeconomic factors.

There are many studies examining the distribution of refractive error and the risk factors for the refractive errors. In an adult population, it has been reported that there is a significant association between myopia and several different factors such as age,[6,7,9–11,16,19–24] family history,[2–5] education level,[6–8] socioeconomic status,[9–11] and cataracts.[9,11] The relationships between refractive error and height or weight are unconvincing, although eye size may be linked to body stature.[25] Other factors such as nutrition, ultraviolet exposure, use of drugs, cigarette smoking, hypertension, and diabetes might be associated with myopia, because they are associated with the prevalence of age-related cataracts.[26]

Previous population-based surveys reported a racial difference in the prevalence of myopia. The proportion of myopia is 17–26.2% in white populations[3,6,7,9,19,20] and 13–21.9% in black populations.[7,11,20] In contrast, the prevalence of myopia in East Asian countries is much higher. Wong et al[10] showed that the prevalence of myopia in Singapore Chinese people between 40 and 79 years of age was 38.7%, and Van Newkirk measured the prevalence in Hong Kong at approximately 40%.[27] In Japan, it was reported that 47.6% of people 40–69 years old were myopic.[16] The Visual Impairment Project study in Australia[9] concluded that people born in Southeast Asia had significantly higher rates of myopia than in any other geographical area, even after adjusting for age and education level. Our results showed that the prevalence of myopia in Japan is as high as in other Southeast Asian countries.

It has been suggested that genetic variations among races influence the prevalence of myopia in the groups studied.[1] Studies in twins also suggest the importance of genetic factors in myopia. In particular, a recent twin study in the United Kingdom by Hammond et al[5] indicated that the heritability for myopia was 84% to 86%, with the remaining 16% to 14% of the variance due to environmental factors.

Cross-sectional studies have shown that the prevalence of myopia is higher in recent years than in former times.[13–15] In particular, among East Asian countries, the prevalence of myopia has increased remarkably over the last few decades.[13,28]

Because it is highly unlikely that this rapid change could be explained by genetic factors alone, environmental factors are probably also important in the etiology of myopia. A possible reason for the rapid increase in myopia rates in Asian countries is the greater close work demands on the younger generation, such as increased formal education or the shift to white-collar occupations.[1] In fact, several longitudinal studies have revealed that reading or close work could cause refractive myopic shifts from childhood through adolescence.[29–31]

Similarly, we found a significant independent association between education level and the prevalence of myopia in men. The relationship between myopia and certain occupations was demonstrated by data on professionals and clerks in the Visual Impairment Project study,[9] professional and office workers among Singapore Chinese,[10] and with near-work–related occupations (professional, managerial, clerical, technical, electrical) in the Barbados Eye Study.[11] Our study showed similar results in people who stated they were in management or clerical occupations. Sales/service occupations in women also showed a significant relationship to myopia in the present study, which may be due to the indistinct boundary between clerical and sales/service occupations for women. These results seem consistent with the use-abuse theory.[1,32]

Our findings confirmed the age-related increase in hypermetropia with an associated age-related decrease in myopia, which has been reported in previous studies.[6,7,9–11,16,19–24] It was suggested that this trend toward hypermetropia was due to decreasing lens power with aging,[33] or an increasing optical density of the lens cortex making the lens more uniformly refractive.[34] Another possible explanation is that the relationship between age and refraction reflects a worldwide trend. Bengtsson et al[12] showed that a true hypermetropic shift did exist between 55 and 70 years of age; however, there was also a persistent worldwide trend toward myopia using a meta-analysis method. It was assumed that this worldwide trend for myopia is 0.01 D per year.

The relationship between refraction and stature is inconsistent. It was reported in one study that myopic subjects were taller than nonmyopic subjects.[35] In contrast, there was no significant association between height and refractive error after adjustment for sex in the Blue Mountains Eye Study.[19] Wong et al[25] showed that the refraction between tall and short people appeared to be similar, although taller persons tended to have longer globes. Similarly, the relationship that myopia was prevalent in taller and heavier persons in our univariate analysis seems to be apparent in our results. This may be due to the cohort phenomenon that younger persons are larger in physique and more myopic in refraction than elderly persons in Japan.

To the best of our knowledge, there are no available population-based studies on the association of refractive errors with hypertension or cigarette smoking. However, because a significant relationship between cataracts and myopia has been detected in several studies,[9–11] and cataracts appear to be associated with hypertension and smoking,[36] we assume that a history of hypertension or smoking has some influence on refractive errors. However, in our study, they were not significant independent factors affecting the prevalence of myopia. There was also no significant difference in refractive error between people with or without diabetes, which is consistent with the Beaver Dam Eye Study.[6] In contrast, a significantly higher prevalence of myopia in diabetics as compared to nondiabetics was found in two Danish studies.[37,38] Up to the present, longitudinal prospective studies investigating the influence of smoking, hypertension, and diabetes on refractive error have not been conducted.

There are some important limitations in the present study. First, these data were cross-sectional, with all parameters measured simultaneously. Therefore, it is difficult to make conclusive statements about a cause–effect relationship between refractive errors and the educational level or socioeconomic factors. A high education level may not only cause a myopic shift in refraction, but it also seems likely that those with myopia are more likely to choose a higher education level or close work. Second, although we did not have data on cataract status or family history of refractive errors, several studies have indicated the independent effect of family history[1,2] and cataract status[9–11] on refractive errors. Third, there was a selection bias in our population. Because the examinations of the NILS-LSA participants were performed at the National Institute for Longevity Science, those participants with limited activity level or living in an institution may not have been able to travel and participate in our survey, which may have influenced our findings.

In conclusion, we showed the prevalence of refractive errors in a middle-aged and elderly Japanese population. The frequency of myopia was 45.7% in men and 38.3% in women, which are findings similar to those in other Asian surveys and higher than those found in black or white populations. As previously reported, our study confirmed a higher prevalence of my-

Jpn J Ophthalmol
Vol 47: 6–12, 2003

opia among the younger population than the elderly. It was also found that myopia was independently associated with education level and socioeconomic factors. Changing environmental factors, such as an increase in close work, may be one of the reasons for the higher prevalence of myopia in the younger generation. Unfortunately, the cross-sectional approach in the present study limits our conclusions. However, prospective research by the NILS-LSA should provide further information on myopia and its risk factors.

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