CLINICAL INVESTIGATIONS

Association of Life-style with Intraocular Pressure in Middle-aged and Older Japanese Residents

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Purpose: To evaluate the associations of several life-style–related factors with intraocular pressure (IOP).

Methods: Of a total of 649 men and women who had been examined in an annual health check-up being conducted by a general hospital in Ibaraki prefecture, Japan, 569 individuals (age range, 29–79 years) who had not undergone any medical treatment for hypertension, ocular hypertension, or glaucoma, were selected as the subjects of this study. The associations of several life-style–related factors with the IOP were evaluated by multiple regression analyses and analyses of covariance.

Results: Body mass index (BMI), alcohol consumption score, and cigarette consumption were found to have a significantly positive association with the IOP in men (*P* for trend = .002, <.001, and <.001, respectively). In women also, the BMI was positively related to the IOP (*P* for trend = .071). In respect to the effects of coffee consumption, it was shown that in men the mean IOP adjusted for age, the BMI, alcohol intake score, cigarette consumption, and blood pressure were significantly lower in habitual coffee drinkers than in coffee abstainers (*P* = .016).

Conclusion: The results of this study suggest that the IOP level may be substantially affected by daily life-style among Japanese. **Jpn J Ophthalmol 2003;47:191–198** © 2003 Japanese Ophthalmological Society

Key Words: Alcohol consumption, coffee consumption, intraocular pressure, life-style, smoking.

Introduction

Ocular hypertension, usually defined as intraocular pressure (IOP) higher than 21 mm Hg,[1] is one of the major risk factors for open-angle glaucoma.[2–4] Moreover, several studies have reported that relatively high IOP, even though within the normal IOP range, causes optic nerve damage and visual field abnormality.[5] It is potentially important especially for Japanese, who have a higher incidence of normal-tension glaucoma[6] than Europeans and Americans,[7–10] to clarify the factors possibly associated with the increase or decrease of the IOP. There have been many epidemiological studies on the risk factors related to the development of elevated IOP. These studies suggested positive associations between the IOP and age, systolic blood pressure, and obesity,[7,9,11–21] although there is a negative association between the IOP and age in the Japanese population.[22] However, there have been few studies evaluating the associations of the life-style–related factors with the IOP.[20,23,24] Therefore, in this study, we attempted to identify particular life-style–related factors associated with

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the IOP, using the cross-sectional data from the health examinations conducted for Japanese residents in a prefectural capital close to Tokyo.

Materials and Methods

Subjects

A total of 649 Japanese residents living in Ibaraki prefecture, Japan, were examined between August 1999 and August 2000 in a health check-up being conducted by a general hospital located in Mito, the capital city of the prefecture. Of these examinees, 569 individuals (448 men and 121 women) who had not undergone any medical treatment for hypertension, ocular hypertension, or glaucoma were selected as the subjects of this study. The ages of the subjects ranged from 29 to 79 years.

Health Check-up

The health check-up consisted of a questionnaire on several demographic and life-style–related factors: measurement of height, weight, blood pressure, and the IOP, hematological and serum biochemical tests, chest x-ray, electrocardiography, and fundus photography. All the subjects were requested not to consume any food or alcohol after 9 PM of the day before the examination day. The items in the questionnaire included age, marital status, occupation, residence, current status and past histories of medication, family medical history, drinking history, smoking history, cigarette consumption per day, exercise habits, and the number of cups of coffee consumed per day. In the questionnaire, the drinking history was classified into the following four categories: never or seldom, several times per month, several times per week, and every day. Blood pressure was measured by sphygmomanometer, using the right arm, two times consecutively after rest at sitting position for at least 5 minutes. The IOP was measured with a noncontact tonometer (NT-2000, NIDEK, Gamagori, Aichi) three times consecutively for each eye.

Statistical Analyses

For the present analyses, the systolic and diastolic blood pressure (SBP and DBP) of each subject were determined as the mean value of the two measurements. As regards the IOP, first, the mean value of the three measurements was calculated for each eye. However, because there was a strong correlation ($r = 0.84$) between the mean IOP of the right and the left eyes in the 569 subjects, the mean level of the mean IOP of the right and of the left eyes was defined as the IOP for each subject. In the basic analyses of the study, the associations of age with the IOP, the SBP, the DBP and the body mass index (BMI) corresponding to weight (kg) divided by the square of height (m^2) were evaluated by comparing, by sex, the mean values of the four parameters among four age groups (44 or younger, 45–54, 55–64, 65 or older), using the Bonferroni multiple comparison method.[25] Sex differences in the mean levels of the IOP, the SBP, the DBP, and the BMI were evaluated by age group using the Student *t*-test. For the analyses of the associations of several life-style–related factors with the IOP, first, the partial regression coefficients of seven independent variables [age, the BMI, systolic or diastolic blood pressure, alcohol consumption score (never or seldom: “0”, several times per month: “1,” several times per week: “2,” every day: “3”), number of cigarettes per day, habitual exercise (no: “0,” yes: “1”), and cups of coffee per day] were determined by multiple regression analyses. Second, the adjusted mean levels of the IOP calculated by the analyses of covariance were compared between the three categories of the BMI (the subjects were divided into three categories by BMI levels to equalize the number of subjects in each category in both sexes); between the four categories of alcohol consumption (never or seldom, several times per month, several times per week, every day); between the three categories of cigarette consumption (nonsmoker, 1 to 19 per day, 20 or more per day); between the two categories of habitual exercise (no, yes); and between the two categories of cups of coffee per day (abstainer, habitual coffee drinker). In the first analysis, age, the BMI, systolic or diastolic blood pressure, alcohol consumption score, number of cigarettes per day, habitual exercise, and cups of coffee per day were added as other independent variables calling for adjustment. Similarly, in the second analysis, each mean IOP level was adjusted for the other variables except for the corresponding life-style–related factor, age, and systolic or diastolic blood pressure. All the above statistical analyses were conducted using the SAS statistical package.[26]

Results

The relationship of age to the IOP, the SBP, the DBP, and the BMI is shown in Table 1. The mean IOP, DBP, and BMI levels were the highest in the age group of “55–64” in both sexes, whereas the mean BMI for the age group of “45–54” in men also showed the highest level, and the highest levels of mean SBP were noted for the age group of “65 or older” in both sexes. Among all subjects, these pa-

Table 1. Relationship of Age to Intraocular Pressure (IOP), Systolic (SBP) and Diastolic Blood Pressure (DBP), and Body Mass Index (BMI) in Study Subjects by Sex*

			Mean ± SD								*P* Value for Difference Between Men and Women			
Age Group	No. of Subjects		IOP (mm Hg)		SBP (mm Hg)		DBP (mm Hg)		BMI (kg/m²)					
(y)	M	W	M	W	M	W	M	W	M	W	IOP	SBP	DSP	BMI
≤44	49	15	12.8 ± 2.0	12.0 ± 1.5	120.8 ± 14.4[c,d]	111.3 ± 9.4[c,d]	72.0 ± 10.9	64.5 ± 6.4[c]	22.8 ± 2.5	20.9 ± 2.2	.099	.020	.013	.008
45–54	159	43	12.9 ± 2.4	12.1 ± 2.3	122.4 ± 14.0[c,d]	120.3 ± 15.0	71.4 ± 8.9[c]	70.1 ± 8.5	23.3 ± 2.6	22.2 ± 3.0	.041	.421	.377	.028
55–64	211	45	13.5 ± 3.0[d]	13.4 ± 3.5[d]	128.4 ± 14.7[a,b]	123.4 ± 13.1[a]	75.7 ± 9.8[b]	71.6 ± 9.6[a]	23.3 ± 2.8	23.0 ± 2.9	.820	.027	.011	.545
≥65	29	18	11.8 ± 2.6[c]	10.6 ± 2.3[c]	131.9 ± 14.4[a,b]	127.1 ± 18.6[a]	72.2 ± 9.4	68.0 ± 8.5	22.3 ± 2.6	21.2 ± 2.7	.112	.362	.119	.187
Total/mean	448	121	13.1 ± 2.7	12.3 ± 2.9	125.6 ± 14.8	121.4 ± 14.9	73.5 ± 9.8	69.6 ± 8.9	23.2 ± 2.7	22.2 ± 2.9	.009	.005	<.001	<.001

Significant differences noted at the .05 level on the basis of Bonferroni multiple comparison (a: vs. Age "≤44," b: vs. Age "45–54," c: vs. Age "55–64," d: vs. Age "≥65").
*M: Men, W: Women.

rameters were significantly higher in men than in women ($P = .009$ for the IOP, $P = .005$ for the SBP, and $P < .001$ for the DBP and the BMI). According to the Bonferroni multiple comparison method, the mean IOP was significantly lower in the age group of "65 or older" than in that of "55–64" in both sexes ($P < .05$ for both sexes).

Table 2 and Table 3 show the partial regression coefficients and the standardized partial regression coefficients of the seven independent variables for the IOP according to the multiple regression analyses including the SBP (Table 2) or the DBP (Table 3) as an independent variable. After adjustment for the other independent variables, except for the corresponding life-style–related factors, the SBP, the DBP, the BMI, alcohol consumption, and cigarette consumption had a significantly positive association with the IOP in men. In women also, the SBP, the DBP, and the BMI had a significantly positive association with the IOP.

In Table 4 and Table 5, the adjusted mean levels of IOP obtained by the analyses of covariance, including the SBP (Table 4) or the DBP (Table 5) as a covariate, are compared in the several categories of the BMI, alcohol consumption, cigarette consumption, habitual exercise, and coffee (cups per day). The adjusted mean IOP increased in men with the increasing level of the three BMI categories (*P* for trend = .002), the four alcohol consumption categories (*P* for trend < .001), and the three cigarette consumption categories (*P* for trend < .001). In women, the adjusted mean IOP increased with the increasing level of the three BMI categories (*P* for trend = .071). The effects of coffee (cups per day) showed that in men the adjusted mean levels of the IOP were significantly lower in habitual coffee drinkers than in coffee abstainers ($P = .016$).

Discussion

In this study, the mean IOP measured by a noncontact tonometer in all subjects was 13.1 ± 2.7 mm Hg for men and 12.3 ± 2.9 mm Hg for women, and was significantly higher in men than in women ($P = .009$). In both sexes, the mean IOP increased with increasing age group among the subjects aged 64 or younger, although the lowest mean IOP was noted in the age group of "65 or older." On the other hand, many studies,[7,11,27–29] except for a few studies in Japan,[21,22] reported that the IOP increased with age after the age of 40 and decreased in the elderly. Furthermore, many studies pointed out that the IOP level was higher in women than in men after the age of 40.[7,11,14,22,27] Shiose[30] suggested that the increase

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Table 2. Partial Regression Coefficients and Standardized Partial Regression Coefficients of the Seven Independent Variables for Intraocular Pressure (IOP) According to a Multiple Regression Analysis Including Systolic Blood Pressure (SBP) as an Independent Variable

	Partial Regression Coefficients		Standardized Partial Regression Coefficients		*P* Value	
Variables*	Men	Women	Men	Women	Men	Women
Age (years)	0.007	−0.044	0.020	−0.135	.703	.206
BMI (kg/m^2)†	0.144	0.233	0.144	0.240	.004	.014
SBP (mm Hg)	0.028	0.045	0.154	0.230	.003	.027
Alcohol consumption score	0.361	0.199	0.149	0.071	.002	.457
Cigarettes/day	0.027	0.079	0.135	0.129	.006	.183
Habitual exercise	0.155	−0.212	0.028	−0.034	.564	.718
Cups of coffee/day	−0.097	−0.128	−0.060	−0.060	.225	.548

*Age, BMI, SBP, alcohol consumption score (never or seldom: 0, several times/month: 1, several times/week: 2, every day: 3, cigarettes/day, habitual exercise (no = 0, yes = 1), and cups of coffee/day were added as the other independent variables.

†BMI: body mass index.

in the IOP after middle age among Europeans and Americans was caused by the ocular hypertensive effect of hypertension and obesity that overwhelmed the ocular hypotensive effect of aging, and that the decrease in the IOP in the elderly may be due to the decrease in obese hypertensive subjects because of death from cardiovascular accidents; that is, the "survival effect" of healthy individuals. This speculation may be supported by the following Toris report;[31] there was no significant difference in the mean IOP between the subjects in their 20s and those aged 60 or older among healthy Americans.

The sex difference of the IOP in this study does not agree with results from previous studies,[7,11,14,22,27] but the association between the IOP and age agrees with several reports in Western countries.[7,11,27–29] However, the results of this study should not be directly compared with those of other studies because the distribution of the IOP in this study might not represent that of the general population. We excluded all subjects receiving medical treatment for hypertension, ocular hypertension, or glaucoma to evaluate the association of several life-style–related factors with the IOP without any influence from the effects of medication. Therefore, the distribution of the IOP in this study may be somewhat skewed as compared with that of the general population. Furthermore, the number of subjects in this study was too small to show any sex and age trend in the IOP. That the IOP values were obtained in this study by the noncontact

Table 3. Partial Regression Coefficients and Standardized Partial Regression Coefficients of the Seven Independent Variables for Intraocular Pressure According to a Multiple Regression Analysis Including Diastolic Blood Pressure (DBP) as an Independent Variable

	Partial Regression Coefficients		Standardized Partial Regression Coefficients		*P* Value	
Variables*	Men	Women	Men	Women	Men	Women
Age (years)	0.007	−0.034	0.019	−0.104	.710	.298
BMI (kg/m^2)†	0.101	0.190	0.101	0.196	.043	.044
DBP (mm Hg)	0.069	0.098	0.249	0.302	<.001	.002
Alcohol consumption score	0.325	0.222	0.134	0.080	.005	.394
Cigarettes/day	0.029	0.104	0.145	0.170	.003	.073
Habitual exercise	0.216	−0.447	0.039	−0.071	.414	.439
Cups of coffee/day	−0.084	−0.110	−0.052	−0.052	.284	.595

*Age, BMI, DBP, alcohol consumption score (never or seldom: 0, several times/month: 1, several times/week: 2, every day: 3), cigarettes/day, habitual exercise (no = 0, yes = 1), and cups of coffee/day were added as the other variables.

†BMI: body mass index.

Table 4. Adjusted Mean Levels of Intraocular Pressure (IOP) from the Analysis of Covariance Including Systolic Blood Pressure as a Covariate*

Variables	Percentage of Subjects (%)	Mean (±SD) IOP (mm Hg)	*P* Value Based on *F* Value	*P* Value for Trend	*P* Value for the Difference in Mean IOP From the Highest Group
Body mass index (kg/m^2)					
Men					
<22.2	33.9	12.8 ± 0.2	<.001	.002	<.001
22.5 ≤ –<24.2	33.2	12.7 ± 0.2			<.001
24.4≤	32.9	13.8 ± 0.2			—
Women					
<20.9	33.3	11.8 ± 0.4	.191	.071	.070
20.9 ≤ –<23.5	33.7	12.3 ± 0.4			.270
23.5≤	33.0	13.0 ± 0.5			—
Alcohol consumption					
Men					
Never or seldom	46.5	12.2 ± 0.3	.003	<.001	<.001
Several times/month	23.0	12.6 ± 0.3			.024
Several times/week	14.6	13.4 ± 0.3			.933
Every day	15.9	13.4 ± 0.2			—
Women					
Never or seldom	62.9	11.9 ± 0.3	.098	.179	.241
Several times/month	16.1	13.5 ± 0.6			.552
Several times/week	10.4	12.0 ± 0.9			.450
Every day	10.6	12.9 ± 0.8			—
Cigarette smoking (number/day)					
Men					
0	60.5	12.8 ± 0.2	.020	<.001	.006
1 ≤ –≤19	7.3	13.3 ± 0.4			.530
20≤	32.2	13.6 ± 0.2			—
Women					
0	93.6	12.3 ± 0.3	.052	.438	.043
1 ≤ –≤ 19	5.0	10.7 ± 1.2			.015
20≤	1.4	16.4 ± 2.0			—
Habitual exercise					
Men					
No	60.3	13.1 ± 0.2	.564		
Yes	39.7	13.2 ± 0.2			
Women					
No	70.9	12.5 ± 0.3	.718		
Yes	29.1	12.2 ± 0.5			
Coffee consumption (cups/day)					
Men					
0	42.2	13.5 ± 0.2	.016		
1≤	57.8	12.8 ± 0.2			
Women					
0	45.4	12.5 ± 0.4	.676		
1≤	54.6	12.3 ± 0.4			

*Each mean IOP level was adjusted for the other variables except for the corresponding life-style–related factor, age, and diastolic blood pressure.

tonometer, which is less accurate than the Goldmann applanation tonometer, should also be considered.

Many studies have reported positive associations of the IOP with the SBP and the BMI.[7,12–21] On the other hand, reports showing a positive association of the IOP with the DBP have been few.[12] In this study, positive associations with the IOP were found not only for the SBP but also for the DBP in both sexes. According to the reports on the mechanism of the association between the IOP and blood pressure,[20–22,32] it is suggested that high blood pressure may elevate the IOP by increasing the ultrafiltration of aqueous

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Table 5. Adjusted Mean Levels of Intraocular Pressure (IOP) from the Analysis of Covariance Including Diastolic Blood Pressure as a Covariate*

Variables	Percentage of Subjects (%)	Mean (±SD) IOP (mm Hg)	*P* Value Based on *F* Value	*P* Value for Trend	*P* Value for the Difference in Mean IOP from the Highest Group
Body mass index (kg/m²)					
Men					
<22.2	33.9	12.9 ± 0.2			.011
22.5 ≤ –<24.2	33.2	12.7 ± 0.2	.003	.014	<.001
24.4≤	32.9	13.7 ± 0.2			—
Women					
<20.9	33.3	11.9 ± 0.4			.218
20.9 ≤ –<23.5	33.7	12.3 ± 0.4	.465	.215	.532
23.5≤	33.0	12.8 ± 0.5			—
Alcohol consumption					
Men					
Never or seldom	46.5	12.3 ± 0.3			.004
Several times/month	23.0	12.6 ± 0.3	.006	.002	.026
Several times/week	14.6	13.4 ± 0.3			.897
Every day	15.9	13.4 ± 0.2			—
Women					
Never or seldom	62.9	11.9 ± 0.3			.234
Several times/month	16.1	13.5 ± 0.6	.096	.156	.555
Several times/week	10.4	12.1 ± 0.9			.498
Every day	10.6	12.9 ± 0.8			—
Cigarette smoking (number/day)					
Men					
0	60.5	12.8 ± 0.2			.003
1 ≤ –≤ 19	7.3	13.2 ± 0.4	.010	.002	.416
20≤	32.2	13.6 ± 0.2			—
Women					
0	93.6	12.3 ± 0.2			.013
1 ≤ –≤ 19	5.0	10.8 ± 1.2	.019	.246	.005
20≤	1.4	17.3 ± 1.9			—
Habitual exercise					
Men					
No	60.3	13.0 ± 0.2	.414		
Yes	39.7	13.3 ± 0.2			
Women					
No	70.9	12.5 ± 0.3	.439		
Yes	29.1	12.1 ± 0.5			
Coffee consumption (cups/day)					
Men					
0	42.2	13.5 ± 0.2	.028		
1≤	57.8	12.9 ± 0.2			
Women					
0	45.4	12.5 ± 0.4	.796		
1≤	54.6	12.3 ± 0.4			

*Each mean IOP level was adjusted for the other variables except for the corresponding life-style–related factor, age, and diastolic blood pressure.

humour through elevation of ciliary artery pressure. The elevated SBP may be more important for the increase in ultrafiltration than the elevated DBP. However, the strong positive correlation between the SBP and the DBP would necessarily lead also to the apparent positive relationship of the IOP to the DBP.

In this study, the BMI was positively associated with the IOP in both sexes. The reduction in aqueous humour outflow due to the elevation of intraorbital pressure with excessive intraorbital fat tissue and the increase in outflow resistance for the episcleral vein through the increase of blood viscosity with weight gain may have led to the increased IOP, as suggested in previous studies.[19,20,33]

The results of this study showed that alcohol intake and cigarette consumption were positively associated with the IOP in men. On the other hand, these significant positive associations were not found in women. However, because the proportions of drinkers and smokers were very small because of the relatively small sample size of women, these associations may not have reached a statistically significant level in women. Furthermore, there were some limitations in our survey on the associations of alcohol intake and cigarette consumption with the IOP since the duration of drinking or smoking was not taken into account in the analyses.

Although some studies have also suggested the positive associations of the IOP with alcohol consumption[20,24] and cigarette consumption,[20,23] the mechanisms remain unclear. Because blood pressure was also included as a covariate in the analysis of covariance in this study, the positive alcohol–IOP relationship cannot be explained by the positive associations of blood pressure with alcohol[34] and the IOP. Similarly, the positive association between cigarette consumption and the IOP also cannot be accounted for by the effects of smoking on blood pressure. One possible explanation for the positive association between cigarette consumption and the IOP is that the increase in blood viscosity caused by cigarette smoking may elevate the IOP. Actually, it was also shown by this study that both the adjusted mean levels of haematocrit and the IOP increased with increasing levels of the three cigarette consumption categories in men (P for trend $< .001$ for haematocrit and P for trend $= .015$ for the IOP, respectively, data not shown).

One interesting finding of this study is that in men the adjusted mean IOP was significantly lower in habitual coffee drinkers than in coffee abstainers. This is the first report showing that there is a negative association between coffee consumption and the IOP. Recent epidemiological studies on the associations of daily life-style with blood pressure have reported that blood pressure was significantly lower in habitual coffee drinkers than in coffee abstainers.[35,36] Thus, the effects of coffee on blood pressure might account for the negative association between coffee consumption and the IOP. However, because there is a report indicating that caffeine, which is the main active ingredient in coffee, was positively associated with the IOP,[37] further analyses are required for reliable evidence of the effect of coffee consumption on the IOP.

In conclusion, the results of this study suggested that alcohol consumption and cigarette consumption might be related to the elevation of the IOP, although coffee consumption might be inversely associated with the IOP. Because high IOP is a major risk factor for open-angle glaucoma, daily alcohol consumption and heavy smoking may be especially harmful to the patients with open-angle glaucoma or ocular hypertension.

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