Original Article

Intraocular pressure and influencing systemic health parameters in a Korean population

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Aim: To evaluate the relationship between intraocular pressure (IOP) and systemic health parameters such as age, gender, body mass index (BMI), total cholesterol, high density lipoprotein (HDL), and triglyceride (TG) in a Korean population. **Materials and Methods:** A total of 30,893 healthy subjects underwent automated multiphasic tests, including non-contact tonometry, automated perimetry, fundus photography, and blood samplings for total cholesterol, HDL, and TG. Seven age groups were divided by decades ranging from 20 to 29 years to 80 + years. The association between IOP and BMI, plasma lipid profiles was examined using cross-sectional analysis. **Results:** The mean age of subjects was 47.7 years. The mean IOP of subjects was 15.4 ± 3.2 mmHg for both eyes. The mean IOP of men was significantly higher than women (P = 0.000). By multiple linear regression analysis, IOP was positively associated with gender (male), BMI, total cholesterol, and TG and negatively associated with age (P = 0.000). BMI, total cholesterol, and TG had significantly positive correlations with IOP after adjusting for age, gender, and other variables which can influence the IOP (P = 0.000). **Conclusions:** In a Korean population, the mean IOP, total cholesterol, TG, and BMI values of men were higher than women. IOP was found to increase with total cholesterol, TG, BMI, and to decrease with only age regardless of sex.

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Elevated intraocular pressure (IOP) is one of the major risk factors for glaucomatous optic neuropathy. A number of epidemiological studies of Western populations have attempted to identify a relationship between IOP and systemic health parameters, such as sex, age, blood pressure, and obesity.[1-3] And a few epidemiological studies have reported a relationship between systemic health parameters associated with IOP in oriental populations.[4-9] According to these reports, negative correlations between IOP and age were found in Japan, Taiwan, and Korean populations,[4,5,8,9] but IOP was found to increase with age in Pakistani and Western populations.[1-3,6]

Also, Stewart *et al*.[10] suggested that increased total cholesterol and high density lipoprotein (HDL) levels are not risk factors for increased IOP in patients with chronic open-angle glaucoma or ocular hypertension. However, to our knowledge, relationship between IOP and plasma lipid profiles has not been evaluated in oriental populations.

Therefore, we performed this study to evaluate not only the influence of age and gender but also body mass index (BMI) and plasma lipid profiles such as total cholesterol, HDL, and triglyceride (TG) on IOP in a Korean population as one country of many oriental countries.

Materials and Methods

We examined 30,893 healthy subjects at the Health Promotion Center from January 2000 to December 2006. The majority of the subjects were office workers and their families who resided in Pusan city (3.5 million populations). The participation rate was 0.88% of the total population in Pusan city. Informed consent was obtained from all patients, and the present clinical study was approved by the institutional review board.

For the purpose of this study, we used seven age groups divided by decades ranging from 20 to 29 years to 80+ years. Before the testing, each participant was interviewed about previous health problems and medical history including ocular disease by physician and ophthalmologist. Participants having history of intraocular disease or surgery at least in one eye and receiving medical treatment for glaucoma, hyperlipidemia, hypertension, and/or diabetes mellitus were excluded.

The test schedule of the automated multiphasic tests, which consisted of 40 items, including best-corrected visual acuity by Snellen chart, non-contact tonometry (NCT), Humphrey automated perimetry (central 30-2 program, Zeiss Humphrey, Dublin, CA, USA), fundus photography (30 degree color stereophotographs) for the optic disc and macula and blood sampling for total cholesterol, HDL, and TG on the same day. Height and weight were measured with the subjects wearing a light weight hospital gown in a standing position without shoes. BMI was calculated as weight (kg) divided by height (m) squared. The IOP was determined by the mean value of three successive reading of both eyes by NCT (Canon T-2, Canon, Tokyo, Japan) only between 09:00 and 11:00 hours to minimize the effect of diurnal variation. To avoid interexaminer and intertonometer variances, all IOP measurements were taken by the same trained paramedical assistant without applying topical anesthetic. To obtain total cholesterol, HDL, and TG, blood samples were taken after fasting for 8 hours.

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Cross-sectional analysis was based on data obtained at the visit of each subjects. The relationship between IOP and gender, age, total cholesterol, TG, HDL, and BMI was analyzed using Student's *t*-test, analysis of variance (ANOVA) test, Chi-square test, Chi-square test for trend and multiple linear regression test. Partial correlation coefficients were calculated to evaluate the relationship between IOP and total cholesterol, TG, HDL, and BMI after adjustment for age, gender, and other variables. Linear regression analysis was performed to examine the relationship between IOP and total cholesterol, TG, HDL, and BMI. *P* values less than 0.05 were considered statistically significant. All data were processed and analyzed by the SPSS version 12.0K software for Windows (SPSS Inc., Chicago, IL, USA) and MedCalc version 9.3.9 (www.medcalc.org).

Results

A total of 30,893 healthy Korean people, 15,735 men (50.6%) and 15,158 women (49.4%), were selected from the Health Promotion Center in Pusan National University Hospital. The distribution of subjects by age and gender are shown [Table 1]. The mean age of subjects was 47.7 years old (range 20-89 years). There was no statistically significant difference in age between men and women. However, total cholesterol, TG and BMI values were significantly higher in men than in women. HDL was significantly lower in men than in women. The mean values of other health parameters including IOP are shown [Table 2].

The mean IOP of total subjects was 15.4 ± 3.2 mmHg. The mean IOP of men was 15.8 ± 3.3 mmHg and 15.7 ± 3.3 mmHg for right and left eyes, respectively, which was significantly higher than women (15.1 ± 3.1 mmHg and 15.0 ± 3.1 mmHg, Student's *t*-test and ANOVA test) [Table 3].

The IOP had linear trends of increase with BMI, total cholesterol, and TG (Chi-square test for trend, $P < 0.0001$) [Tables 4-6]. However, IOP tended to decrease with increasing HDL (Chi-square test for trend, $P < 0.0001$) [Table 7]. A linear regression model showed that each kg/m^2 of BMI resulted in an increase in IOP of 0.107 mmHg and 0.116 mmHg for right and left eyes, respectively ($P = 0.000$) [Figs. 1 and 2]. A linear regression model showed that each mg/dL of total cholesterol resulted in an increase in IOP of 0.008 mmHg and 0.009 mmHg for right and left eyes, respectively ($P = 0.000$) [Figs. 3 and 4]. A linear regression model showed that each mg/dL of TG resulted in an increase in IOP of 0.005 mmHg and 0.006 mmHg for right and left eyes, respectively ($P = 0.000$) [Figs. 5 and 6]. A linear regression model showed that each mg/dL of HDL

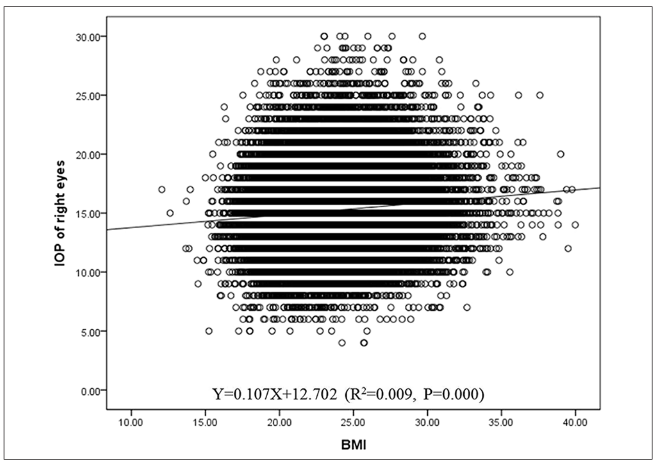

Figure 1: Linear regression model of the BMI versus the IOP of the right eyes (BMI: Body mass index, IOP: Intraocular pressure)

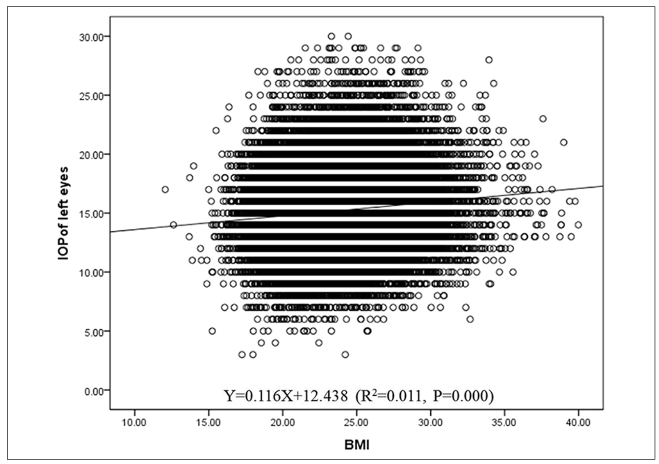

Figure 2: Linear regression model of the BMI versus the IOP of the left eyes (BMI: Body mass index, IOP: Intraocular pressure)

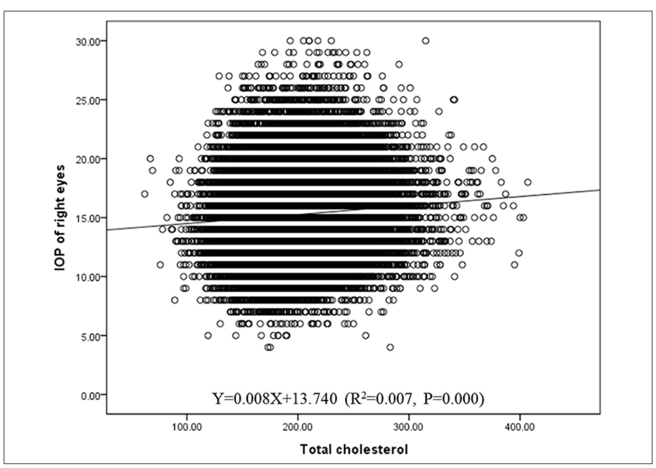

Figure 3: Linear regression model of the total cholesterol versus the IOP of the right eyes (IOP: Intraocular pressure)

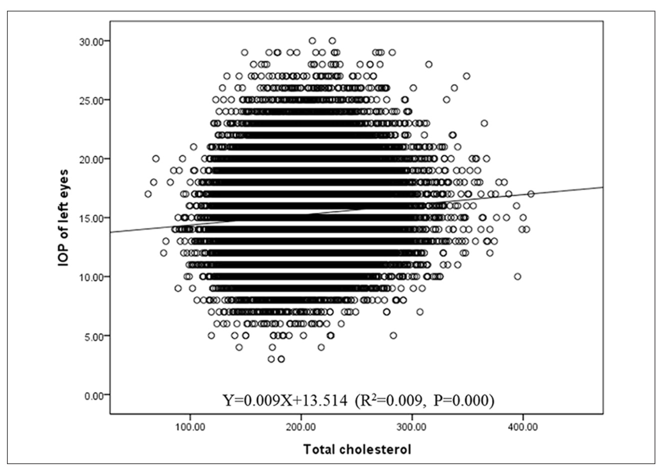

Figure 4: Linear regression model of the total cholesterol versus the IOP of the left eyes (IOP: Intraocular pressure)

Table 1: Distribution of age and sex in the study population

Age (years)	No. (%)		
	Men	Women	Total
20-29	606 (3.9)	630 (4.2)	1,236 (4.0)
30-39	2,818 (17.9)	2,721 (17.9)	5,539 (17.9)
40-49	5,721 (36.4)	5,582 (36.8)	11,303 (36.6)
50-59	4,234 (26.9)	4,151 (27.4)	8,385 (27.2)
60-69	2,050 (13.0)	1,791 (11.8)	3,841 (12.4)
70-79	286 (1.8)	276 (1.8)	562 (1.8)
≥80	20 (0.1)	7 (0.1)	27 (0.1)
Total	15,735 (100.0)	15,158 (100.0)	30,893 (100.0)

Table 2: General features of some selected variables of the study subjects (*N*=30,893)

Variables	Men	Women	*P* value between men and women
Age (years)	47.8±10.7	47.6±10.5	0.07
Total cholesterol (mg/dL)	200.5±35.2	198.2±36.7	0.000
HDL (mg/dL)	50.6±12.5	57.5±13.7	0.000
TG (mg/dL)	146.7±92.3	106.5±66.0	0.000
BMI (kg/m^2)	24.4±2.8	23.6±3.0	0.000
IOP (Rt) (mmHg)	15.8±3.3	15.1±3.1	0.000
IOP (Lt) (mmHg)	15.7±3.3	15.0±3.1	0.000

Values are mean±standard deviation, HDL: High density lipoprotein, TG: Triglyceride, BMI: Body mass index, Weight/(height) 2, IOP (Rt): Intraocular pressure of right eyes, IOP (Lt): Intraocular pressure of left eyes

Table 3: Mean intraocular pressure of right and left eyes by age and gender in the study population

Age (years)	IOP (mmHg)					
	Right eyes			Left eyes		
	Men	Women	*P* value*	Men	Women	*P* value*
20-29	15.9±3.4	14.9±3.5	<0.001	15.7±3.4	14.5±3.3	<0.001
30-39	16.0±3.4	14.9±3.2	<0.001	15.9±3.4	14.6±3.3	<0.001
40-49	15.9±3.2	15.1±3.0	<0.001	15.9±3.3	15.1±3.1	<0.001
50-59	15.7±3.2	15.2±3.0	<0.001	15.7±3.3	15.2±3.0	<0.001
60-69	15.3±3.2	14.9±3.0	0.0001	15.4±3.3	15.1±3.1	0.0015
≥70	14.9±3.2	14.7±3.0	0.3745	15.1±3.3	14.7±3.0	0.2069
Total	15.8±3.3	15.1±3.1	<0.001	15.7±3.3	15.0±3.1	<0.001
P value†	<0.0001	<0.0001		<0.0001	<0.0001	

*Student's *t*-test, †ANOVA test, IOP: Intraocular pressure

Table 4: Mean intraocular pressure by level of body mass index

BMI (kg/m^2)	No. (%)	IOP (mmHg)	
		Rt	Lt
<18.5	643 (2.1)	14.7±3.1	14.7±3.2
18.5-22.9	11,157 (36.1)	15.2±3.2	15.1±3.2
23-24.9	8,677 (28.1)	15.5±3.2	15.4±3.2
25-29.9	9,747 (31.5)	15.7±3.2	15.7±3.3
≥30	669 (2.2)	16.1±3.5	16.0±3.4
P value*	30,893 (100.0)	*P*<0.0001	*P*<0.0001

BMI: Weight/(height) 2, BMI classification was corresponded to the criteria of World Health Organization Asia-Pacific region, Rt: Right, Lt: Left
*by Chi-square test for trend, IOP: Intraocular pressure

Table 5: Mean intraocular pressure by level of total cholesterol

Total cholesterol (mg/dL)	No. (%)	IOP (mmHg)	
		Right eyes	Left eyes
<200	16,766 (54.3)	15.3±3.2	15.2±3.2
200-239	10,466 (33.9)	15.6±3.2	15.5±3.3
≥240	3,661 (11.8)	15.8±3.2	15.8±3.3
P value*		<0.0001	<0.0001

Cholesterol level classification was corresponded to national cholesterol education program adult treatment panel III, *Chi-square test for trend, IOP: Intraocular pressure

Table 6: Mean intraocular pressure by level of triglyceride

TG (mg/dL)	No. (%)	IOP (mmHg)	
		Right eyes	Left eyes
<150	22,949 (74.3)	15.2±3.2	15.2±3.2
150-199	4,115 (13.3)	15.9±3.2	15.8±3.3
≥200	3,829 (12.4)	16.2±3.3	16.2±3.3
P value*		<0.0001	<0.0001

TG level classification was corresponded to national cholesterol education program adult treatment panel III, *Chi-square test for trend, IOP: Intraocular pressure

resulted in a decrease in IOP of 0.016 mmHg and 0.017 mmHg for right and left eyes, respectively ($P = 0.000$) [Figs. 7 and 8].

Table 8 describes the multiple linear regression analysis for the variables significantly associated with IOP. Gender (male), age, BMI, total cholesterol, TG, and HDL were selected in the stepwise analysis. HDL did not enter as a significant factor when considered with the other variables. Multiple linear regression analysis showed that IOP was positively associated with gender (male), total cholesterol, TG, and BMI and negatively associated with age ($P = 0.000$) [Table 8].

Partial correlation coefficients among IOP, age, gender, BMI, total cholesterol, TG, and HDL were calculated to explore the independent effects of BMI, total cholesterol, TG, and HDL on IOP controlled for age, gender and other variables which can influence the IOP. In both eyes, BMI, total cholesterol, and TG were positively correlated with IOP ($P = 0.000$) [Table 9].

Multiple linear regression analysis showed that IOP was positively associated with BMI, total cholesterol, TG, and HDL and negatively associated with age in men ($P < 0.01$) [Table 10]. However, IOP was negatively associated with HDL in women ($P = 0.000$) [Table 11].

Partial correlation coefficients among IOP, age, BMI, total cholesterol, TG, and HDL were calculated to explore the

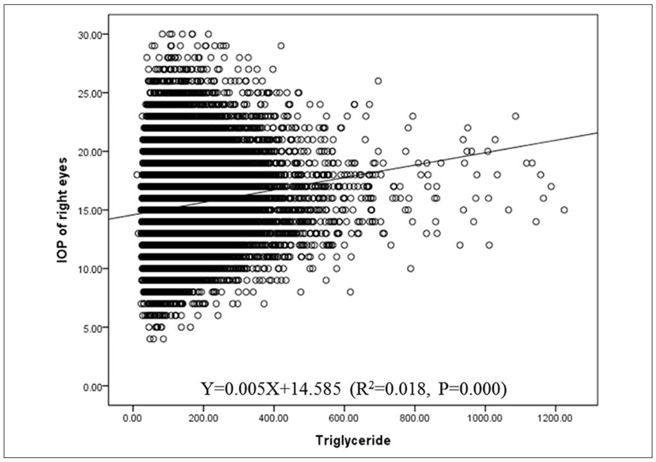

Figure 5: Linear regression model of the triglyceride versus the IOP of the right eyes (IOP: Intraocular pressure)

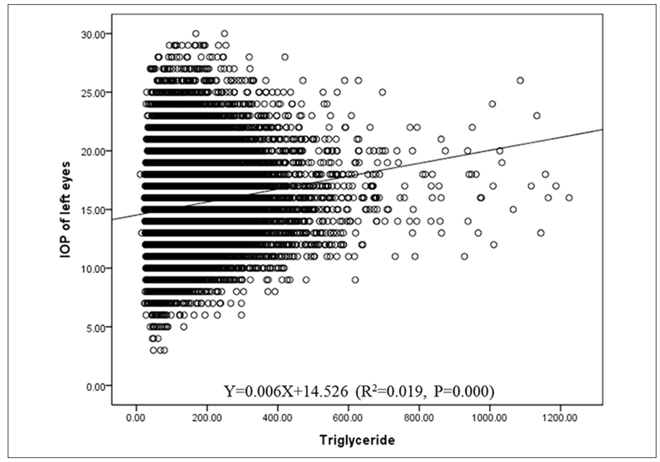

Figure 6: Linear regression model of the triglyceride versus the IOP of the left eyes (IOP: Intraocular pressure)

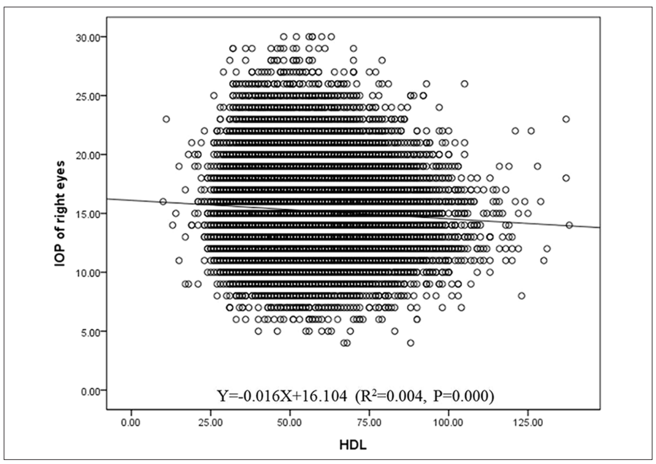

Figure 7: Linear regression model of the HDL versus the IOP of the right eyes (HDL: High density lipoprotein, IOP: Intraocular pressure)

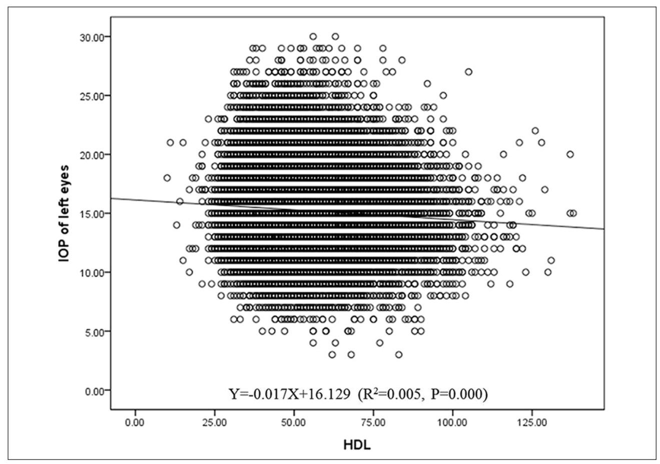

Figure 8: Linear regression model of the HDL versus the IOP of the left eyes (HDL: High density lipoprotein, IOP: Intraocular pressure)

independent effects of BMI, total cholesterol, TG, and HDL on IOP controlled for age and other variables in men and women. BMI, total cholesterol, and TG were positively correlated with IOP in both genders (P = 0.000). HDL was positively correlated with IOP in men and negatively correlated with IOP in women (P < 0.01, P = 0.000) [Tables 12 and 13].

Discussion

IOP is an inherent physiological characteristic of importance in maintaining structure and function of the eye. And, elevated IOP is known major risk factor for glaucomatous optic neuropathy. Therefore, many systemic health parameters influencing IOP have been studied. There were some reports concerned with positive relationships between IOP and age in Western and Pakistani populations.[1-3,6] However, a few studies showed negative relationships between IOP and age in Japan, Taiwan, and Korean populations.[5,8,9] It seemed that relationships between IOP and age might vary according to racial differences, lifestyles, environmental factors, and inherent constitution.[4,7,11]

It was also reported the influence of lipid profiles on IOP and they suggested that increased total cholesterol and HDL levels are not risk factors for increased IOP.[10] However, thereafter, relationship between IOP and plasma lipid profiles have not been evaluated in oriental populations. Accordingly, we planned to evaluate the influence of age and gender on IOP and further to assess the relationship between IOP and BMI, plasma lipid profiles such as total cholesterol, HDL, and TG in a Korean population using cross-sectional analysis.

Although the variation of IOP obtained with NCT was greater than that with Goldmann applanation tonometry, it was reported that NCT is reliable within normal IOP range.[12] We simultaneously checked the value of IOP estimated with the NCT and Goldmann tonometry in small healthy Korean population during the early stages of the study. As there was no statistically significant difference found in the IOP measurement between the two methods, we used the NCT in IOP measurement.[13] In addition, NCT has been shown to correlate well with Goldmann applanation.[14,15]

In this study, the mean IO*P* values using NCT were 15.8 mmHg in right eyes of men and 15.1 mmHg in right eyes of women, which were almost equal to the values of other surveys using applanation tonometer.[16-18] Some studies have reported higher IO*P* values in women[6,8] and others in

Table 7: Mean intraocular pressure by level of high density lipoprotein

HDL (mg/dL)	No. (%)	IOP (mmHg)	
		Right eyes	Left eyes
<40	4,078 (13.2)	15.7±3.2	15.6±3.3
40-59	18,227 (59.0)	15.5±3.2	15.4±3.2
≥60	8,588 (27.8)	15.2±3.2	15.2±3.2
P value*		<0.0001	<0.0001

HDL level classification was corresponded to national cholesterol education program adult treatment panel III, *Chi-square test for trend , IOP: Intraocular pressure

Table 8: Multiple linear regression analysis for relationship between intraocular pressure and some selected variables in study population

	Right eyes		Left eyes	
	Coefficient (*P* value)	S.E.	Coefficient (*P* value)	S.E.
Male	0.568 (0.000)	0.033	0.600 (0.000)	0.033
Age	−0.018 (0.000)	0.002	−0.007 (0.000)	0.002
BMI	0.063 (0.000)	0.006	0.065 (0.000)	0.006
Chol	0.005 (0.000)	0.001	0.005 (0.000)	0.001
TG	0.003 (0.000)	0.000	0.003 (0.000)	0.000

S.E: Standard error, BMI: Body mass index, Chol: Total cholesterol; TG: Triglyceride; HDL: High density lipoprotein

Table 9: Partial correlation between intraocular pressure and some selected variables in study population

	Right eyes		Left eyes	
	Coefficient	*P* value	Coefficient	*P* value
BMI	0.052*	0.000	0.053	0.000
Chol	0.051†	0.000	0.053	0.000
TG	0.070‡	0.000	0.069	0.000
HDL	−0.006§	0.249	−0.007	0.168

*Partial correlation coefficient adjusted by age, gender, Chol, TG, and HDL, †Partial correlation coefficient adjusted by age, gender, BMI, TG, and HDL, ‡Partial correlation coefficient adjusted by age, gender, BMI, Chol, and HDL, §Partial correlation coefficient adjusted by age, gender, BMI, Chol, and TG, BMI: Body mass index, Chol: Total cholesterol, TG: Triglyceride, HDL: High density lipoprotein

Table 10: Multiple linear regression analysis for relationship between intraocular pressure and some selected variables in men

	Right eyes		Left eyes	
	Coefficient (*P* value)	S.E.	Coefficient (*P* value)	S.E.
Age	−0.024 (0.000)	0.002	−0.014 (0.000)	0.002
BMI	0.067 (0.000)	0.009	0.076 (0.000)	0.009
Chol	0.005 (0.000)	0.001	0.005 (0.000)	0.001
TG	0.004 (0.000)	0.000	0.003 (0.000)	0.000
HDL	0.007 (0.002)	0.001	0.006 (0.002)	0.002

S.E.: Standard error; BMI: Body mass index, Chol: Total cholesterol, TG, Triglyceride; HDL: High density lipoprotein

Table 11: Multiple linear regression analysis for relationship between intraocular pressure and some selected variables in women

	Right eyes		Left eyes	
	Coefficient (*P* value)	S.E.	Coefficient (*P* value)	S.E.
Age	−0.013 (0.000)	0.002	−0.014 (0.000)	0.002
BMI	0.053 (0.000)	0.009	0.047 (0.000)	0.008
Chol	0.006 (0.000)	0.001	0.006 (0.000)	0.001
TG	0.003 (0.000)	0.000	0.003 (0.000)	0.000
HDL	−0.009 (0.000)	0.001	−0.009 (0.000)	0.002

S.E: Standard error; BMI: Body mass index, Chol: Total cholesterol, TG: Triglyceride, HDL: High density lipoprotein

Table 12: Partial correlation between intraocular pressure and some selected variables in men

	Right eyes		Left eyes	
	Coefficient	*P* value	Coefficient	*P* value
BMI	0.054*	0.000	0.060*	0.000
Chol	0.044†	0.000	0.045†	0.000
TG	0.087‡	0.000	0.085‡	0.000
HDL	0.024§	0.001	0.021§	0.002

*Partial correlation coefficient adjusted by age, Chol, TG, and HDL, †Partial correlation coefficient adjusted by age, BMI, TG, and HDL, ‡Partial correlation coefficient adjusted by age, BMI, Chol, and HDL: §Partial correlation coefficient adjusted by age, BMI, Chol, and TG, BMI: Body mass index, Chol: Total cholesterol, TG: Triglyceride, HDL: High density lipoprotein

Table 13: Partial correlation between intraocular pressure and some selected variables in women

	Right eyes		Left eyes	
	Coefficient	*P* value	Coefficient	*P* value
BMI	0.046*	0.000	0.039*	0.000
Chol	0.055†	0.000	0.057†	0.000
TG	0.047‡	0.000	0.045‡	0.000
HDL	−0.033§	0.000	−0.033§	0.000

*Partial correlation coefficient adjusted by age, Chol, TG, and HDL, †Partial correlation coefficient adjusted by age, BMI, TG, and HDL, ‡Partial correlation coefficient adjusted by age, BMI, Chol, and HDL, §Partial correlation coefficient adjusted by age, BMI, Chol, and TG, BMI: Body mass index, Chol: Total cholesterol, TG: Triglyceride, HDL: High density lipoprotein

men,[9,19] while some have shown no difference between men and women.[16,17,20] In accordance with previous studies,[9,21] the mean IOP in men was significantly higher than in women except in the older group (≥70 years). The reason for the IOP difference between men and women may be that total cholesterol, TG, and BMI values were significantly higher in men than in women.[9,13,16,21] In addition, the IOP difference with sex among these Western or oriental countries may be due to ethnic, hormonal, environmental, and inherent conditions.[4,22]

As mentioned above, there have been debates on relationship between IOP and age. This study showed that IOP was significantly decreased with age in both sexes by multiple linear regression analysis. This result was consistent with that we reported previously.[9] The difference between Japanese and Western studies was explained as being because the Japanese population tended to be less hypertensive and less obese with age than the white population.[4,5] Also, from an environmental effect to view, we suggest that the nutritional intake of the young Korean people having shifted toward the Western style may be one among causes that raise IOP in younger Korean people, compared with older Korean people.

As for relationship between IOP and plasma lipid profiles, our data demonstrated that IOP had strongly positive relationships with total cholesterol and TG by multiple linear regression analysis for both sexes. Positive correlations after adjusting age, gender, and other variables were found between IOP and total cholesterol, TG in the present study. Several reports also showed that hyperlipidemia, which is strongly related to an increased BMI, a measure of obesity, was associated with elevated IOP.[9,16,21] In contrast, some could not show a direct association with an elevated IOP.[17]

This study showed that IOP had positive relationships with BMI by multiple linear regression analysis for both sexes. Positive correlation after adjusting age, gender, and other variables which can influence IOP was found between IOP and BMI in the present study. Results of the present study correspond with the results of previous studies which reported that BMI was correlated positively with IOP.[9,13,16]

The mechanism has been explained as follows. Mori *et al*.[23] reported that obesity related to hyperlipidemia might increase IOP due to excess intraorbital fat tissue, an increase in episcleral venous pressure, and a consequent decrease in outflow facility. Also, others suggested that hyperlipidemia might increase blood viscosity and consequently increased outflow-resistance of episcleral veins resulted.[21]

We also analyzed a relationship between HDL, one among lipid profiles and IOP. In contrast to other lipid profiles, it is well known that the plasma level of HDL is inversely related to BMI. Our study showed that IOP tended to decrease with increasing HDL by Chi-square test for trend and simple linear regression analysis. Multiple linear regression analysis showed that IOP was significantly associated with HDL in men and women. However, HDL was not significantly related with IOP in all subjects combined by multiple regression analysis. This result was consistent with that we reported previously in a Korean population.[21]

In conclusion, based on the results of this study, IOP was found to increase with total cholesterol, TG, BMI and to decrease with only age regardless of sex in a normal Korean population. Therefore, we suggest that IOP should be checked periodically in the subjects with high level of total cholesterol, TG, and BMI because of its possibility of being raised.

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