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Relationship Between Intraocular Pressure and Systemic Health Parameters in the Korean Population

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This study examined the influence of age, sex, blood pressure, and obesity index on intraocular pressure (IOP), in order to investigate the relationship between the upper limits of the following two conditions in the general Korean population: the "systolic or diastolic hypertensive and obese" group and the "systolic or diastolic hypotensive and lean" group. A total of 6828 healthy subjects (13,656 eyes) underwent automated multi-phasic tests, including tonometry, blood pressure, visual field, and body mass index. The 6,828 subjects were divided into five groups based on age; less than 40, 40 to 49, 50 to 59, 60 to 69, and over 70 years old. They were also divided into four categories on the basis of sex, age, blood pressure, and obesity index. The mean IOP in males (15.8 ± 3.3 mmHg) was significantly higher than in females (14.8 ± 3.1 mmHg) ($P < 0.05$), but this difference decreased proportionally with increasing age. IOP had a tendency to decrease with increasing age ($P < 0.05$). IOP increased significantly with increasing systolic blood pressure, diastolic blood pressure and obesity index (all, $P < 0.05$). The mean IOP of the "systolic or diastolic hypertensive and obese" group was higher than that of the "systolic or diastolic hypotensive and lean" group in the general Korean population ($P < 0.05$). These data could aid investigation into the epidemiological, etiologic and oriental influences related to the risk factors of glaucoma, especially in oriental populations.

Key words: age, diastolic blood pressure, intraocular pressure, obesity index, systolic blood pressure

INTRODUCTION

In western populations, many epidemiological studies have shown that IOP concerned with health parameters increases with aging in both sexes.[1-4] However, in oriental populations, not many studies have evaluated certain IOP regularitiesaccording to health parameters such as sex, age, blood pressure, and obesity index. Until now, only a few such studies have been available to make comparisons between various health parameters and oriental populations.[5-8] Regarding age-related changes in IOP, Shiose and Kawase[5] reported a negative correlation between IOP and age in a Japanese population, but Qureshi[7] reported that IOP progressively increased with age in both sexes in a Pakistani population. Although these two countries belong to the same

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oriental cultures, there are some differences in the IOP relationships with age and sex between Japan and Pakistan.

We conducted this study to evaluate certain IOP regularities in general Korean populations by sex, age, systolic and diastolic pressure, and obesity index. Further, our normative data were compared with those of previously reported studies concerning the relationships of IOP with age, sex, blood pressure, obesity index.

METHODS

We examined 13,656 eyes of 6,828 healthy subjects who underwent health checkup at the automated multiphase health testing system of the "Health Promotion Center" in Pusan National University Hospital from May 1, 1996 to April 31, 1999.

Male subjects numbered 3,447 (50.5%) and female 3,381 (49.5%). Before testing, each patient's medical history was carefully checked by a physician. Using questionnaires, it was attempted to eliminate the data of patients who were being medically treated for previously known glaucoma.

All automated multi-phasic tests, consisting of 80 items, included visual acuity, tonometry, and blood pressure, were conducted on the same day for an average of 20 persons per day. All IOP measurements were taken by the same trained paramedical assistant and with a non-contact tonometer (Canon T-2, Canon, Tokyo, Japan), without the application of topical anesthetic, to avoid inter-examiner and inter-tonometer variances, and only between 9 and 11 AM to minimize the effect of diurnal variation, Monday through Friday. IOP measurements were determined by taking the median value of three successive readings. With the subjects in the sitting position, blood pressure was measured in the upper right arm. Heights and weights were measured with the subjects wearing a lightweight hospital gown in the standing position without shoes.

The 6,828 subjects were divided into four categories on the basis of sex, age, blood pressure, and obesity index. They were also separated into five age groups; less than 40, 40 to 49, 50 to 59, 60 to 69, over 70 years old. Systolic blood pressure was categorized as low ($\leq$ 99 mmHg), normal (100 to 139 mmHg), and high ($\geq$ 140 mmHg), and diastolic as low ($\leq$ 84 mmHg), normal (85 to 89 mmHg), and high ($\geq$ 90 mmHg). Further stratification was made by body build [weight (kg) $\div$ (height (cm) - 100) X 0.9 X 100]; lean ($\leq$ 99%), normal (100 to 119%) and obese ($\geq$ 120%). We analyzed the differences in the upper limits of the two conditions: the "hypertensive ($\geq$ 140 mmHg in systolic, $\geq$ 90 mmHg in diastolic) and obese ($\geq$ 120%)" group, and the "hypotensive ($\leq$ 99 mmHg in systolic, $\leq$ 84 mmHg in diastolic) and lean ($\leq$ 99%)" group.

Analysis of variance (ANOVA) test was used to check the statistical significance at the $P < 0.05$ levels. No statistically significant difference was found between data for the right and left eyes ($P > 0.05$). Thereafter, all statistical tests and analyses were based on only right eye data rather than whole subjects so that the results could be correlated with those reported by other investigators.

RESULTS

A total of 6,828 (13,596 eyes) healthy Korean people, 3,447 males (50.5%) and 3,381 female (49.5%) were selected from those enrolled at the "Health Promotion Center" in Pusan National University Hospital. The mean age of subjects was 47.1 years old (range, 35 to 76 years). The mean IOP in males (15.8 $\pm$ 3.3 mmHg) was significantly higher than in females (14.8 $\pm$ 3.1 mmHg) ($P < 0.05$). The mean age of males was higher than that of females, although not significantly (Table 1).

The mean IOP ($\pm$ SD) values in the various age groups for each sex and the whole population are shown in Figure 1. With increasing age, the IOP difference between males and females decreased proportionally, eventually reaching similar values for subjects over 70 years old. Generally, the mean male IOP decreased proportionally with increasing age, but the female value showed a slight increase up to 50 years old, and then decreased over 60 years. However, there was a tendency toward significant decrease in the total mean IOP with increasing age ($P < 0.05$). A tension exceeding 21 mmHg without signs of glaucoma field or optic disc damage was found in 4.8% of men and 2.2% of women. IOP greater than 21 mmHg was more frequent in the middle age group, 50-60 years old (Table 2).

The mean systolic and diastolic blood pressures

Table 1. Subject characteristics

Sex	Subjects (%)	Age	IOP	Systolic BP	Diastolic BP	Obesity index
		Mean ± Standard deviation				
Male	3447 (50.5%)	47.8 ± 10.2	15.8 ± 3.3	123 ± 15.2	77 ± 5.7	109 ± 13.1
Female	3381 (49.5%)	46.6 ± 11.4	14.8 ± 3.1	120 ± 14.7	73 ± 4.9	115 ± 14.9
P value		P > 0.05	P < 0.05	P > 0.05	P > 0.05	P > 0.05

Table 2. Numbers of ocular hypertension cases by gender and age

Sex		Age (years)					
		≤ 39	40-49	50-59	60-69	≥ 70	Total
Male	Cases	943	1220	846	372	66	3447
	No. of ≥ 21 mmHg	36	59	54	16	1	166(4.8)†
Female	Cases	809	1057	1026	406	53	3381
	No. of ≥ 21 mmHg	17	22	26	8	1	74(2.2)†

†: No. of right eye of IOP greater than 21 mmHg / Total No. of right eye in all ages for this gender × 100

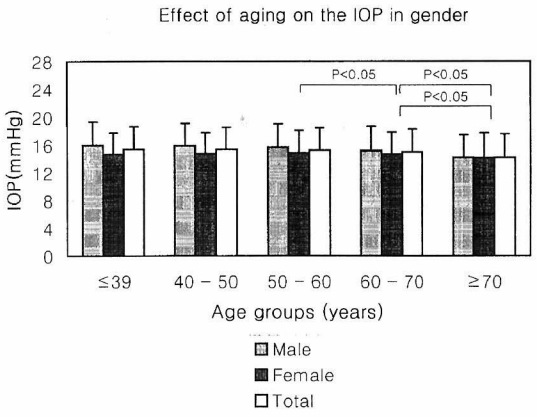

Fig. 1. With aging, the mean IOP difference between males and females decreased proportionally, resulting in similar values for over 70 years old. P < 0.05 indicates a significant difference when the mean IOP of one age group was compared with its preceding age group.

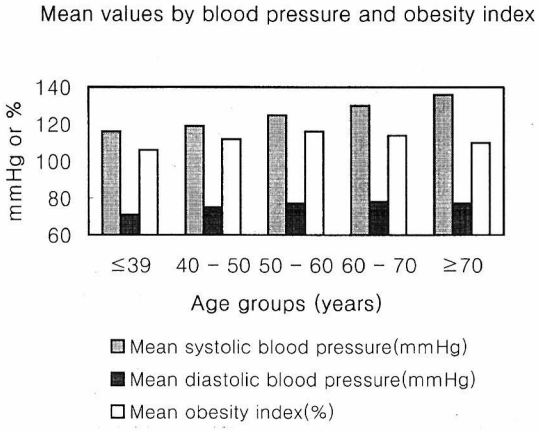

Fig. 2. Mean systolic blood pressure markedly increased with aging, but mean diastolic blood pressure and obesity index decreased over 50 years old (P>0.05).

were distinctly higher in males than females, although the mean obesity index of females was higher than that of males (Table 1). With increasing age, the mean systolic blood pressure increased markedly, and the mean diastolic blood pressure also had a tendency to increase, except that it showed a decrease over 70 years old. The mean obesity index increased proportionally with increasing age, although decrease was also noted over 60 years old (Fig. 2).

With the increasing tendency of blood pressure or obesity index, the mean IOP values of blood pressure and obesity index were higher in males than in

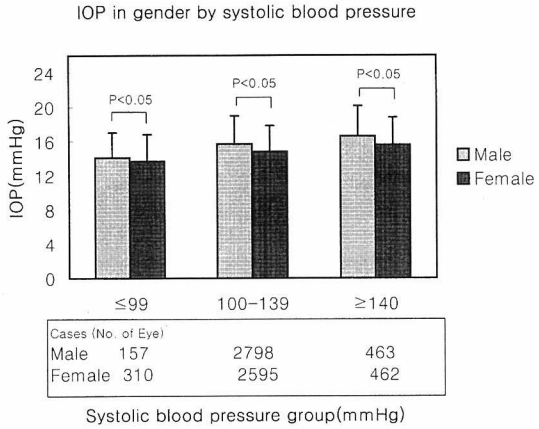

Fig. 3. Mean IOP increased proportionally with increasing systolic blood pressure. P<0.05 indicates a significant difference between the two sexes. The subject numbers are given under each systolic blood pressure group.

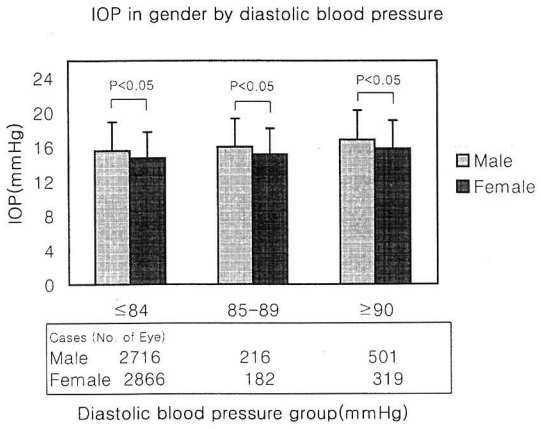

Fig. 4. Mean IOP increased proportionally with increasing diastolic blood pressure, especially in males. P < 0.05 indicates a significant difference between the two sexes. The subject numbers are given under each diastolic blood pressure group.

females for all subjects. IOP increased in proportion with increasing systolic blood pressure, and mean IOP of males was also higher than that of females in all categories of systolic blood pressure (Fig. 3). According to diastolic blood pressure, IOP was correlated with a high diastolic blood pressure. With increasing diastolic blood pressure, IOP increased more markedly in males than in females (Fig. 4). The mean IOP increased proportionally with the degree of obesity, and IOP was higher in males than in females regardless of the mean obesity index, which was higher in females (Fig. 5).

This study also examined the difference in the upper limits of two conditions: the "hypertensive and obese" group and the "hypotensive and lean" group. Relative to systolic blood pressure and obesity index, the difference of mean IOP between the "systolic hypertensive and obese" group and the "systolic hypotensive and lean" group showed a statistical significance. Relative to sex, the mean IOP of males was higher than that of females in both groups ($P < 0.05$) (Table 2). According to diastolic blood pressure and obesity index, there was a significant difference of mean IOP between them ($P < 0.05$) (Table 3).

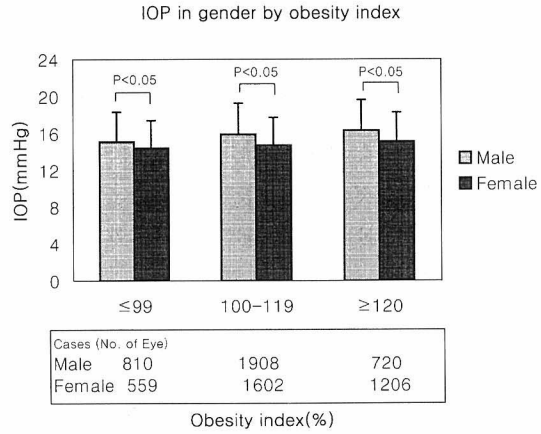

Fig. 5. Mean IOP increased proportionally with increasing obesity index. P < 0.05 indicates a significant difference between the two sexes. The subject numbers are given under each obesity index group.

DISCUSSION

Although the effect of age and sex on IOP has not been clearly elucidated, IOP has been known to increase with increasing age among Western populations,[1-4] whereas it has been found to decrease in the Japanese population.[5,6] This difference between Western and Japanese populations in healthy sub-

Table 3. Difference in upper limit of normal intraocular pressure between "systolic hypertensive & obese" group and "systolic hypotensive & lean" group.

Sex	Systolic hypertensive (≥ 140 mmHg) & obese (≥ 120%)		Systolic hypotensive (≤ 99 mmHg) & lean (≤ 99%)		P value
	Eyes (cases, %)	IOP (mean ± SD*)	Eyes (cases, %)	IOP (mean ± SD*)	
Male	100/6828 (1.5%)	16.9 ± 3.3	63/6828 (0.9%)	14.0 ± 3.3	P < 0.05
Female	214/6828 (3.1%)	15.5 ± 3.3	98/6828 (1.4%)	13.3 ± 2.8	P < 0.05
Total	314/6828 (4.6%)	16.2 ± 3.5	161/6828 (2.3%)	13.6 ± 3.1	P < 0.05

Table 4. Difference in upper limit of normal intraocular pressure between "diastolic hypertensive & obese" group and "diastolic hypotensive & lean" group.

Sex	Diastolic hypertensive (≥ 90mmHg) & obese (≥ 120%)		Diastolic hypotensive (≤ 84mmHg) & lean (≤ 99%)		P value
	Eyes (cases, %)	IOP (mean ± SD*)	Eyes (cases, %)	IOP (mean ± SD*)	
Male	178/6828 (2.6%)	17.0 ± 3.4	33/6828 (0.5%)	14.7 ± 3.0	P < 0.05
Female	207/6828 (3.0%)	15.8 ± 3.5	16/6828 (0.2%)	15.6 ± 3.4	P > 0.05
Total	385/6828 (5.6%)	16.5 ± 3.4	49/6828 (0.7%)	13.8 ± 3.0	P < 0.05

jects has been thought to be caused by different ethnic groups or environmental effects.[6] Shiose and Kawase[5] reported that IOP in the Japanese population tends to decrease with aging, and more markedly in males than in females. However, Qureshi[7] reported that IOP progressively increases with age in both sexes in the Pakistan population, but more markedly in females. Therefore, this study planned to evaluate the influence of age, sex, blood pressure, and obesity index on IOP among various age groups in an apparently healthy population from Korea, and further to compare the IOP effect with that reported in the literature for the other oriental populations such as Pakistani and Japanese.

Non-contact tonometry is reliable within the normal IOP range. We simultaneously checked estimated IOP values with two methods from an early study; NCT and Goldmann tonometer. As there was no significant difference of IOP values between the two methods in this study (not shown), non-contact tonometry was considered acceptable for the practical purpose of correlation with systemic variables. Furthermore, the coefficient of repeatability (twice the standard deviation of the mean difference) in this study on non-contact tonometry was 5.0 mmHg for right and 4.5 mmHg for left eyes. As more than 95% of the differences between second and third IOP values fell within 2 SD from the mean difference, non-contact tonometry can be considered to have acceptable reproducibility.

Some investigators have reported higher IOP in females,[5] and others in males,[9] while some have failed to find any difference at all between the sexes.[4, 10] Using non-contact tonometers, the mean IOP values were between 11.9 and 13.1 mmHg in males, and between 11.5 and 13.4 mmHg in females in Japan.[5, 6] According to our results, the mean IOP was 15.8 ± 3.3 mmHg in males and 14.8 ± 3.1 mmHg in females,; a finding that is similar to the mean IOP values, within the normal IOP range.

While Shiose[6] showed that the mean IOP was higher in males than in females, Qureshi[7] reported the mean IOP in females was higher than in males, especially after the age of 40 years. In our study, the mean IOP in males was significantly higher than in females ($P < 0.05$); a finding that is similar to that of

the Japanese population.

In relation with age, IOP showed a significant decrease beginning in males over 40 years old, and in females over 50 years, whereas in the Japanese population it became significant only after of 60 years. However, in the Pakistani population, the increase became statistically significant in males over 50 years old, while in females it occurred one decade earlier. Our study showed that IOP had a definite tendency to decrease with increasing age regardless of sex, especially in males over 50 years old. Such a decrease was also noted in females over 60 years old, but the difference was not so significant over 70 years old. We think that the IOP difference observed among these oriental countries is concerned with aging processes due to hormonal effects, environmental conditions, and inherent constitutions.[15, 11-13]

Ocular tensions exceeding 21 mmHg without signs of glaucoma field or optic disc damage occurred in about 7.0% of cases in our study, more frequently in middle age groups. A similar frequency for ocular tensions more than 21 mmHg has been described by several studies.[7, 14] The increased frequency of high ocular tension in middle age was caused by the effect of age-related changes in the trabecular meshwork and also by systemic healthy parameter factors, as well as by higher blood pressure and obesity index than in other age groups.[10]

With aging, the mean systolic and diastolic blood pressure increased proportionally. However, the increase in mean obesity index was noted until 60 years old, after which it showed a tendency to decrease. According various epidemiological studies,[15] there are twice as many obese people (more than 10% over their ideal weight) and systolic hypertensive people (more than 160 mmHg in blood pressure) among the elderly population in the United States than in oriental populations. This fact may have influenced the rising effect of IOP with aging in Western culture.

Both systolic and diastolic blood pressure were positively and dependently correlated with intraocular pressure.[2, 3, 5, 12] Although some authors reported systolic blood pressure was more closely correlated with IOP than diastolic or mean blood pressure, the relationship between diastolic blood pressure and IOP has also been discussed in a few studies.[8, 12] Our study showed that systolic and diastolic blood pressures are positively correlated with IOP regardless of gender. It is thought that the physiologic basis for this IOP-blood pressure relationship may be an increased production of aqueous humor by ultrafiltration through the elevated ciliary artery pressure.[7-12] Systemic hypertension could lead to increased IOP through this relationship, but other physiologic factors such as the effect of generalized sympathetic tone or serum corticosteroids and sclerotic changes, may also influence the relationship between IOP and blood pressure.[2] This suggests that several factors other than blood pressure may be significant in the relationship between diastolic blood pressure and IOP.

Obesity may also exert a direct effect on IOP, because increased orbital pressure from excess fat may lead to high episcleral venous pressure and decreased outflow facility due to corticosteroid secretions in obese persons.[6, 12] However, several factors such as sympathetic tone, hormone, or sclerotic changes may also be important in the relationship between obesity index and IOP; in a manner similar to the IOP effects on diastolic blood pressure.[5, 6, 12]

According to our results, the level of IOP is maintained by the counterbalance between the IOP-raising factors of systolic and diastolic blood pressure and obesity, and the IOP-lowering factors of the aging process. In high blood pressure or high obesity cases, IOP should be checked periodically because of its possibility of being raised. Furthermore, to compare the ethnic differences and to evaluate of the general risk factors of IOP, an epidemiological study of IOP should include other populations such as Asian, South American, African or Australian. Since most of the epidemiological studies of glaucoma have been limited to the white populations in Western Europe and North America, we think that further assessment of the influence of healthy systemic parameters on IOP is necessary.

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