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Original Research Article

A Hospital-Based Study to Investigate Fluctuation of Intraocular Pressure (IOP) and Seasonal Variation of 24-Hour IOP

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Conflict of interest: Nil

Abstract

Aim: The aim of the present study was to investigate fluctuation of intraocular pressure (IOP) and seasonal variation of 24-hour IOP.

Methods: The present study conducted in the Department of Ophthalmology, DMCH Darbhanga, Bihar, India for one year and twenty healthy volunteers (10 females and 10 males) were recruited. Each subject received a comprehensive ophthalmic examination including slit-lamp and ophthalmoscopy examination, and no participant demonstrated any signs of ophthalmic and/or systemic diseases or had a family history of glaucoma.

Results: The yearly fluctuation curve showed IOP in the summer months were lower than other seasons. This survey began in December and lasted until January. The lowest IOP was obtained during summer and the deviation between the lowest and highest IOP was an average of 0.4-0.5 mm Hg. Both eyes fitting curves yearly showed IOP fluctuation. It demonstrates that the winter months IOP are higher than those in the spring, summer and autumn months. There was no significant relationship with other individual/environmental confounding factors. When evaluating temperature, IOP was significantly lower on hotter days (β=-0.9, P=0.012, temperature >24°C). The calculated β-value is rising with increasing of the sunshine duration, it gets to -0.5 when day length is above 48242.0s (about 13.5h). Moreover, the trend tests show statistically significant findings in temperature and sunshine duration.

Conclusion: IOP is trend to be higher in cold days than warm days. IOP have negative association with both environmental temperature and duration of sunshine. On a season-to-season basis, 24-hour IOP is not highly reproducible in healthy volunteers.

Keywords: Intraocular Pressure, Season, Temperature, Sunshine Duration.

Introduction

Glaucoma is the second leading cause of blindness worldwide. [1] It is estimated that the total number of global glaucoma cases will rise to 111.8 million in 2040. [2] Glaucomatous visual field defects are irreversible. Therefore, rapid diagnosis and intervention are insufficient, and future glaucoma progression should be predicted at an early stage.

Elevated intraocular pressure (IOP) is considered the most important and only clinically modifiable risk factor for the development and progression of glaucoma. [3] At present, IOP reduction is the only proven treatment approach for glaucoma. However, IOP is not a fixed value and fluctuates over time. [4] In the earlier study, a long-term longitudinal investigation revealed that IOP in healthy eyes showed a physiologic reduction with age. [5] They also focused on 24-hour fluctuations in IOP and presented evidence that night-time IOP increased in many patients with primary open-angle glaucoma (POAG). [6] Because IOP changes could be a potential risk factor for glaucoma progression, [7] it is essential to consider IOP fluctuations in addition to the IOP value itself. Lee et al [8] indicated that in eyes with POAG, greater IOP fluctuations between visits contributed to the progression of visual field loss. Other previous studies also reported that IOP fluctuations influenced glaucoma progression. [3,4,9]

Intraocular pressure is known to be higher in winter than in summer. Gardiner et al10 investigated IOP in eyes with ocular hypertension in 6 climatically similar geographic regions and showed significant seasonal fluctuations in IOP in all regions, although interregional differences were observed in the magnitude of seasonal fluctuations. [10-15] I t is recognized that intraocular pressure (IOP) measurements play an important role in diagnosis and management of some ocular diseases, especially those related to IOP elevation. Considering the factor that IOP does not have a constant value, many glaucoma researchers have conducted studies to characterize its short/long-term variations in order to better understand the mechanisms of glaucomatous damage and its potential contributory factors [1-2]. Previous reports demonstrated that IOP was not strictly consistent during one day and tended to peak early in the morning and decline over time [3]. The instability of 24-hour IOP fluctuations in young healthy subjects were also confirmed in a previous study [4]. Moreover, fluctuations in diurnal IOP were considered as independent risk factors for the progression of glaucoma [5-6]. There are some studies focus on the variations of IOP through a whole year, however, lack of consecutive recording IOP for a long time other than that from each month during the year [7].

The aim of the present study was to investigate fluctuation of intraocular pressure (IOP) and seasonal variation of 24-hour IOP during one year in healthy participants. [16,17]

Materials and Methods

The present study conducted in the Department of Ophthalmology, DMCH Darbhanga, Bihar, India for one year and twenty healthy volunteers (10 females and 10 males) were recruited. Each subject received a comprehensive ophthalmic examination including slit-lamp and ophthalmoscopy examination, and no participant demonstrated any signs of ophthalmic and/or systemic diseases or had a family history of glaucoma.

Blood pressure was measured using sphygmomanometer. Sphygmus, respiration and heart rate were also recorded before IOP evaluations. Additionally, to determine IOP patterns in the participants' daily lives, they were not hospitalized and their sleep cycles were not controlled. Subjects were allowed to continue with their lives as normal and maintained their regular eating habits. The spring term was from 4th February to 4th May, summer from 5th May to 6th August, autumn from 7th August to 6th November and winter from 7th November to 3rd February.

Intraocular Pressure Measure Procedures The IOP measurements were taken Goldmann applanation tonometer at a fixed time from 8:00 a.m. to 9:00 a.m. to minimize the effect of diurnal variations. IOP was measured after subject had been seated for at least 5 min. The measurement procedure was automated by default and only done manually if there was any difficulty achieving results. During each visit, three measurement series within a maximum range of 3 mm Hg were obtained and the mean corrected IOPs were documented. The 24-hour IOP measurements were taken every 4h over a 24-hour period (2:00 a.m., 6:00 a.m., 10:00 a.m., 2:00 p.m., 6:00 p.m., 10:00 p.m.) one day out of each season. Four parameters of maximum, minimum, average and daily fluctuations were determined for IOP each day of the 24-hour IOPs. Daily fluctuation was defined as the difference between the maximum and minimum measurements in the study period. Meanwhile temperature, humidity, atmosphere pressure, sunshine duration and other environment parameters were recorded. To avoid bias, clinicians had no knowledge of prior IOP values.

Statistical Analysis Stata was used for the data management, data analysis and figure drawing. Principle component analysis was applied to reduce the dimension of the data and avoid potential collinearities among confounding factors. Multiple locally weighted scatterplot smoothing models were first performed to assess the relationship between IOP and the month when data were collected. Then the multivariable generalized estimating equation (GEE) models were conducted to evaluate the association between the IOP and internal/environmental factors since it is a typical repeated measure designed study. Besides, intra-class correlation coefficients (ICCs) were also calculated to individually assess the reproducibility of the 24-hour IOP (maximum, minimum, average, daily fluctuation). All the above-mentioned hypothesis tests were two-sided and the significant level was set as 0.05.

Results

Table 1: Demographics of participants

Parameters	Total	Spring	Summer	Autumn	Winter
N	20	-	-	-	-
Age	24.1±2.9	-	-	-	-
M/F	10/10	-	-	-	-
CCT_OD (μm)	525.8±39.2	-	-	-	-
CCT_OS (μm)	526.8±39.3	-	-	-	-
AL_OD (mm)	24.5±1.4	-	-	-	-
AL_OS (mm)	24.5±1.4	-	-	-	-
Refraction, OD (D)	-2.4±2.0	-	-	-	-
Refraction, OS (D)	-2.6±2.1	-	-	-	-
Adjusted IOP, OD (mm Hg)	14.1±1.9	13.5±2.0	12.9±1.9	13.3±2.1	13.5±2.3
Adjusted IOP, OS (mm Hg)	14.0±3.4	13.7±2.6	13.3±2.6	13.5±2.6	13.6±2.9
Sbp (mm Hg)	111.8±10.0	106.4±11.0	103.8±9.6	105.1±9.1	106.5±9.1
Dbp (mm Hg)	68.2±5.8	62.9±7.5	61.6±7.2	63.5±23.7	66.0±20.0
Breath (breaths/min)	14.2±2.0	12.1±1.8	11.8±1.5	11.6±1.7	12.4±2.0
Pulse (beats/min)	83.8±12.4	79.9±9.3	78.6±8.6	77.9±9.3	80.6±10.4
Temperature (℃)	6.1±1.9	15.7±4.1	25.7±2.1	19.2±4.7	6.8±3.7
Humidity (%)	71.7±15.3	86.1±9.0	86.0±12.5	79.2±9.7	74.3±16.5
Atmosphere (MPa)	1018.2±2.6	1012.8±5.8	1003.2±3.7	1015.4±5.7	1022.5±4.7
Wind scale (0-17)	3.2±1.9	4.8±2.9	5.4±2.6	4.8±2.4	4.6±2.5
Visibility (m)	45.3±27.7	38.6±39.7	64.2±61.9	69.9±55.6	86.4±80.1
Daily rain (mm)	0.5±1.2	0.3±1.0	0.1±0.4	0.0±0.1	0.0±0.0

The yearly fluctuation curve showed IOP in the summer months were lower than other seasons. This survey began in December and lasted until January. The lowest IOP was obtained during summer and the deviation between the lowest and highest IOP was an average of 0.4-0.5 mm Hg. Both eyes fitting curves yearly showed IOP fluctuation. It demonstrates that the winter months IOP are higher than those in the spring, summer and autumn months.

Table 2: Generalized estimating equation model analysis of correlated factors with intraocular pressure (OD)

Variable	Mean±SD	Crude			Adjusted		
		β	SE	P	β	SE	P
Temperature							
-0.4℃-11.6℃	13.5±2.3	0.0	0.0	0.520	0.0	0.0	0.160
11.7℃-17.0℃	13.4±2.1	-0.1	0.2	0.121	-0.3	0.2	0.020
17.1℃-23.9℃	13.2±2.0	-0.4	0.2	0.060	-0.7	0.30	0.010
24.0℃-29.7℃	13.0±1.9	-0.5	0.3	<0.001	-0.9	0.4	<0.001
Trend test							
Sunshine duration							
37324.0-39673.0s	13.6±2.2	0	0.0	0.035	0.0	0.0	0.300
39674.0-44229.0s	13.2±2.2	-0.4	0.2	0.335	-0.2	0.2	0.983
44230.0-48241.0s	13.4±2.0	-0.2	0.2	0.006	-0.0	0.2	0.035
48242.0-050110.0s	13.0±2.0	-0.6	0.2	<0.001	-0.5	0.2	0.003

There was no significant relationship with other individual/environmental confounding factors. When evaluating temperature, IOP was significantly lower on hotter days (β=-0.9, P=0.012, temperature >24°C). The calculated β-value is rising with increasing of the sunshine duration, it gets to -0.5 when day length is above 48242.0s (about 13.5h). Moreover, the trend tests show statistically significant findings in temperature and sunshine duration.

Table 3: Intraclass correlation coefficients for comparison of intraocular pressure parameters for seasons among healthy young individuals

Parameters	IOP for each individual (mm Hg)	ICC values	P
Maximum	11.7 to 20.3	0.152 (-0.07 to 0.501)	0.104
Minimum	7.5 to 14.3	0.224 (-0.019 to 0.570)	0.038
Average	10.5 to 16.5	0.263 (0.011 to 0.604)	0.002
Fluctuation	1.3 to 9.2	0.016 (-60.157 to 0.345)	0.471
2 a.m.	7.8 to 20.1	0.126 (-0.088 to 0.474)	0.143
6 a.m.	7.5 to 20.3	0.159 (-0.065 to 0.509)	0.094
10 a.m.	10.4 to 18.4	0.094 (-0.109 to 0.440)	0.204
2 p.m.	9.8 to 16.6	0.109 (-0.099 to 0.457)	0.173
6 p.m.	8.3 to 18.9	0.174 (-0.055 to 0.265)	0.078
10 p.m.	8.2 to 17.4	-0.017 (-0.176 to 0.302)	0.525

In the multivariable generalized estimating equation analysis, IOP had a negative correlation with both temperature and sunshine duration (P<0.05). There also was a seasonal effect on 24-hour IOP. However, all intraclass correlation coefficients values of minimum, maximum and average of the 24-hour IOP and each individual IOP were less than 0.30.

Discussion

There are many studies related to the effects of climatic changes on IOP whether in normal or in glaucoma patients. [18,19] Such as Qureshi et al [18] who used a Goldmann applanation tonometer (GAT) to measure IOP in 103 healthy male Chinese volunteers over a 14mo period. It was found that IOP was highest during the winter and lowest in summer, and that the discrepancy was 1.4±0.7 mm Hg. There were several possible reasons for the fluctuation of IOP in a whole year.

It was implied that the IOP fluctuations are correlated to the amount of sunlight exposure. It was supported by our report, especially the sunshine duration was more than 13.5h. Qureshi et al [18] hypothesized that the winter month's decreased levels of sunlight and the amount of certain chemicals secreted by the pineal gland increased which induced IOP raise. According to this hypothesis, prolonged sunlight affects certain secretions from pineal gland, causing reduced IOP in summer, especially during the nocturnal sleeping periods. The Pineal gland is considered as the "biological clock" with melatonin as its main secretion. The chemicals would result in an increase in the secretion of progesterone and estrogen, which have been reported to reduce IOP values by increasing aqueous outflow. [20] Moreover, Stoupel et al [21] reported that levels of daily geomagnetic and extreme yearly solar activity can affect IOP. The possible reason was that geomagnetic activity influenced human physiology (plasma viscosity increased, leucocyte aggregation and drop of growth hormone) and caused a decreasing in IOP.

However, the internal factors, such as blood pressure, pulse rate, breathe had no effects on the IOP. Some previous reports demonstrated blood pressure maybe a possible influence factor. Based on the Beaver Dam Eye Study, there was a 0.21 mm Hg and 0.43 mm Hg increase in IOP for a 10 mm Hg increase in systolic and diastolic blood pressure respectively. [22] The present study was failed to find the relationship between blood pressure and IOP. It was speculated that it might be due to all participants in the study were normal healthy subjects. Sehi et al [23] reported that diastolic blood pressure significantly influenced IOP over the course of a day in glaucoma patients but not in normal subjects. Although the dynamic role of blood pressure has in aqueous production and aqueous outflow regulation by their effects on episcleral venous pressure and pulse dependent motion of the trabecular meshwork. While in healthy subjects participated in this study, the blood pressures were all in normal range.

In our study, 24-hour IOPs were not reproducible on a seasonal basis, even in healthy young subjects. Realini et al24 investigated diurnal IOP patterns in the eyes of 40 healthy subjects without glaucoma and revealed that diurnal IOP patterns were not replicated in the short term. Another prospective, cross-sectional survey found that apart from the IOP fluctuations, the maximum/minimum values of IOP and blood pressure were in excellent agreement. [25] In the current study, all the IOP parameters consistent with that Realini et al's [24] study were not reproducible. Moreover, our seasonal ICC values over showed that IOP fluctuations were worse than those found in previous reports. As compared to previous studies, this showed how over longer periods of time there was less replicability. Another possible reason was that the daily lives of participants were not controlled during the study. Although GAT is regarded as the gold standard for IOP measuring, the inherent flaw of contact tonometer is that it requires corneal anesthesia and fluorescein staining. Considering the high frequency measurements of IOP, GAT could not be tolerated by volunteers every day. Therefore, non-contact tonometer was used in this study. However, previous report found that there was consistence between GAT and non-contact tonometer in healthy eye. [26] Meanwhile 3 repeated IOP measurements would also reduce measurement bias. Moreover, the main purpose of this study was to investigate the IOP fluctuation over time. As long as the device had good repeatability, it was sufficient to complete the study. [27]

Besides potentially contributing to the increasing risk for glaucoma events during the colder seasons, yearly IOP variations can influence results of clinical trials and epidemiological surveys. The current results, least in parts, were supported by

IOP yearly fluctuation and some possible mechanisms. These results in normal eyes did not diminish the value of assessing diurnal IOP patterns of individuals with suspected or diagnosed glaucoma. However, it implied that fully characterizing diurnal IOP variability in such individuals may require more than a single 24-hour diurnal IOP testing session.

Conclusion

In conclusion, IOP showed a yearly fluctuation which tended to be lower in warm seasons, while the exact physiological mechanism variation of IOP was still unknown. The 24-hour IOP was not highly reproducible in healthy young volunteers, which implies that a single 24-hour IOP assessment may not be sufficient to evaluate the daily IOP fluctuations.

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