Circadian Pattern of Intraocular Pressure Fluctuations in Young Myopic Eyes With Open-Angle Glaucoma

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PURPOSE. To characterize the circadian pattern of habitual-position intraocular pressure (IOP) and its association with ocular dimension in young myopic patients with open-angle glaucoma (OAG).

METHODS. A total of 108 young OAG patients with moderate to severe myopia (myopia group) and 67 age-matched OAG patients with emmetropia or mild myopia (control group) were recruited prospectively over 3 years. IOP was recorded 11 times over a 24-hour period by a single, well-trained ophthalmology resident using a handheld tonometer.

RESULTS. A total of 87 men and 88 women were included in this study. Analysis of the entire myopia group indicated no acrophase in habitual-position IOP over 24 hours. Subgroup analysis indicated that 44 patients (40.7%) had a diurnal acrophase, 17 patients (15.7%) had a nocturnal acrophase, and 47 patients (43.6%) had no evident acrophase. By contrast, the control group showed an overall nocturnal acrophase in habitual-position IOP, with 14 patients (20.8%) having a diurnal acrophase, 30 patients (44.8%) having a nocturnal acrophase, and 23 patients (34.4%) having no evident acrophase in subgroup analysis. There was a negative correlation between nocturnal habitual-position IOP elevation and axial length in the overall population.

CONCLUSIONS. In young myopic OAG eyes, there is no significant nocturnal elevation in habitual-position IOP, while IOP increases at night-time in age-matched control eyes. The overall 24-hour IOP pattern in the myopia group did not show an acrophase. Finally, data showed a negative relationship between nocturnal habitual-position IOP elevation and axial length.

Keywords: intraocular pressure, circadian pattern, myopia, glaucoma

Myopia has been increasing dramatically among young Asians in the last few decades. Structural ophthalmic changes associated with myopia include elongated axial length (A/L), increased disc and cup size, large and/or skewed optic canal opening, thin sclera and lamina cribrosa, and accompanying parapapillary atrophy (PPA). These changes can inherently increase patient susceptibility to glaucomatous damage irrespective of intraocular pressure (IOP) level, particularly during adolescence and early adulthood during which eyeball elongation often occurs with myopia. Indeed, myopia has been identified as a risk factor for OAG in many population-based studies. As a result, occult open-angle glaucoma (OAG) is often discovered incidentally during screening examinations for myopia or during keratorefractive surgery (KRS) to correct myopia in young patients.

Previous studies, including our own work, reported that untreated OAG patients have a higher nocturnal (supine) IOP than diurnal (seated) IOP. In addition, data suggest that elevated nocturnal IOP in the supine position may be a risk factor for optic nerve and visual field (VF) defects in OAG patients. Researchers have speculated that nocturnal IOP elevation in OAG is in part due to increased choroidal (uveal) vascular volume resulting from the change in posture at nighttime. However, whether the same mechanisms responsible for nocturnal IOP elevation in OAG may also affect OAG eyes with increased A/L remains unknown. Liu et al., who measured 24-hour IOP in the habitual position in young adults with moderate to severe myopia, found a significant nocturnal supine IOP elevation in the myopic group without glaucoma; however, the degree of nocturnal IOP elevation was less than that of the emmetropic control group. We hypothesized that OAG eyes with longer A/L may have different 24-hour IOP patterns compared to eyes with emmetropia or low myopia due to greater ocular dimensions and diminished sclera rigidity.

Previous reports have shown that young myopic adults without glaucoma are likely to have higher daytime IOP than young adults without myopia, although the underlying mechanisms remain unknown. Therefore, it is plausible that daytime IOP may also be higher in myopic glaucomatous eyes than in emmetropic glaucomatous eyes. With this in mind, we measured changes in habitual-position IOP over time in a large group of young patients who were newly diagnosed with moderate to severe myopic OAG. Data were also collected from age-matched OAG subjects with emmetropia or low myopia as a control group. The purpose of the current study was to: (1) report the 24-hour habitual-position IOP pattern including peak IOP timing (acrophase) and amplitude over a 24-hour period in young myopic OAG subjects (myopia group); (2) compare the data from the myopia group with that of an age-matched control group; and (3) study the relationship between ocular
dimension based on A/L and nocturnal IOP elevations using linear regression.

**Patients and Methods**

**Subjects**

We prospectively recruited consecutive OAG patients examined by a single glaucoma specialist (MSK) from March 2010 to March 2013 in the glaucoma clinic of the Asan Medical Center, Seoul, Korea. All patients were newly diagnosed with OAG, based on clinical and VF examinations at our glaucoma clinic, and underwent in-hospital, 24-hour monitoring of IOP when eligible for the study. All eligible OAG patients were healthy, nonsmoking individuals, aged between 18 and 50 years, male and female. In the current study, the age cutoff values (18–50 years) were chosen to study 24-hour IOP patterns because there is an increased incidence of OAG in young myopic patients and because myopia can be induced by lenticular and/or anterior chamber depth change associated with aging.20 Regardless of baseline IOP level, all OAG patients had optic nerves that appeared to be glaucomatous based on diffuse or focal neural rim thinning, disc hemorrhage, enlarged vertical cupping greater than 0.7, vertical cupping asymmetry greater than 0.2, or nerve fiber layer defects indicative of glaucoma, in addition to corresponding loss of VF on repeated exams; best-corrected visual acuity greater than 20/40; and normal anterior segment, anterior chamber, and open-angle based on slit-lamp and gonioscopic examination. Eligible OAG patients were consecutively divided into two groups based on refractive error (RE) and A/L. The myopia group had RE based on spherical equivalent (SE) less than or equal to −3.00 diopters (D) in both eyes (moderate to severe myopic error) in addition to A/L > 24 mm. The control group had RE greater than −3 D based on SE in both eyes (emmetropia [−0.75 to 0.75 D] to low myopia [−0.76 to −2.99 D]) and A/L ≤ 24 mm. These cutoff values for moderate to severe myopia and emmetropia were based on a previous study on the relationship between IOP and myopia.21 Refraction was determined by the noncycloplegic method with a subjective trial of lenses.

Patients were excluded if they had one or more of the following: severe myopic disc and fundus changes impairing adequate optic nerve/VF evaluation for glaucoma; evidence of intracranial or otolaryngological lesion; history of massive hemorrhage or hemodynamic crisis; previous or current use of antiglaucoma medications or systemic or topical steroids; presence of any other ophthalmic disease that could result in optic nerve and VF defects; and/or a history of diabetes mellitus. Individuals who smoked or had an irregular daily sleep schedule were also excluded. Finally, patients who had previous ocular laser procedures or surgeries including KRS or had corneal abnormalities that prevented reliable IOP measurements were also excluded.

Central corneal thickness (CCT) was measured three times by ultrasonic pachymetry (DGH-550; DGH Technology Inc., Exton, PA, USA) at the initial visit, and an average was calculated. A/L was measured using an optical biometer (IOLMaster; Carl Zeiss Meditec, Dublin, CA, USA) at the initial visit. All procedures conformed to the tenets of the Declaration of Helsinki, and the study was approved by the Institutional Review Board of the Asan Medical Center at the University of Ulsan, Seoul, Korea. All patients provided informed consent.

**Visual Field Examination**

VF examinations were performed with the 24-2 Swedish Interactive Threshold Algorithm (SITA) standard program on the Humphrey field analyzer (HFA; Carl Zeiss Meditec). Eyes with glaucomatous VF defects had at least two of the following characteristics in the second repeat VF examination following a first glaucomatous VF reading to minimize the learning effect: (1) a cluster of three points with a probability of less than 5% on a pattern deviation map in at least one hemisphere; (2) at least one point with a probability of less than 1%; or a cluster of two points with a probability of less than 1%; (2) glaucoma hemifield test (GHT) results outside 99% of the age-specific normal limits; and (3) pattern standard deviation (PSD) outside 95% of the normal limit. We only included patients who had reliable VF measurements within 1 month of the initial VF evaluation, defined as a false-positive error of less than 15%, false-negative error of less than 15%, and a fixation loss of less than 20%.

**Measurement of In-Hospital IOP Over 24 Hours**

All IOP measurements were performed by a single, well-trained ophthalmology resident (DWJ). First, a separate pilot study to test the accuracy of the handheld tonometer (TonoPenXL; Mentor Ophthalmics, Santa Barbara, CA, USA) against Goldmann applanation tonometry (GAT) was performed by DWJ, in which we compared the TonoPenXL and GAT readings by performing a cross-sectional study of 52 consecutive patients (104 eyes) with glaucoma or suspected glaucoma. The results indicated an excellent correlation between IOP readings obtained by the TonoPenXL and GAT (r = 0.93, P < 0.001). The difference between GAT and the TonoPenXL readings was less than 2 mm Hg in 95% of the measurements.

All eligible patients in our main study were instructed to abstain from alcohol and caffeine for 3 days prior to hospital admission. The length and times of diurnal/nocturnal periods at home may have differed among enrolled patients. All measurements of IOP were obtained with the TonoPenXL at 8 AM, 10 AM, 12 PM, 2 PM, 4 PM, 6 PM, 8 PM, and 10 PM (diurnal IOP), and at 12 AM, 3 AM, and 6 AM (nocturnal IOP) in both eyes of each patient. One or two drops of 0.5% proparacaine were instilled as topical anesthetic before each IOP measurement at various time points. Three measurements were taken for each measurement, and the average value was used for analysis in both sitting and supine positions. Subjects were instructed to continue normal indoor activities during the diurnal period, and diurnal IOP was measured when patients were seated. During the nocturnal period, lights in individual rooms were turned off by the nurse at 10 PM, and patients were instructed to sleep with their head at the same level as their body. Subjects were awakened (if necessary) and IOP measurements were taken with the TonoPenXL under dim light, with patients in the supine position (because activation of the sympathetic nervous system by changing body position at night could be nonphysiological). Following a 10-minute resting period in the upright position, nocturnal IOP was measured while the patient was seated. IOP obtained with the TonoPen XL was used in the data analysis without correction for CCT.

**Statistical Analysis**

Our previous study showed that emmetropic OAG eyes had an average nocturnal IOP elevation of approximately 2.0 mm Hg with an SD of 1.75 mm Hg in the supine position. Therefore, assuming that myopic OAG eyes show no nocturnal IOP elevation compared with the emmetropic control group, a sample size calculation was performed to acquire 80% power to detect differences in nocturnal IOP changes between the two groups of greater than 1.0 mm Hg by controlling the probability of a type I error at 0.05 in a two-tailed test. A
sample size of at least 49 subjects or greater was needed to meet these conditions with a SD of 1.75 mm Hg.

We measured the IOP of both eyes in all enrolled OAG patients. If both eyes were eligible for the study, the left eye was arbitrarily selected for analysis. First, habitual-position mean IOP measurements obtained at different time points for each group were compared using paired t-tests. Various habitual-position IOP parameters, separated by different time periods (diurnal versus nocturnal), were compared between the two groups using unpaired t-tests. Two IOP calculations following the body posture change were made. These included short-term posture-induced changes (supine to sitting) in mean IOP at 10 minutes during nighttime and long-term habitual-position induced changes (sitting to supine) in mean IOP during 24 hours. Measurements in mean peak (diurnal and nocturnal), trough (24-hour), and peak minus trough (24-hour) IOP in the habitual position were compared between the two groups using unpaired t-tests. As our study was exploratory and observational in nature, differences were considered statistically significant at \( P < 0.05 \) when two means were compared at multiple testing. We also determined the 24-hour mean IOP flow and frequency of peak IOP times for seated and habitual-position IOP measurements in each group.

A cosinor model has been used to describe the pattern of 24-hour habitual-position IOP and the acrophase recording; this model has been proven useful for fitting symmetric and stationary rhythmic patterns such as in 24-hour IOP behavior. Briefly, the cosinor model uses sine and cosine terms to describe a diurnal variation and is expressed as \( Y(t) = b_0 + b_1 \times \cos(2\pi t/24) + b_2 \times \sin(2\pi t/24) \times t \), where \( y \) is the observed IOP at time \( t \) after the IOP measurement is initiated, and \( b_0, b_1, \) and \( b_2 \) are regression coefficients. The constant \( (2\pi/24) \) and the coefficient \( b_0 \) represent the 24-hour periodicity of IOP and the 24-hour rhythm-adjusted mean IOP, respectively. Thus, the amplitude \( (A) \) that represents half of the extent of rhythmic change in a cycle can be given as \( A = \sqrt{b_1^2 + b_2^2} \). The 24-hour pattern was analyzed using this cosinor model for all patients in each group. Individual analysis was also performed and classified based on the acrophase in each group. The distributions of the different acrophases were compared between the two groups using the \( \chi^2 \) test.

Two surrogate parameters were calculated to represent nocturnal habitual IOP elevation from the following formula: (1) nighttime supine average IOP minus daytime sitting average IOP (nocturnal habitual IOP elevation); (2) nighttime supine peak IOP minus daytime sitting trough IOP (range of 24-hour IOP fluctuation). The correlations between A/L and nocturnal habitual IOP elevation and range of 24-hour IOP fluctuation were analyzed by linear regression. All statistical tests were performed using statistical software (SPSS 15.0 for Windows; SPSS, Inc., Chicago, IL, USA). The criterion for statistical significance was \( P < 0.05 \).

**Results**

A total of 175 eyes of 175 patients with OAG that met the inclusion criteria were analyzed in this prospective study. Of these, 108 myopic OAG patients were enrolled in the myopia group. Among the 108 myopia subjects, 52 were men, 56 were women, and all were native Koreans. The remaining 67 OAG patients (35 men and 32 women) composed the control group. Demographic and clinical characteristics of both groups are summarized in Table 1.

With respect to nocturnal IOP changes, mean habitual-position IOP during sleeping hours was significantly higher...
Table 2. Comparison of Mean Habitual-Position IOP at Different Times in Each Group

<table>
<thead>
<tr>
<th></th>
<th>Daytime</th>
<th>Nighttime</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia</td>
<td>14.94 ± 2.27</td>
<td>14.98 ± 2.40</td>
<td>0.454</td>
</tr>
<tr>
<td>Control</td>
<td>14.18 ± 2.38</td>
<td>15.62 ± 2.40</td>
<td>&lt;0.001*</td>
</tr>
</tbody>
</table>

Measured by handheld tonometer. * Statistically significant.

than that of waking hours in the control group (P < 0.001; Table 2); in contrast, no such difference was found in the myopia group (P = 0.454; Table 2). In intergroup comparison, mean habitual-position IOP in the myopia group was significantly higher than that of the control group during waking hours (P < 0.05; Table 3). However, mean habitual-position IOP in the myopia group was lower than that of the control group during sleeping hours, although this difference did not reach statistical significance (P = 0.087; Table 3). Both short- and long-term posture-induced IOP changes were significantly greater in the control group than in the myopia group (P < 0.01 and P < 0.01, respectively; Table 4).

The myopia group showed a significantly higher peak IOP during waking hours than the control group (P = 0.037). However, the control group showed a significantly higher peak IOP during sleeping hours (P = 0.031) and lower trough IOP during the 24-hour period than the myopia group (P = 0.046). Therefore, the range of 24-hour IOP fluctuation (peak minus trough) was higher in the control group than in the myopia group, although the difference did not reach statistical significance (Table 5).

In the myopia group, peak habitual-position IOP values and the highest frequency of IOP peaks occurred during waking to early morning hours (6–10 AM; Figs. 1A, 1B). By contrast, in the control group, peak habitual-position IOP values and the highest frequency of IOP peaks occurred during sleeping hours (3–6 AM; Figs. 1A, 1B). In the sitting position, both groups showed peak IOP values and highest frequency of IOP peaks during morning hours (8 AM–12PM; Figs. 1A, 1B).

An analysis of the entire myopia group based on the cosinor model showed no evident peak (acrophase) in habitual-position IOP measurements during the 24-hour period (Fig. 2A). However, further analysis of individual patients indicated that 44 patients (41%) had a diurnal acrophase (Fig. 2B), 17 patients (15%) had a nocturnal acrophase (Fig. 2C), and 47 patients (44%) had no evident acrophase (Fig. 2D). When analyzing the entire control group, a nocturnal peak (acrophase) of habitual-position IOP was found at approximately 3 to 6 AM (Fig. 3A); while in an analysis of individual patients, 14 patients (21%) had a diurnal acrophase (Fig. 3B), 30 patients (45%) had a nocturnal acrophase (Fig. 3C), and 23 patients (34%) had no evident acrophase (Fig. 3D). Therefore, significant differences were noted in the distribution of diurnal and nocturnal acrophases between the two groups (P < 0.05, χ² test; Table 6).

The relationship between nocturnal habitual-position IOP change and A/L as well as the relationship between the range of 24-hour IOP fluctuation and A/L are shown in Figures 4A and 4B, respectively. Statistically significant correlations were found between these two parameters and A/L measured in the same eye using Pearson’s correlation analysis.

### Discussion

In the current study, there was a statistically significant nocturnal elevation in habitual-position IOP in the control group. By contrast, no such nocturnal elevation in IOP was seen in the myopia group. There are multiple explanations for our finding. Recent studies using spectral-domain optical coherence tomography (SD-OCT) showed that increased choroidal thinning is associated with higher severity of myopia.23–25 Therefore, choroidal thinning, which is associated with the myopia group, may weaken the impact on choroidal vascular volume change and lowers the IOP elevation resulting from a change in posture.

In the control group, since choroidal expansion following posture change may equilibrate over time, choroidal volume change may not entirely explain nocturnal IOP elevation, which was observed after many minutes and hours following posture change in our study. Therefore, nocturnal IOP elevation is affected in a complex manner by multiple factors including axial length, state of choroidal equilibrium, episcleral venous pressure (EVP), baseline IOP level, angle anatomy, uveoscleral outflow, and CCT.

Postural changes can simultaneously induce an elevation in EVP and consequently affect IOP measurements taken during the night in patients in the recumbent position. Although how EVP responds differently to postural changes between the myopia and control group remains unclear, a speculation can be made. Myopia is structurally characterized by reduction of collagen fiber bundles and the size of individual collagen fibrils within the sclera as well as thinning of sclera, resulting in low scleral rigidity.26,27 This low scleral rigidity may result in more extensible intrascleral and episcleral venous system in the myopic eyes, leading to less EVP elevation with increased aqueous outflow compared to emmetropic eyes during posture change.

Another mechanism is that conventional outflow pathway is driven by a pressure gradient across the tissue between

Table 4. Comparison of Short- and Long-Term Mean Habitual-Position IOP Change Between the Two Groups

<table>
<thead>
<tr>
<th></th>
<th>Myopia</th>
<th>Control</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night supine minus night-sitting IOP</td>
<td>0.88 ± 1.11</td>
<td>2.26 ± 1.11</td>
<td>&lt;0.01*</td>
</tr>
<tr>
<td>Night supine minus day-sitting IOP</td>
<td>0.04 ± 1.77</td>
<td>1.44 ± 1.71</td>
<td>&lt;0.01*</td>
</tr>
</tbody>
</table>

Measured by handheld tonometer. * Statistically significant.

Table 5. Comparison of Mean Peak (day, night), Trough (24 hours), and Peak Trough (24 hours) IOP in the Habitual Position

<table>
<thead>
<tr>
<th></th>
<th>Myopia</th>
<th>Control</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak sitting, day</td>
<td>17.33 ± 2.60</td>
<td>16.43 ± 2.99</td>
<td>0.037*</td>
</tr>
<tr>
<td>Peak supine, night</td>
<td>16.25 ± 2.74</td>
<td>17.16 ± 2.65</td>
<td>0.031*</td>
</tr>
<tr>
<td>Trough sitting, 24 h</td>
<td>12.06 ± 2.26</td>
<td>11.40 ± 1.86</td>
<td>0.046*</td>
</tr>
<tr>
<td>Peak minus trough, 24 h</td>
<td>5.27 ± 1.65</td>
<td>5.76 ± 2.00</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Measured by handheld tonometer. * Statistically significant.
inside the eye and EVP. In our study, myopic eyes have higher mean baseline IOP than that of emmetropic eyes, although the difference is within 1.0 mm Hg. Therefore, conventional aqueous outflow may be higher in the myopia group with higher baseline IOPs, particularly during IOP elevation period at nighttime, than the control group, resulting in less elevation of nocturnal IOP. Further, greater anterior chamber angle width associated with the myopia group may also facilitate aqueous outflow through conventional and uveoscleral pathway despite EVP rise in the recumbent position.

Sit et al.,\textsuperscript{28} who measured diurnal and nocturnal aqueous humor flow rate, IOP, and outflow facility in young adults with moderate myopia, suggested that nocturnal IOP pattern could be explained by changes in EVP and/or uveoscleral outflow. In the current study, smaller choroidal volume expansion following posture change at nighttime in the myopia group may lead to less compactness of the ciliary body intercellular space than that of emmetropic group, resulting in greater uveoscleral aqueous outflow. In addition, hand-held tonometer readings can be influenced by corneal biomechanical properties including CCT that may change over 24 hours.\textsuperscript{29,30} Kida et al.\textsuperscript{31} showed that CCT was thicker, and IOP was higher during the nocturnal period than during the diurnal period. Despite similar baseline pachymetry values, 24-hour variations in CCT may partially play a role in giving different IOP readings at night between groups. Future aqueous humor dynamic studies are needed to confirm our speculations.

Our data showed that the mean IOP of the myopia group was significantly higher than that of the control group at a sitting position during the daytime similar to young myopic adults without glaucoma.\textsuperscript{15–19} Of interest, in the recumbent position, mean nocturnal IOP of the myopia group was actually lower than that of the control group. Therefore, our results suggest that regardless of the presence of glaucoma, axial myopia may result in blunting of nocturnal IOP elevation in young adults, thereby making supine IOP in myopic patients lower than that of age-matched, emmetropic adults at nighttime. As a result, posture-induced changes in mean IOP were significantly greater in the control group than in the myopia group during the 24-hour study period as well as at 10 minutes after posture change at night.

In intergroup comparison, the 24-hour peak IOP of the control group was significantly higher than that of the myopia group, while the 24-hour trough IOP of the control group was significantly lower than that of the myopia group. This resulted in a greater mean 24-hour habitual-position IOP fluctuation in the control group than in the myopia group.

Considering the 24-hour habitual-position IOP data, the peak IOP time (acrophase) and the most frequent peak IOP time were different between the two groups. In the control group, we observed a peak IOP and the most frequent peak
FIGURE 2. Average 24-hour rhythms of habitual-position IOP in all patients (A) and in three subgroups of patients (B-D) based on the cosinor model (mean ± SE) in the myopia group.

FIGURE 3. Average 24-hour rhythms of habitual-position IOP in all patients (A) and in three subgroups of patients (B-D) based on the Cosinor model (mean ± SE) in the control group.
IOP time toward the end of the sleep period (3–6 AM). The magnitude of the nocturnal IOP peak in the control group was similar to that reported previously in NTG eyes with similar RE. By contrast, in the myopia group, peak IOP time and the most frequent peak IOP time were noted during early morning hours (6–10 AM). Although the physiological mechanism responsible for the different acrophases found between groups is unclear, it may be in part related to differences in ocular sizes between groups, which may affect the nocturnal habitual-position IOP elevation as noted in the current study.

There is limited data on the daily pattern of IOP in glaucoma subjects, including OAG subjects with myopia. Using the cosinor model to describe the pattern of IOP over 24 h, no acrophase in IOP was found in an analysis of the entire myopic OAG population. However, in individual analysis, we identified three major habitual-position IOP patterns among the 108 myopic patients: diurnal acrophase (41%), nocturnal acrophase (15%), and no identifiable acrophase (44%). By contrast, three significantly different acrophase patterns were found in the control group compared to the myopia group, which are in agreement with our previous report. The important clinical implications of our current study include that 24-hour IOP patterns and the amplitude of 24-hour IOP peak among different types of OAG can potentially influence the selection

![Figure 4](iovst.org)
of optimal dosing and choice of medical therapy based on individualized 24-hour IOP patterns and amplitude.

Previously, using linear regression, Liu et al.14 found a positive correlation between the refractive state based on SE and habitual elevations in IOP during sleep hours in young healthy patients without glaucoma. This was supported by a more recent study by Sakata et al.12 in which the authors showed a positive correlation between refractive power and peak habitual-position IOP occurring at nighttime. However, these studies differed from our study by the relatively smaller sample size (n = 36 and 33, respectively, versus n = 175 in this study), healthy patient population (young healthy eyes by Liu et al.14 versus OAG eyes in this study), and older age group (mean age = 50.3 years by Sakata et al.12 versus 32.2 years in this study).

In our analysis of OAG eyes with a wide range of A/L (22–32 mm), we found that the elevation in habitual-position IOP at nighttime correlated negatively with A/L (Figs. 4A, 4B). In other words, eyes with a longer A/L had smaller nocturnal IOP increases (mean nocturnal supine IOP minus mean diurnal sitting IOP) as well as a smaller range of 24-hour IOP fluctuations (peak nocturnal supine IOP minus trough diurnal sitting IOP). In line with our findings, a study on patients without glaucoma showed that high myopes had significantly less daytime postural differences in IOP than low myopes.32

Our study has a few limitations. First, measurement of habitual-position IOP using a handheld tonometer in the hospital may not provide the best physiological 24-hour ocular tension data from our OAG subjects as our habitual-position IOP measurements were based on a theoretical assumption (sitting during the day and supine at night). Ideally, the use of a continuous implantable IOP sensor at home in the habitual body position may provide the most ideal measure of physiological IOP. Second, our observations are based on IOP data collected in relatively young OAG subjects in both the myopia and control groups. Therefore, caution should be exercised in extending these conclusions to older OAG groups. Older patients may have different anterior segment dimensions with enlarged lens and loose zonules, which could impact aqueous humor dynamics with different aqueous outflow facility than in our two groups.

In conclusion, the present study showed no overall nocturnal mean IOP elevation in a large proportion of young OAG patients with moderate to severe myopia when IOP was measured in patients’ habitual positions. This is in contrast to the control group, which showed significant nocturnal habitual-position IOP elevation. In addition, individual analysis revealed three distinct acrophase patterns among the myopia subjects that differed from those of the control group. The 24-hour IOP range and nocturnal habitual IOP elevation were negatively correlated with A/L in our young OAG cohorts. Further studies are needed to identify ocular factors that can influence the 24-hour IOP pattern, as this may provide clinicians with a better understanding of the mechanisms of glaucoma and aid in determining an optimal individualized IOP-lowering treatment strategy.

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References


