Yogic Pranayama and Diaphragmatic Breathing: Adjunct Therapy for Intraocular Pressure in Patients With Primary Open-angle Glaucoma: A Randomized Controlled Trial

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Purpose: Currently, medical or surgical lowering of intraocular pressure is the only therapeutic approach for treating primary open-angle glaucoma. Intraocular pressure maintenance is influenced by autonomic activity (sympathetic and parasympathetic). “Yogic pranayama” and “diaphragmatic breathing” are exercises that can affect autonomic activity by stimulating a wakeful hypometabolic state of parasympathetic dominance. We aimed to assess the effect of yogic pranayama and diaphragmatic breathing on intraocular pressure to determine whether it can be recommended for individuals with established glaucoma in combination with glaucoma medication as an adjuvant therapy.

Materials and Methods: In this prospective, randomized trial, 90 patients with primary open-angle glaucoma (180 eyes, age: above 40 y) were assigned to either the control or yogic pranayama and diaphragmatic breathing exercise group. In the latter group, yogic pranayama and diaphragmatic breathing were practiced daily for 6 months. We measured the intraocular pressure at presentation and subsequently after 1, 3, and 6 months.

Results: Compared with the wait-list group, the yogic pranayama and diaphragmatic breathing exercise group had significantly lowered intraocular pressure (right eye: 20.85 ± 3.39 to 14.90 ± 2.86 mm Hg; left eye: 20.30 ± 4.12 to 14.25 ± 3.85 mm Hg; P < 0.001).

Conclusion: Yogic pranayama and diaphragmatic breathing exercises can reduce intraocular pressure in patients with primary open-angle glaucoma and can therefore be recommended as an adjuvant therapy.

Key Words: glaucoma, intraocular pressure, yogic breathing exercises, pranayama, diaphragmatic breathing, autonomic nervous system (J Glaucoma 2021;30:115–123)

Glaucoma is the second leading cause of global blindness and the primary cause of irreversible blindness with primary open-angle glaucoma (POAG) being the prevailing type. Since vision loss is often considered to be progressive and irreversible, patients experience continuous anxiety and fear of becoming blind. The biochemical changes associated with stress and the pathogenesis of glaucoma share numerous common features. Mental stress (acute and chronic) is associated with an elevation in intraocular pressure (IOP), a process mediated by cortisol. Glucocorticoids, proinflammatory cytokines, and endothelin-1 are factors that accelerate POAG through impairment of vascular autoregulation and contribution to endothelial dysfunction via decreased nitric oxide (NO) actions. NO is a known regulator of ocular blood flow. Literature shows that a reduction in blood NO is associated with glaucoma. Stress is one of the main causes of sympathetic nervous system activation. In inflammatory conditions, psychological stress is the major provocative factor in the increase of proinflammatory mediators tumor necrosis factor α and interleukin-6 (IL-6). Proinflammatory cytokines tumor necrosis factor α, IL-6, and IL-8 are elevated in glaucoma patients and stress disorders, revealing a connection between proinflammatory mediators, stress, and glaucoma.

Considering the similarities between glaucoma pathogenesis and stress-associated changes, there is a possibility that IOP can be normalized if stress is counteracted by means of relaxation techniques. Among alternative and complementary therapies, yoga is widely used to improve quality of life. Yogic pranayama and diaphragmatic breathing (YPDB) exercises have been known since ancient times and it is one of the most efficient traditional and integrative body-mind training techniques used to calm the body and mind. Anuloma-Viloma pranayama is also called Nadi-Suddhi pranayama and it is the first of the pranayama practices described in the Hatha Yoga Pradipika. Nadi shodhana translates to “nadi purification” and the practice is believed to balance the subtle energy, or prana, of the energetic body. Its practice leads to a reduction in oxidative stress, improvement in autonomic functions, decreased oxygen consumption, increased amplitude of theta waves, a reduction in IL-6 levels, and an increase in brain-derived neurotrophic factor. There are subjective reports of relaxation, and improved well-being and quality of life after yogic breathing exercises due to increased melatonin production. Diaphragmatic breathing or deep breathing has been investigated in association with meditation, ancient Eastern religions (such as Buddhism) and martial arts and it has been considered to be a core component of yoga and Tai Chi Chuan. It may improve sustained attention and decrease cortisol levels. Relaxation techniques have been reported to reduce IOP and improve neuroendocrine regulation of the ciliary body and the production of aqueous humor. It also increases brain and aqueous NO and improves outflow pathways.

With this background knowledge of similarities between glaucoma and stress consequences, a key question arises: Can yogic breathing exercises be used in glaucoma patients? The aim of this study was to determine the effect of yogic pranayama and diaphragmatic breathing exercises on lowering IOP in patients with primary open-angle glaucoma.
of this study was to explore the impact of YPDB on IOP by testing the hypothesis that lowering stress through YPDB can lower IOP and that YPDB can therefore be used as an adjunctive therapy in patients suffering from POAG.

MATERIALS AND METHODS

Study Design

This prospective, single-blinded, randomized, controlled trial was performed in the Department of Ophthalmology, All India Institute of Medical Sciences (AIIMS), Rishikesh, India. The study protocol (Fig. 1) complied with the consolidated standards of reporting trial (CONSORT) and was approved by the institutional ethics committee.

Participants

There is no previous study reported that evaluated the effect of pranayama and diaphragmatic breathing on patients with POAG. A sample size of 90 patients was taken and randomized into 2 groups (group A: control group, glaucoma medication only and group B: treatment group, combination of YPDB exercises and glaucoma medication). Randomization into 2 groups was done by computer-based randomization. The generated random number was transferred to a sealed envelope to conceal the randomization till the actual allocation.

The POAG patients were recruited from our outpatient clinic.

Inclusion/Exclusion Criteria

Patients included in the study were those who had established POAG (moderate/severe POAG according to Hodapp-Parrish-Anderson classification), who were currently on eye drop medication, and who consented for study participation with regular follow-up. Patients were excluded if there was a history of intraocular surgery/laser in previous 3 months, malignancy, systemic diseases (diabetes mellitus, hypertension, thyroid disease, coronary artery disease, and respiratory disease), ocular trauma, angle-closure glaucoma already practicing yoga in any form and/or if they could not avail themselves for regular follow-up. We did not discriminate patients according to the current glaucoma medication or dose.

Study Procedure

The total period of study was 6 months (28 wk). In group B, it comprised 4 weeks of everyday YPDB sessions under the guidance of a trained yoga instructor at AYUSH as per protocol provided by the Department of Physiology, All India Institute of Medical Sciences, Rishikesh and rest 24 weeks (follow-up period) of everyday YPDB sessions at home. No change was done to the standard treatment of any patient. The participants in the YPDB group practiced the session for 30 minutes/day in the morning from 9:00 AM to 10:00 AM for 7 days a week for up to 4 weeks. The regularity and frequency of the participants for practicing the sessions were strictly monitored. After 4 weeks of practice, the patients were instructed to practice the same at home for the next 24 weeks (follow-up period), compliance of which is ensured by repeated and daily telephonic conversation. Diaphragmatic breathing was practiced first followed by Anuloma-Viloma pranayama.

Practicing Procedure for Diaphragmatic Breathing

Diaphragmatic breathing involves contraction of the diaphragm, expansion of belly, and deepening of inhalation and exhalation.

- Patients sat comfortably on the floor.
- Eyes were closed and the whole body was relaxed.
● Patients were asked to place one hand on their chest and another hand on the stomach.
● Patients were asked to breathe in through the nose for about 2 seconds and experience the air moving through nostrils into the abdomen. During this type of breathing, stomach will move outward and chest will remain relatively still.
● In the end, patients were instructed to press their lips and press gently on stomach and exhale slowly for about 2 seconds. These steps were repeated 5 times.

**Practicing Procedure for Pranayama**

The term is derived from Sanskrit, whereby “prāṇa” means a life force that controls all activities in the universe while “ayama” means regulation, which essentially means that pranayama refers to regulated breathing. Nadiṣodhanam (channel purification) is the simplest form of the various pranayama techniques and affects cardiorespiratory and autonomic function by reducing stress by improving sympathetic and parasympathetic tones. “Nadī” means channel or flow of energy and “ṣodhana” means purification. In this the step followed are as follows:

- The patients are asked to sit in any meditative asana.
- Right nostril is closed with the thumb and air was drawn in from the left nostril.
- Now thumb is released and the left nostril is closed with the ring finger. Then breathe out slowly through the right nostril.
- Next, air is taken in from the right nostril and then released through the left nostril.
- These steps are repeated 4 times.

The control group (group A) was continued with medical management.

**Parameter Assessment: IOP, Visual Fields (Mean Deviation), Optical Coherence Tomography (OCT), Average Retinal Nerve Fiber Layer (RNFL)**

The primary outcome was to observe the impact of YPDB on IOP and the secondary outcome was to observe the impact of YPDB on visual fields and average RNFL analysis. Goldmann applanation tonometry was used to measure IOP for all patients and at all follow-ups. In group B, IOP was measured just before the intervention, immediately after intervention and 1 hour after the intervention. After 1 month, IOP was measured on respective follow-up (3 and 6 mo). Each IOP measurement was obtained in the original form and was not corrected by central corneal thickness or pachymetry values to prevent the introduction of further errors in IOP measurements. Visual field (Humphrey SITA standard 30-2) and OCT (average RNFL thickness or pachymetry values) were performed as part of the complete glaucoma assessment. Optic disc was assessed on slit lamp using 90 D lens.

**Statistical Analysis**

It has been estimated that enrollment of 90 participants would yield a power of 90% to determine an absolute between-group difference of 35 percentage points in lowering IOP with a 2-sided α level of 5% while assuming that 10% of the enrolled patients would be lost to follow-up.

All statistical analyses were performed using the Statistical Package for the Social Sciences, version 21.0. Categorical variables were described as proportion and continuous data as mean ± SD or median with interquartile range. Between-group comparisons of proportions and means were performed using χ² test and Student t test, respectively. We performed multiple regression analyses to identify independent outcome variables. Statistical significance was set at a P-value < 0.05.

**RESULTS**

In all, 100 patients with POAG were assessed for eligibility using inclusion/exclusion criteria. Of these, 90 patients were enrolled, randomized into group A (control group—45 patients) and group B (treatment group—45 patients) and followed up for 6 months. During the follow-up time period, 5 patients in group A and 4 patients in group B were lost to follow-up. At the end of 6 months, 40 patients in group A and 41 patients in group B were analyzed.

**Demographics**

There were no significant differences in baseline characteristics between the 2 groups (Table 1).

**IOP (Primary Endpoint)**

In group A, the mean IOP (right eye) (mm Hg) decreased significantly from a maximum of 19.51 at the baseline to a minimum of 15.76 at the 6-month follow-up (Friedman test: χ² = 100.7, P < 0.001). In group B, the mean IOP (right eye) (mm Hg) decreased significantly from a maximum of 20.85 at the baseline to a minimum of 14.90 at the 6-month follow-up (Friedman test: χ² = 105.7, P < 0.001). The overall change in IOP (right eye) (mm Hg) over time was compared in the 2 groups using the generalized estimating equations method. There was a significant difference in the trend of IOP (right eye) (mm Hg) over time in both the groups (P < 0.001) (Table 2). The mean IOP (right eye) (mm Hg) decreased from a maximum of 20.17 at the baseline to a minimum of 17.60 at the immediate post-intervention. This change was statistically significant (Wilcoxon test: V = 820.0, P < 0.001). In group A, the mean IOP (left eye) (mm Hg) decreased significantly from a maximum of 19.32 at the baseline to a minimum of 15.32 at the 6-month follow-up (Friedman test: χ² = 109.3, P < 0.001). In group B, the mean IOP (left eye) (mm Hg) decreased from a maximum of 20.30 at the

| TABLE 1. Clinical Characteristic and Demographic Features of Participants Included in This Trial |
|---------------------------------------------------------------|
| **Mean ± SD** | **YPDB Group** | **Control Group** |
|----------------|----------------|------------------|
| Sample demographics | | |
| Mean age (y) | 57.92 ± 10.18 | 56.95 ± 11.22 |
| No. males | 25 | 25 |
| No. females | 20 | 20 |
| Baseline characteristics | | |
| IOP (OD/OS) (mm Hg) | 20.85 ± 3.39/20.30 ± 4.12 | 19.51 ± 2.64/19.32 ± 2.69 |
| Mean deviation (OD/OS) | −13.93 ± 3.85/−12.86 ± 2.29 | −14.14 ± 3.94/−13.41 ± 3.76 |
| Average RNFL (OD/OS) | 81.35 ± 15.46/78.90 ± 16.57 | 78.10 ± 15.46/78.10 ± 16.07 |
| CDR | 0.67 ± 0.09/0.72 ± 0.10 | 0.70 ± 0.09/0.70 ± 0.10 |

CDR indicates cup disc ratio; IOP, intraocular pressure; OD, right eye; OS, left eye; RNFL, retinal nerve fiber layer; YPDB, yogic pranayama and diaphragmatic breathing.
TABLE 2. Comparison of 2 Groups in Terms of Change in IOP Over Time in the Right and Left Eyes

| Groups | A | B | P-value for Comparison of the 2 Groups at Each of the Timepoints (Wilcoxon Test) |
|--------|---|---|-------------------------------------------------------------|
| IOP (right eye) (mm Hg) | Mean (SD) Median (IQR) | Mean (SD) Median (IQR) | |
| Baseline | 19.51 (2.64) 20.00 (2.00) | 20.85 (3.39) 20.00 (6.00) | 0.047 |
| 1-mo follow-up | 17.46 (2.53) 18.00 (2.00) | 17.15 (3.23) 18.00 (4.00) | 0.965 |
| 3-mo follow-up | 16.73 (2.56) 16.00 (2.00) | 15.55 (3.05) 16.00 (4.00) | 0.175 |
| 6-mo follow-up | 15.76 (2.54) 16.00 (2.00) | 14.90 (2.86) 14.00 (2.00) | 0.113 |
| P-value for change in IOP (right eye) (mm Hg) over time within each group (Friedman test) | < 0.001 | < 0.001 | |
| Overall P-value for comparison of change in IOP (right eye) (mm Hg) over time between the 2 groups (generalized estimating equations method) | | < 0.001 | |
| IOP (left eye) (mm Hg) | Mean (SD) Median (IQR) | Mean (SD) Median (IQR) | |
| Baseline | 19.32 (2.67) 20.00 (2.00) | 20.30 (4.12) 20.00 (4.00) | 0.270 |
| 1-mo follow-up | 17.32 (2.43) 18.00 (2.00) | 16.95 (4.22) 16.00 (6.00) | 0.316 |
| 3-mo follow-up | 16.59 (2.38) 16.00 (2.00) | 15.40 (4.06) 16.00 (6.00) | 0.081 |
| 6-mo follow-up | 15.32 (2.67) 16.00 (2.00) | 14.25 (3.85) 14.00 (8.00) | 0.105 |
| P-value for change in IOP (left eye) (mm Hg) over time within each group (Friedman test) | < 0.001 | < 0.001 | |
| Overall P-value for comparison of change in IOP (left eye) (mm Hg) over time between the 2 groups (generalized estimating equations method) | | < 0.001 | |

Nonparametric tests were used to make statistical inference as data were not normally distributed. Wilcoxon rank-sum test (Mann-Whitney U test) was used to compare the 2 groups in terms of IOP (right and left eyes) (mm Hg) at each of the timepoints (right-most column in the table above). Friedman test was used to explore the change in IOP (right and left eyes) (mm Hg) over time within each group (second-last row in the table above). Generalized estimating equations method was used to explore the difference in change in IOP (right and left eyes) (mm Hg) between the 2 groups over time (last row in the table above).

IOP indicates intraocular pressure; IQR, interquartile range.

Baseline to a minimum of 14.25 at the 6-month follow-up (Friedman test: $\chi^2 = 110.7$, $P < 0.001$). The overall change in IOP (left eye) (mm Hg) over time was compared in the 2 groups using the generalized estimating equations method. There was a significant difference in the trend of IOP (left eye) (mm Hg) over time in both the groups ($P < 0.001$) (Table 2). The mean IOP (left eye) (mm Hg) decreased from a maximum of 19.80 at the baseline to a minimum of 17.35 at the immediate postintervention timepoint (Wilcoxon test: $V = 820.0$, $P < 0.001$). Within-group comparisons showed a significant decrease (all $P < 0.01$) in the mean IOP after 6 months in the YPDB exercise group alone. Specifically, 40 (89%) participants who completed the YPDB exercises showed a > 28% IOP reduction (Table 3).

Humphrey Visual Field Analysis (VFA) SITA STD 30-2 (Mean Deviation)

It was performed at baseline, 3-month follow-up and 6-month follow-up. There were no significant changes in VFA in either group (Tables 4, 5).

Baseline

In group A, 41.5% of the participants had normal VFA and 58.5% of the participants had abnormal VFA in right eye. In group B, 47.5% of the participants had normal VFA and 52.5% of the participants had abnormal VFA in the right eye. There was no significant difference between the various groups in terms of distribution of VFA (right eye) (baseline) ($\chi^2 = 0.299$, $P = 0.585$) (Table 4A). In group A, 29.3% of the participants had normal VFA and 70.7% of the participants had abnormal VFA in left eye. In group B, 37.5% of the participants had normal VFA and 62.5% of the participants had abnormal VFA in the left eye. There was no significant difference between the various groups in terms of distribution of VFA (left eye) (baseline) ($\chi^2 = 0.617$, $P = 0.432$) (Table 5A).

Three-Month follow-up

In group A, 41.5% of the participants had normal VFA and 58.5% of the participants had abnormal VFA in the right eye. In group B, 47.5% of the participants had normal VFA and 52.5% of the participants had abnormal VFA in the right eye. There was no significant difference between the various groups in terms of distribution of VFA (right eye) (3-month follow-up) ($\chi^2 = 0.299$, $P = 0.585$) (Table 4B). In group A, 36.6% of the participants had normal VFA and 63.4% of the participants had abnormal VFA in the left eye. In group B, 37.5% of the participants had normal VFA and 62.5% of the participants had abnormal VFA in the left eye. There was no significant difference between the various groups in terms of distribution of VFA (left eye) (3-mo follow-up) ($\chi^2 = 0.007$, $P = 0.932$) (Table 5B).

Six-Month Follow-up

In group A, 41.5% of the participants had normal VFA and 58.5% of the participants had abnormal VFA in the
# TABLE 3. Mean Change in IOP (mmHg) From Baseline to the Various Follow-up Timepoints

| Timepoint Comparison | Group: A (Control Group) | Group: B (YPDB Group) | P-value of Absolute Change | P-value of % Change |
|----------------------|---------------------------|------------------------|----------------------------|---------------------|
| Absolute Change [Mean (SD)] | % Change [Mean (SD)] | P-value of Change Within Group | Absolute Change [Mean (SD)] | % Change [Mean (SD)] | P-value of Change Within Group | P-value of Absolute Change | P-value of % Change |
| 1-mo follow-up—baseline | -2.05 (0.71) | -10.6% (3.5) | <0.001 | -3.70 (1.47) | -17.9% (7.1) | <0.001 | <0.001 | <0.001 |
| 3-mo follow-up—baseline | -2.78 (1.33) | -14.2% (6.3) | <0.001 | -5.30 (1.47) | -25.6% (7.0) | <0.001 | <0.001 | <0.001 |
| 6-mo follow-up—baseline | -3.76 (1.02) | -19.4% (5.2) | <0.001 | -5.95 (1.66) | -28.6% (6.8) | <0.001 | <0.001 | <0.001 |

Change in IOP (left eye) (mm Hg) from baseline to follow-up timepoints

| Timepoint comparison | Group: A (control group) | Group: B (YPDB group) | P-value of Absolute change | P-value of % change |
|----------------------|---------------------------|------------------------|----------------------------|---------------------|
| Absolute change [mean (SD)] | % change [mean (SD)] | P-value of change within group | Absolute change [mean (SD)] | % change [mean (SD)] | P-value of change within group | P-value of absolute change | P-value of % change |
| 1-mo follow-up—baseline | -2.00 (0.77) | -10.3% (3.8) | <0.001 | -3.35 (1.23) | -17.0% (7.0) | <0.001 | <0.001 | <0.001 |
| 3-mo follow-up—baseline | -2.73 (0.98) | -14.1% (4.4) | <0.001 | -4.90 (1.43) | -24.8% (7.7) | <0.001 | <0.001 | <0.001 |
| 6-mo follow-up—baseline | -4.00 (1.00) | -21.0% (5.6) | <0.001 | -6.05 (1.47) | -30.4% (7.6) | <0.001 | <0.001 | <0.001 |

The table summarizes the mean change in IOP (right and left eyes) (mm Hg) from the baseline timepoint to the various follow-up timepoints. It also summarizes the statistical comparison of the 2 groups in terms of this difference.

Post hoc pairwise tests for Friedman test performed using Nemenyi test were used to explore the statistical significance of the change in IOP (right and left eyes) (mm Hg) from the baseline timepoint to the various follow-up timepoints. Group comparisons for change in IOP (right and left eyes) (mm Hg) performed using Wilcoxon test.

Shading denotes statistically significant difference at $P<0.05$.

IOP indicates intraocular pressure; YPDB, yogic pranayama and diaphragmatic breathing.
right eye. In group B, 47.5% of the participants had normal VFA and 52.5% of the participants had abnormal VFA in the right eye. There was no significant difference between the various groups in terms of distribution of VFA (right eye) (6-mo follow-up) ($\chi^2 = 0.299, P = 0.585$) (Table 5C). In group A, 36.6% of the participants had normal VFA and 63.4% of the participants had abnormal VFA in the left eye. In group B, 37.5% of the participants had normal VFA and 62.5% of the participants had abnormal VFA in the left eye. There was no significant difference between the various groups in terms of distribution of VFA (left eye) (6-mo follow-up) ($\chi^2 = 0.007, P = 0.932$) (Table 5C).

**OCT (Average RNFL Analysis)**

There were no significant changes in OCT in either group (Table 6).

**Adverse/Events**

There were no adverse events such as worsening of IOP or any physical discomfort during the observation period.

**DISCUSSION**

Glaucoma is the leading cause of severe visual compromise, cognitive decline, compromised quality of life, and ensuing stress and anxiety globally. We aimed to disrupt the connection between glaucoma and stress by using YPDB techniques. The result of our study suggests that regular practice of YPDB might reduce IOP in patients with POAG. However, there were no significant changes in the results of visual field and RNFL analyses in either group.

To our knowledge, there has been no study on the effect of YPDB on patients with POAG; however, some studies have reported the effect of yoga-based ocular exercises on IOP.16-18 In 2018, Sankalp and colleagues hypothesized that “Tratak Kriya,” a yoga-based intervention involving ocular exercises, could lower IOP in patients with glaucoma. They suggested that the exercises induce ciliary muscle contraction and relaxation, which may increase aqueous humor outflow. Moreover, they suggested that this yoga-based intervention may decrease stress and improve the quality of life in patients with glaucoma.16 Gupta and Aparna17 have analyzed the effect of yoga ocular exercises (palming, blinking, sideways viewing, front and sideways viewing, diagonal viewing, rotational viewing, nose-tip gazing, near and distant viewing, concentrated gazing, and acupressure point on the palm) on IOP in 2019. They found that yoga ocular exercises induced a significant reduction in IOP. In 2017, Dimitrova and Trenceva18 have conducted a pilot study on 23 individuals to study the effects of yoga ocular exercises (slow and continuous movement and stretching of the bulbomotor muscle in maximal horizontal, vertical, and right and left side circular movement of the eyeball) on IOP and reported a significant decrease in IOP among individuals who performed yoga ocular exercises.瑜伽-based interventions including yogic breathing have shown promising results in many diseases such as asthma.

### Table 4. Association Between Groups and Visual Field Analysis (Right Eye) at Follow-up Timepoints

| Visual Field Analysis (Right Eye) | A [n (%)] | B [n (%)] | Total [n (%)] | $\chi^2$ | P |
|----------------------------------|----------|----------|---------------|--------|---|
| (A) Association between group and visual field analysis (right eye) (baseline) | | | | | |
| Normal | 17 (41.5) | 19 (47.5) | 36 (44.4) | 0.299 | 0.585 |
| Abnormal | 24 (58.5) | 21 (52.5) | 45 (55.6) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |
| (B) Association between group and visual field analysis (right eye) (3-mo follow-up) | | | | | |
| Normal | 17 (41.5) | 19 (47.5) | 36 (44.4) | 0.299 | 0.585 |
| Abnormal | 24 (58.5) | 21 (52.5) | 45 (55.6) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |
| (C) Association between group and visual field analysis (right eye) (6-mo follow-up) | | | | | |
| Normal | 17 (41.5) | 19 (47.5) | 36 (44.4) | 0.299 | 0.585 |
| Abnormal | 24 (58.5) | 21 (52.5) | 45 (55.6) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |

### Table 5. Association Between Group and Visual Field Analysis (Left Eye) at Follow-up Timepoints

| Visual Field Analysis (Left Eye) | A [n (%)] | B [n (%)] | Total [n (%)] | $\chi^2$ | P |
|----------------------------------|----------|----------|---------------|--------|---|
| (A) Association between group and visual field analysis (left eye) (baseline) | | | | | |
| Normal | 12 (29.3) | 15 (37.5) | 27 (33.3) | 0.617 | 0.432 |
| Abnormal | 29 (70.7) | 25 (62.5) | 54 (66.7) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |
| (B) Association between group and visual field analysis (left eye) (3-mo follow-up) | | | | | |
| Normal | 15 (36.6) | 15 (37.5) | 30 (37.0) | 0.007 | 0.932 |
| Abnormal | 26 (63.4) | 25 (62.5) | 51 (63.0) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |
| (C) Association between group and visual field analysis (left eye) (6-mo follow-up) | | | | | |
| Normal | 15 (36.6) | 15 (37.5) | 30 (37.0) | 0.007 | 0.932 |
| Abnormal | 26 (63.4) | 25 (62.5) | 51 (63.0) | | |
| Total | 41 (100.0) | 40 (100.0) | 81 (100.0) | | |
hypertension, diabetes, obesity, and aging. Singh et al19 have shown that breathing from one nostril Stimulates the cognitive autonomic function of the contralateral cerebral hemisphere and breathing from both nostrils alternately brings about a balance in the functioning of both cerebral hemispheres.

No literature on the effects of YPDB on IOP exists. Thus, the only possible mechanisms of YPDB that may be involved in decreasing IOP can be discussed. The only modifiable risk factor for POAG is IOP. At present, available treatment options for glaucoma are aimed at lowering IOP through pharmacological or surgical means. Parasympathomimetic drugs reduce IOP and its effect is mediated through the contraction of the ciliary muscle. Beta adrenergic antagonists block the activity of the ciliary muscle contraction. This could facilitate stretching of the trabecular meshwork to wide open an angle of the anterior chamber, resulting in free drainage of aqueous humor and subsequently a fall in IOP. In a calm state of mind, sympathetic activity is reduced. This reduced sympathetic activity may also lead to a reduction in aqueous humor secretion. Thus, it appears that through various interrelated and integrated mechanisms, YPDB exerts an influence on aqueous humor regulation. To establish the exact effects of these YPDB techniques would require sophisticated instruments, which was a limitation of our study.

In 2002, a research group in Stockholm reported that NO is formed in the nasal sinuses. These sinuses are in contact with the nostrils through small openings. Upon inhalation, NO flows from the air into the lungs. As NO acts as a dilator, the blood vessels that come in contact with the pulmonary vesicles expand. Consequently, a greater amount of blood that passes through the vessels can be oxidized. Closing the nose with the fingers and holding one’s breath creates a slight upward pressure in the nose and increases the air supply to the sinuses where NO is generated. Thus, it appears that pranayama increases the level of endogenous

\[ \text{TABLE 6. Change in Average RNFL Over Time in Group A and Group B} \]

| Groups          | A (Control Group) | B (YPDB Group) | P-value for Comparison of the 2 Groups at Each of the Timepoints (t Test) |
|-----------------|-------------------|----------------|-------------------------------------------------------------------------|
|                 | Mean (SD) | Median (IQR) | Mean (SD) | Median (IQR)  |                                                             |
| Average RNFL (right eye) (µm) |            |            |           |           |                                                             |
| Baseline        | 75.71 (16.83) | 80.00 (28.00) | 81.35 (15.46) | 83.50 (18.50) | 0.120                                                      |
| 1-mo follow-up  | 75.12 (16.85) | 78.00 (28.00) | 80.90 (15.56) | 82.50 (23.00) | 0.113                                                      |
| 3-mo follow-up  | 75.27 (16.72) | 78.00 (28.00) | 80.83 (15.83) | 82.00 (23.00) | 0.128                                                      |
| 6-mo follow-up  | 75.22 (16.73) | 78.00 (28.00) | 81.20 (15.50) | 82.50 (23.00) | 0.099                                                      |
| P-value for change in average RNFL (right eye) (µm) over time within each group (repeated measures ANOVA) | 1.000 | 0.998 |
| Overall P-value for comparison of change in average RNFL (right eye) (µm) over time between the 2 groups (2-way repeated measures ANOVA method) | 0.894 |
| Average RNFL (left eye) (µm) |            |            |           |           |                                                             |
| Baseline        | 80.10 (14.80) | 84.00 (20.00) | 78.90 (16.57) | 81.00 (21.00) | 0.733                                                      |
| 1-mo follow-up  | 79.90 (14.89) | 82.00 (20.00) | 77.97 (16.23) | 80.00 (18.50) | 0.579                                                      |
| 3-mo follow-up  | 80.02 (15.01) | 83.00 (20.00) | 78.35 (16.21) | 80.50 (18.25) | 0.631                                                      |
| 6-mo follow-up  | 79.85 (14.87) | 82.00 (20.00) | 78.47 (16.04) | 80.50 (18.25) | 0.690                                                      |
| P-value for change in average RNFL (left eye) (µm) over time within each group (repeated measures ANOVA) | 1.000 | 0.994 |
| Overall P-value for comparison of change in average RNFL (left eye) (µm) over time between the 2 groups (2-way repeated measures ANOVA method) | 0.690 |

The table shows comparison of the 2 groups in terms of change in average RNFL (right and left eyes) (µm) over time. Parametric tests were used to make statistical inference as data were normally distributed. Student t test was used to compare the 2 groups in terms of average RNFL (right and left eyes) (µm) at each of the timepoints (right-most column in the table above). Repeated measures ANOVA was used to explore the change in average RNFL (right and left eyes) (µm) over time within each group (second-last row in the table above). Two-way repeated measures ANOVA method was used to explore the difference in change in average RNFL (right and left eyes) (µm) between the 2 groups over time (last row in the table above).

ANOVA indicates analysis of variance; IQR, interquartile range; RNFL, retinal nerve fiber layer; YPDB, yogic pranayama and diaphragmatic breathing.
NO, which relaxes blood vessels and increases oxygen and blood flow. This endogenous NO can lower IOP by relaxing the juxtacanalicular cells increasing pressure-dependent outflow.23

An increase in oxidative stress plays a key role in glaucoma pathogenesis by causing mitochondrial damage and apoptosis in the trabecular meshwork as well as retinal ganglion cell loss.24 YPDB can cause a reduction in oxidative stress by increasing superoxide dismutase and decreasing the number of free radicals. In 2018, Dada et al4 documented the role of short-term meditation practice in decreasing oxidative stress and increasing total antioxidant capacity in patients with POAG.

POAG has been associated with psychological stress, anxiety, and poor quality of life. Cortisol, one of the reliable markers of stress, has been found to increase in patients with ocular hypertension and glaucoma.25 In 2018, Dada et al4 provided a confirmatory evidence of an association between stress and glaucomatous neurodegeneration, indicating that stress is a major causal factor of IOP elevation. Moreover, they reported that stress reduction through relaxation techniques not only normalizes IOP but also improves stress biomarkers, gene expression changes, and quality of life. They assigned 90 patients with POAG to a control or mindfulness meditation group for a period of 4 weeks and found that 75% of patients had >25% IOP reduction. The present study was also conducted on 90 patients with POAG. Patients were divided into a control or a YPDB group. A noteworthy difference between the 2 studies is that in this YPDB techniques were used as a mode of relaxation as opposed to meditation. A longer study period of 6 months was also used to observe long-term effects. What YPDB and meditation have in common is that they counteract stress through relaxation. At the end of this study there was >25% IOP reduction in the right eye and >30% IOP reduction in the left eye.

Studies have also shown changes in various parts of the brain of POAG patients including in the prefrontal cortex.26 Stress associated with POAG also affects the prefrontal cortex. A hypothesis provided by Jerath et al22 suggests that breathing stimulates vagal activation of gamma-amino butyric acid pathways from the prefrontal cortex and insula, inhibiting amygdale overactivity.27 Evidence from brain imaging studies supports this hypothesis. These results suggest that long and regular breathing that involves meditation practice significantly deactivates the limbic system28 and rostral prefrontal cortex29 and increases the activation of the right dorsolateral prefrontal cortex while performing an attention-focused task.

Limitations of the Study

This study has several limitations including the use of a small sample size. In addition, measuring IOP only once daily limits our findings since IOP varies diurnally. The study was a single-blind study. A major limitation is the assumption that circulating stress biomarkers are reduced by YPDB exercises. Another limitation is the assumption that YPDB exercises improve quality of life based on subjective reports of relaxation and improved well-being. This study also included only patients with moderate to severe glaucoma, while patients with a history of surgery or laser as well as several systemic medications were excluded. These factors limit the generalizability of the study. Moreover, it remains unclear whether YPDB has long-term effects on visual field function and RNFL.

CONCLUSIONS

This study presents evidence of IOP reduction through YPDB exercises, which is a cost-effective technique that can easily be adapted by patients with glaucoma, including the elderly. It can be used to significantly alleviate suffering in patients with glaucoma and may reduce the need for medication. These YPDB exercises can be recommended as an adjunctive therapy; however, our findings do not support it as a substitute for medications or treatment options such as eye drops. Further studies are needed to determine whether yogic breathing exercises could reduce or prevent vision loss progression or allow vision restoration.

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