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A Study Showing Influence of Autonomic Nervous Activity and Meditation on Intra-Ocular Pressure

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Abstract **Purpose:** Maintenance of normal intra-ocular pressure (IOP) involves aqueous humour dynamics at several steps, like active secretion of aqueous humour by ciliary body, its flow along pupillary area and ultimately its drainage through trabecular meshwork, schelemm's canal and collector channels. Almost each of these steps is influenced by autonomic activity (sympathetic and parasympathetic). This autonomic activity, which is otherwise not under voluntary control, can be modified with the help of meditation. Meditation is said to be 'a wakeful hypo metabolic state of parasympathetic dominance'. The present study is aimed to assess the influence of meditation on autonomic activity and intra-ocular pressure so that a regular regime of meditation may be recommended in Glaucoma prone persons or combined with the Glaucoma treatment. **Methods:** The study was carried out on 40 healthy non-meditator male subjects and 20 healthy meditator male subjects of the age 40-50 years who have been performing regular meditation for at least 5 years. Their IOP was recorded in each eye. All these subjects were catagorized into 3 groups based upon 2 criteria, viz. non meditators versus meditators and secondly, normal IOP versus border line IOP amongst non meditators. Thus 3 groups were formed, viz. Group A: 20 Non-meditator persons with normal IOP Group B: 20 Non-meditators who had borderline IOP Group C: 20 Meditators who had normal IOP Subsequently a battery of tests were undertaken to assess autonomic activity in all the groups after seeking their consent and making them familiar with the tests. **Results:** The values observed in different tests in meditator group (Group C) showed parasympathetic dominance and blunted sympathetic drive in comparison to both subgroups of non-meditators (Group 1 & Group 2). **Conclusions:** This study can help us in clinical practice by this fact that regular meditation in 'glaucoma suspect' & 'ocular hypertensive' patients can bring down IOP due to improved parasympathetic tone and reduced sympathetic tone.

Keywords: *autonomic test, meditators, glaucoma, intra-ocular pressure, sympathetic tone, parasympathetic drive*

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1. Introduction

Glaucoma is a clinical condition characterized by increased intra ocular pressure (IOP) and optic nerve head changes leading to visual field loss. It is one of the most important causes of blindness in India. Maintenance of normal intra ocular pressure depends on active secretion of aqueous humor by ciliary body, its flow along pupillary area and ultimately its drainage through trabecular meshwork, schelemm's canal and collector channels. Almost each of these steps are influenced by autonomic (sympathetic and parasympathetic) activity [1-6].

In human body, organs other than skeletal muscles are innervated by autonomic nervous system (ANS) and through this, body functions are carried out without conscious control. Functionally the two divisions of ANS i.e. sympathetic (catabolic division of nervous system) and parasympathetic (anabolic division of nervous system) are essentially antagonistic and work to maintain the perfect homeostasis in body. Even noninvasive assessment of autonomic functions provide important tool to understand the etiology and the remedy of certain diseases [7,8]. More recently, raised intraocular pressure has been found to be associated with autonomic dysfunction [9,10,11].

Meditation practices originated from ancient India are now known across several parts of the world. A lot of studies have been performed on meditation in India and in some parts of world. Meditation is said to be a wakeful hypo metabolic state of parasympathetic dominance. It has been observed that many functions that are not under voluntary control (like heart beats, pulse and respiration) can be influenced by meditation [7,8,9].

Considering the facts that autonomic (sympathetic and parasympathetic) activity has a role in aqueous inflow and outflow, and medtation has been found to influence autonomic activity, the present study is aimed to find the role of meditation on intraocular pressure. This will help us to assess whether a regular regime of meditation may

be recommended in Glaucoma prone persons or it (meditation) may be combined with Glaucoma treatment.

2. Material & Methods

The study was undertaken on 40 healthy non-meditator male subjects of 40-50 years of age with similar socio-economic status and physical activity and 20 healthy meditator male subjects of the similar age group and doing meditation for at least 5 years for 8-10 hours per week (Subjects chosen were from YSS Dhyan Mandali, Dehradun). No food, coffee, or nicotine was permitted for 3 hours before the tests. After seeking their consent all the persons were familiarized with the tests beforehand. None of the patients were taking any long term medication neither for hypertension, diabetes mellitus, thyroid disorder nor did they have history of undergoing for any intra-ocular surgery.

3 groups were formed, viz. Group A: 20 Non-meditators, those who had normal IOP Group B: 20 Non-meditators who had borderline IOP and Group C: 20 Meditators who had normal IOP.

Over all mean ± s.d of age in total subjects was 47.44±1.3 (Group A = 46.52±1.6, Group B = 47.66±1.0 and Group C = 48.12±1.4)

2.1. Intra-ocular Pressure Recording

Intra ocular pressure (IOP) was recorded in both the eyes of each subject almost at the same time of the day using a Goldmann applanation tonometer. Two readings were taken in both the eyes keeping an interval of half an hour in order to be more accurate. The subjects, in whom IOP was found to be borderline raised for the first time, were kept in Group B. After IOP measurement they were subjected to visual field evaluation (30-2 program over Humphrey's automated perimeter, Carl Zeis) and fundus examination using +90 D lense. The subjects with normal fundus and visual field were only included in study group B.

2.2. Assessment of the Autonomic Nervous System Activity

Subsequently a battery of tests were undertaken in all the groups to assess both the components of autonomic activity viz sympahtetic and parasympathetic. A number of simple well established tests of autonomic nerve function based on cardiovascular reflexes allow quite an accurate assessment of the autonomic nervous system. Tests included for assessing autonomic activity were:

1. Sympathetic activity: Changes in the blood pressure responses show normal sympathetic activation; a) Hand Grip Test, b) Cold Pressor Test.
2. Parasympathetic activity: Changes in heart rate during Valsalva manoeuvre, as well as during deep breathing reflect parasympathetic modulation. c) Valsalva Ratio in Valsalva Manoeuvre; d) E: I Ratio in Deep Breath Test [15,16,17,18,19].

Basal parameters for each of the aforementioned tests were recorded. Subject was made to lie down supine on the bed for at least 10 minutes to attain the basal state. Each test was performed after a resting period of 10 minutes, in supine or sitting position as required.

A basal value of blood pressure-systolic and diastolic (SBP and DBP) was recorded by automatic blood pressure instrument (National) and Heart Rate (HR) was measured from the R-R interval of ECG recording in Lead II (By BPL Cardiart machine).

2.2.1. Hand Grip Test

After recording of basal Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP), subject was asked to hold the dynamometer in right hand (dominant) and to press its handle as hard as possible. Assess this maximum developed tension. After that subject is asked to maintain a tension of 30% of the maximum voluntary capacity for 3-5 minutes or as long as effort was possible by the subject. SBP and DBP were recorded from the inactive arm just before the release of hand grip, after 1 min and 5 minutes of the release of hand grip. The sustained hand grip results in increased cardiac output. This happens due to sympathetic activation mediated through the adrenergic receptors of ANS, thus leading to peripheral vasoconstriction, and increase in SBP and DBP. The rise should be within 15-20 mmHg. The value of rise in SBP & DBP as 11-15 mm Hg is border line and 10 mm Hg or less is sympathetic insufficiency. The test result is presented as the difference between Blood Pressure (SBP and DBP) recorded 'during manoeuvre' and the 'basal' value.

2.2.2. Cold Pressor Test

After recording of basal SBP and DBP, subject was asked to immerse his left hand upto first crease of the wrist in cold water of 8° Celsius for 2 min or as long as effort was possible. SBP and DBP were recorded from the right arm during the immersion of hand. Due to activation of afferent pain and temperature fibres from the skin and due to emotional arousal, reflex sympathetic activation takes place, which results in increased SBP and DBP. A rise in diastolic blood pressure is calculated. It should normally exceed 15 mmHg. The rise should be within 15-20 mmHg. The value of rise in SBP & DBP as 11-15 mm Hg is taken as borderline and 10 mm Hg or less is sympathetic insufficiency. The test result is presented as the difference between the highest SBP: DBP (during manoeuvre) and basal SBP: DBP.

2.2.3. Valsalva Manoeuvre -Valsalva Ratio

It is a voluntary forced expiratory effort by a subject against a resistance and reflects parasympathetic (cardiovagal) activity.

Subject is asked to be seated and to blow in the mouthpiece with both nostrils clipped. Mouthpiece is connected to aneroid manometer and subject is asked to raise the pressure to 40 mm of Hg and to hold/strain for 15 sec and then to release the strain. An unremitting ECG is recorded during rest, strain and within 45 sec of release.

The change in heart rate during the Valsalva manoeuvre was used as an index of response and expressed as the Valsalva Ratio. This is the ratio of the longest R-R interval 'after the Valsalva' to the shortest R-R interval 'during the Valsalva'. A ratio of <1.20 is defined as abnormal, 1.21-1.45 as borderline and >1.45 as normal parasympathetic activity.

2.2.4. Deep Breath Test

Normal variation of heart rate with respiration is known as sinus arrhythmia. Inspiration increases and expiration decreases heart rate. This is primarily mediated by parasympathetic (vagal) innervation of heart as sinus arrhythmia is abolished by parasympathetic block but not by sympathetic dysfunction. During deep breathing (6 breaths per min) the difference of maximum and minimum heart rate is pronounced and is known as Deep Breath Difference (DBD). Respiratory arrhythmia declines with age. Difference of more than 10-15 beats per minute is regarded as normal. After the age of 50 years, DBD should not be less than 5 beats per minute.

After recording of resting ECG for 1 min, subject is asked to lie supine and to breathe deeply through the nostrils for 60 sec, at a rate of 6 breaths / min as 5 sec is given for each phase of inspiration and expiration. Continuous recording for ECG is done during deep breathing, and after 1 min of deep breathing. Heart Rate changes during the deep breathing expressed as the expiratory-inspiratory ratio (E: I ratio), longest R-R interval during expiration/ shortest R-R interval during inspiration. For calculation, sum of 6 longest RR intervals are divided by 6 shortest RR intervals. Normal E: I ratio in young person should be higher than 1.2.

It is ensured before starting the test that resting respiratory pattern should be normal and mean heart rate should not fluctuate.

Statistical analysis was carried out by SPSS version 7 by using T test, multivariate analysis, Univariate analysis and Post Hoc Test. Further Post Hoc test-Scheffe's method was used to make inter-group comparison. Statistical significance was defined as $p<0.05$.

3. Observation and Results

3.1. Intra Ocular Pressure

Mean ± s.d. of intra ocular pressure in both the eyes is reflected in Table 1. It shows that non-meditators Group A has normal IOP, Group B has borderline raised IOP and meditators Group C has normal IOP nearing lower side of normal range. The values of IOP were found statistically significantly lowest in meditators than in non-meditators of Group A & Group B.

Table 1. Mean ± s.d. Intra Ocular Pressure in three groups

Group	Intra Ocular Pressure (IOP)	
	Right Eye Mean ± s.d.	Left Eye Mean ± s.d.
Group A (Non-Meditators)	17.1±0.76	16.9±0.85
Group B (Non-Meditators)	21.2±1.0	22.1±1.2
Group C (Meditators)	14.5±1.1	15.41±1.1

3.2. Sympathetic System Evaluation

Mean ± s.d. of basal SBP and DBP were highest in Group B followed by Group A and Group C, indicating lowest sympathetic tone in Group C [Table 2].

Multivariate analysis of sympathetic tests showed statistically significant difference in both SBP and DBP parameters during basal and manoeuvre phases in all three groups ($SBP_{2,240}=20.032$, p value. 000 and $DBP_{2,240}=83.79$, p value. 000) [Table 3].

Multiple group analysis (post hoc-Scheffe Test) showed a rise of SBP & DBP 'during manoeuvre versus basal level', which was statistically significantly lower in Group C in comparison to both Group A and Group B. However there was no statistically significant difference of rise in SBP & DBP between Group A & Group B [Table 4].

Thus this can be inferenced that meditators had significantly lower sympathetic response in comparison to non-meditators

Table 2. Sympathetic System Evaluation: Mean ± sd of HGT and CPT

Group	Phases	Tests of Sympathetic System Evaluation								N
		Hand Grip Test				Cold Pressor Test				
		SBP		DBP		SBP		DBP		
		Mean	± sd	Mean	± sd	Mean	± sd	Mean	± sd	
A	Basal	120.3	6.5	76.3	4.6	120.3	6.5	76.3	4.6	20
	During manoeuvre	137.2	3.2	94.9	2.2	136.5	4.1	94.8	2.6	20
	Rise (difference of Basal and During Manoeuvre)	16.90	7.1	18.60	4.2	16.25	4.4	18.55	3.7	
B	Basal	126.1	5.3	80.2	2.7	126.1	5.3	80.2	2.7	20
	During manoeuvre	142.2	5.5	98.3	4.2	145.5	6.0	97.0	3.0	20
	Rise (difference of Basal and During Manoeuvre)	16.10	3.4	18.10	4.10	19.35	3.2	15.80	2.9	
C	Basal	106.8	6.0	68.7	5.5	106.8	6.0	68.7	5.5	20
	During manoeuvre	115.2	6.2	71.9	6.3	113.2	6.0	70.8	5.6	20
	Rise (difference of Basal and During Manoeuvre)	8.45	3.1	3.20	2.70	6.45	2,8	2.10	1.7	

Table 3. Multivariate analysis of Sympathetic tests in different Groups and phases

Tests of Between-Subjects Effects						
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	SBP	38829.283[a]	11	3529.935	111.554	.000
	DBP	29349.446[b]	11	2668.131	141.524	.000
Intercept	SBP	3729528.017	1	3729528.017	117861.087	.000
	DBP	1593325.104	1	1593325.104	84513.749	.000
Group	SBP	25791.258	2	12895.629	407.530	.000
	DBP	16189.308	2	8094.654	429.360	.000
Phase	SBP	11620.417	1	11620.417	367.230	.000
	DBP	9971.704	1	9971.704	528.923	.000
Tests	SBP	.600	1	.600	.019	.891
	DBP	10.004	1	10.004	.531	.467
Group * Phase	SBP	1267.758	2	633.879	20.032	.000
	DBP	3159.408	2	1579.704	83.791	.000
Group * Tests	SBP	74.325	2	37.162	1.174	.311
	DBP	4.508	2	2.254	.120	.887
Phase * Tests	SBP	.600	1	.600	.019	.891
	DBP	10.004	1	10.004	.531	.467
Group * Phase * Tests	SBP	74.325	2	37.162	1.174	.311
	DBP	4.508	2	2.254	.120	.887
Error	SBP	7214.700	228	31.643		
	DBP	4298.450	228	18.853		
Total	SBP	3775572.000	240			
	DBP	1626973.000	240			
Corrected Total	SBP	46043.983	239			
	DBP	33647.896	239			

Table 4. Sympathetic System; Post Hoc Test (Scheffe Test)

			Hand Grip Test		Cold Pressor Test	
Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
Rise in SBP (difference of SBP in Basal and during manoeuvre value)	A	B	.8000	.878	-9.8000*	.000
		C	-8.4500*	.000	3.1000*	.030
	B	A	.8000	.878	-9.8000*	.000
		C	-7.6500*	.000	-3.1000*	.030
	C	A	8.4500*	.000	-12.9000*	.000
		B	7.6500*	.000	9.8000*	.000
Rise in DBP (Difference of DBP in Basal and during manoeuvre value)	A	B	-.5000	.916	12.9000*	.000
		C	-15.4000*	.000	-1.7500	.181
	B	A	.5000	.916	-16.4500*	.000
		C	-14.9000*	.000	1.7500	.181
	C	A	15.4000*	.000	-14.7000*	.000
		B	14.9000*	.000	16.4500*	.000
					14.7000*	.000

3.3. Parasympathetic System Evaluation [Table 6, Table 7 & Table 8]

Mean ± s.d. of Valsalva Ratio and E:I Ratio were highest in Group C followed by Group A and Group B, indicating more parasympathetic tone in Group C as shown in Table 5.

On univariate analysis of parasympathetic tests; Valsalva ratio and E: I ratio showed statistically significant difference in all three groups (Valsalva Ratio $_{1,60}$=41537.432, p value. 000 and E:I Ratio$_{1,60}$= 117.600, p value. 000) as shown in Table 6 and Table 7.

On multiple group analysis (post hoc-Scheffe Test); Mean ± s.d. of Valsalva and E:I ratio were statistically significantly higher in Group C in comparison to Group A

and Group B. There was no statistical significant difference in valsalva and E: I ratio between Group A and Group B as shown in Table 8.

Thus this can be inferenced that medidators had significant higher parasympathetic response in comparison to non-meditators.

Table 5. Parasympathetic System Evaluation: Mean ± s.d. of Valsalva Ratio and E:I Ratio

Valsalva Ratio				E: I Ratio				N
Group		Mean	Std. Deviation	Groups		Mean	Std. Deviation	
Widest R-R interval	1.00	24.5000	.76089	Expiratory R-R interval	1.00	23.9500	.88704	20
	2.00	24.1000	1.02084		2.00	23.5000	.88852	20
	3.00	26.4000	.82078		3.00	26.1000	.85224	20
	Total	25.0000	1.32767		Total	24.5167	1.43198	60
Narrowest R-R interval	1.00	17.3000	.47016	Inspiratory R-R interval	1.00	18.2000	.76777	20
	2.00	17.5500	.60481		2.00	17.9500	.88704	20
	3.00	16.3500	.58714		3.00	16.6500	1.03999	20
	Total	17.0667	.75614		Total	17.6000	1.12295	60
Valsalva Ratio value	1.00	1.4150	.04894	E:I Ratio value	1.00	1.3175	.07643	20
	2.00	1.3715	.04848		2.00	1.3100	.07269	20
	3.00	1.6180	.06779		3.00	1.5725	.10672	20
	Total	1.4682	.12143		Total	1.4000	.14963	60

Table 6. Univariate analysis of Parasympathetic tests (Valsalva Ratio) in different groups and phases

Tests of Between-Subjects Effects					
Dependent Variable: Valsalva Ratio					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.692[a]	2	.346	111.193	.000
Intercept	129.331	1	129.331	41537.432	.000
Group	.692	2	.346	111.193	.000
Error	.177	57	.003		
Total	130.201	60			
Corrected Total	.870	59			

Table 7. Univariate analysis of Parasympathetic tests (E:I Ratio) in different groups and phases

Tests of Between-Subjects Effects					
Dependent Variable: E:I Ratio					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.893[a]	2	.447	59.515	.000
Intercept	117.600	1	117.600	15670.836	.000
Group	.893	2	.447	59.515	.000
Error	.428	57	.008		
Total	118.921	60			
Corrected Total	1.321	59			

Table 8. Parasympathetic System; Post Hoc Test (Scheffe Test)

(I) Group	(J) Group	**Valsalva Ratio**		**E: I Ratio**	
		Mean Difference (I-J)	Sig.	Mean Difference (I-J)	Sig.
1.00	2.00	.0435	.056	.0075	.963
	3.00	-.2030*	.000	-.2550*	.000
2.00	1.00	-.0435	.056	-.0075	.963
	3.00	-.2465*	.000	-.2625*	.000
3.00	1.00	.2030*	.000	.2550*	.000
	2.00	.2465*	.000	.2625*	.000

4. Discussion

In the present study, intra ocular pressure (IOP), sympathetic and parasympathetic systems were evaluated in non-meditators and meditators by forming 3 groups: Group A (Non-meditators with normal IOP), Group B (Non-meditators with marginally raised IOP), Group C (Meditators with normal IOP). It is interesting to note that mean IOP in both eyes was lower in meditators (group C) compared to non-meditators (group A and group B). Statistically also, non-meditators (group A and group B) showed significantly higher sympathetic tone and significantly lower parasympathetic tone in comparison to meditators (group C). Further in Goup B little raised sympathetic and reduced parasympathetic tone in comparison to Group A reflects marginal systemic autonomic dysfunction

The role of the ANS in the regulation of aqueous inflow and outflow is well recognised and more recently it has been found that rise in IOP is associated with autonomic dysfunction [12,13,14]. The ciliary body is innervated with both sympathetic and parasympathetic nerve endings. The catecholamine neurotransmitters released from the sympathetic nerve endings stimulate the adrenergic receptors on the ciliary epithelium, which in turn increases aqueous humor secretion. The parasympathetic fibres secrete acetylcholine, which in turn stimulates cholinergic receptors on the ciliary muscles. The resulting effect is ciliary muscle contraction with reduced resistance to the trabecular aqueous humor outflow. The uveo-scleral outflow of aqueous humor also gets increased [6]. Current medications prescribed in the treatment of glaucoma i.e. guttae adrenaline, guanethedine, timolol and pilocarpine act primarily via autonomic effects in the anterior segment of the eye [4].

Meditator are usually saints and ascetics people, who are inaccessible to the scientific world, but recently in India meditation has been re-popularized among the masses and the number of common people practicing it has risen up again. Meditation leads to variation in physiological responses of the subjects by influencing ANS and thus achieving parasympathetic dominance with better control over sympathetic activity.

A number of simple well established tests of autonomic nerve function based on cardiovascular reflexes allow accurate assessment of the autonomic nervous system.

Various studies suggest that systemic parasympathetic neuropathy occurs in 58% cases of closed angle glaucoma and 42% of ocular hypertension patients [20,21].

Based upon the aforesaid facts it can be implied that meditation can help in regulation of IOP by affecting autonomic nervous system activity.

Meditation may also be of clinical usefulness in other diseases associated with increased sympathetic nervous system activity.

A number of physical ailments i.e. Obsessive Compulsive Neurosis, Epilepsy, Sleep, Addiction and behavioral disorders are reported to get improved by reduction in sympathetic drive [22,23,24]. Few studies exhibit that yogic practices including meditation and deep breathing relaxation exercises bring not only control over sympathetic drive but also induce parasympathetic dominance [8,9]. The hypometabolic state seen during practice of meditation differs from that seen during sleep, but is consistent with an integrated hypothalamic response, recently termed as 'the relaxation response' [25]. This hypothalamic response probably represents a state of decreased sympathetic nervous system activity. Hence it can be inferred that regular practice of meditation can control ‘uncontrollable’ ANS.

5. Conclusions

This study brings this fact that autonomic nervous function plays an important role in control of IOP and thus may contribute as a significant factor in the pathogenesis of Ocular Hypertension and possibly in Primary Glaucomas

Further this study can help us in clinical practice by the fact that regular meditation in ‘Glaucoma Suspect’ & ‘Ocular Hypertensive” patients can bring down IOP due to improved parasympathetic and reduced sympathetic tone. It can be hypothesized that Primary Glaucomas without anatomical abnormalities related to resistance in aqueous outflow facility, might also have some beneficial effect by meditation.

We know for a fact that risk of glaucoma is also based on non-IOP factors. But, the only modality of treatment available to reduce risk is to lower IOP.

Therefore meditation practices may be helpful as an adjuvant to medical therapy.

The present study had a limitation that no female subject was included in this study. Secondly, the age group of participants had not been wide. The effect of meditation practice in ‘established cases’ of Primary Glaucomas, opens scope for further research study.

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Statement of Competing Interests

The authors have no competing interests

List of Abbreviations

Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Deep Breath Difference (DBD),

Expiratory-inspiratory ratio (E: I ratio), standard error of the means (SEM).

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