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Original article

Body Mass Index and its Relationship to Intraocular Pressure in Primary Open-Angle Glaucoma Patients

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Abstract

Background: Glaucoma is the second leading cause of blindness after cataracts. **Purpose:** To investigate the relationship between body mass index and intraocular pressure in primary open-angle Glaucoma patients. **Patients and methods:** Our study included 60 participants above 18 years of age. Thirty participants with healthy eyes (16 male and 14 female)- were selected as a control group (**Group A**). In addition, 30 participants (16 female and 14 male) with eyes suffering from POAG (**Group B**). A T-test at $P<0.05$ was used to compare Group A and Group B. Informed written consent was taken from all the subjects that fulfilled the inclusion-exclusion criteria, and then a detailed ophthalmological examination- was done. Their height and weight were measured, and BMI was calculated. The Pearson correlation coefficient studied the association between IOP in POAG patients and BMI. **Results:** Our results indicated that Group A belongs to the normal weight group, while, Group B is in the obese group. The Intraocular Pressure in the obese group (BMI= 30.29%) was 20.10 and 18.47 mmHg compared to 13.37 and 13.47 mmHg obtained from the normal weight group (BMI= 24.9%)- in the right and left eyes, respectively. A strong positive correlation between BMI and IOP in right eyes (β =0.964, P=0.000) as well as BMI and IOP in left eyes ((β =0.973, P=0.000)- was found in patients with POAG. **Conclusion:** A strong positive correlation exists between BMI and IOP in POAG patients. The most potent effect on IOP was observed in obese individuals in both eyes.

Keywords: BMI, Obesity, IOP, POAG, Correlation coefficient.

Introduction

Glaucoma is a multifactorial degenerative optic neuropathy. It is a type of progressive optic neuropathy characterized by the degeneration of retinal ganglion cells and resulting changes in the optic nerve head. It can progress at variable rates and affect different age groups. It is considered the second leading cause of blindness worldwide [1]. Asymptomatic in the above the age of 40 years have IOP >21 mmHg without any apparent glaucomatous damage on clinical examination [7-8]. The Baltimore eye study and the Barbados eye study- have documented a positive association between IOP and POAG. As per the Baltimore eye study, the risk of POAG increases 39 times if IOP is >35 mmHg compared to the reference group with IOP of >17 mmHg [9-10]. Treatments aim to reduce IOP [11]. Despite this, glaucoma can develop or progress, even within a normal IOP range. Local, systemic, genetic, and environmental factors- have also been proposed to be risk factors for glaucoma [12]. These risk factors may modify the threshold of the optic nerve to withstand glaucomatous insult. However, individuals' optic nerve stress thresholds differ according to age, sex, race, and many other factors [13]. Glaucoma is, therefore, considered a multifactorial disease. Many systemic risk factors are associated with glaucoma, such as metabolic syndrome [14], diabetes mellitus [15], arterial stiffness [16], and renal disease [17]. Heavy smoking [18], low estrogen level [19], and low consumption of certain fruits, vegetables, fatty fish, and walnuts [20] - have been reported to be risk factors for primary open-angle glaucoma (POAG) [19-21].

Recently, several studies have been done to ascertain the role of different lifestyle modifications that could influence IOP and possibly alter the progression of glaucoma. Other modifiable risk factors such as socioeconomic status, diet, exercise, body mass index (BMI), smoking, and early stages, it gradually and progressively reduces the visual field and leads to blindness if untreated. Glaucoma may be classified as congenital and acquired, open-angle and angle-closure, and primary and secondary. Primary open-angle glaucoma (POAG) is more common, affecting 1 in 100 over the age of 40 years. Africa has the highest POAG prevalence (4.0%) among all continents [2].

Furthermore, it was estimated that 57.5 million developed blindness due to open-angle glaucoma [3]. The only modifiable risk factor for glaucoma is intraocular pressure (IOP) [4]. A normal IOP is maintained by balancing the aqueous humor production by the ciliary body with aqueous humor outflow via Schlemm's canal and uveoscleral tissues that drain into ophthalmic veins [5]. Most ophthalmologists believe that eye pressure readings should be between 10 and 20 mmHg, others, between 11-21 mmHg. An intraocular pressure greater than 21 mmHg has been considered a criterion for the existence of glaucoma [6]. It often goes undetected once an advanced stage is reached. Glaucoma symptomatology may vary from a headache to hazy vision, blurring of vision, halos, etc. Diabetes mellitus, central retinal vein occlusion, and a history of myopia- are some of the associated risk factors. The most important and the only modifiable risk factor for glaucoma is raised intraocular pressure (IOP).

Elderly people and women tend to have higher IOP. It is indicated that approximately 7% of the population

Our current study aims to evaluate the associations between body mass index (BMI) and intraocular pressure in primary open-angle glaucoma.

Patients and Methods

This case/control study included 30 participants with healthy eyes; they were selected as a control group (**Group A**), in addition to 30 participants with eyes suffering from Primary Open Angle Glaucoma- were selected as **Group B.** All were collected from Ophthalmology Outpatient Clinic, Benha University Hospitals. This study investigated the relationship between body mass index and intraocular pressure in primary open-angle Glaucoma patients. This study enrolled patients from January 2023 to June 2023 at the Faculty of Medicine (Benha University). Written informed consents were obtained from all participants. This study was approved by ethical committee of Faculty of Medicine, Benha University (Ms: 43-11-2022).

Statistical plan

Sample size calculation was performed using G*Power version 3.1.9.2.[25]. University Kiel, Germany. Copyright (c) 1992-2014. The effect size d was 0.86 using, according to the previous studies, an alpha (α) level of 0.05 and Beta (β) level of 0.05, i.e., power = 95% **(Figures a and b)**; the estimated sample size (n) should be 60 samples for the two groups, 30 samples each **(Table a)**.

sleep apnea have been evaluated [10-22]. Furthermore, obesity is being linked to glaucoma. Obesity- which is emerging as a new epidemic in many countries and is the fifth leading cause of death worldwide- is not only a risk factor for many systemic ailments such as diabetes mellitus, hypertension, myocardial infarction, stroke, and osteoarthritis but the role of obesity has also been implicated in the pathogenesis of various ocular conditions such as age-related cataract, age-related maculopathy, diabetic retinopathy, and glaucoma [23]. The Beaver Dam Eye Study has also suggested a significantly positive relationship between higher IOP and higher BMI [24].

In 2008, more than 1.4 billion adults over 20 years were overweight. In 2010, more than 40 million children under the age of 5 were overweight. Obesity is expressed in terms of BMI, defined as weight in kilograms (Kg) divided by the square of height in meters. Obesity is classified as BMI >30 [23].

More data regarding the relationship between BMI and IOP needs to be available, hence, the need for the present study. Since BMI is a modifiable risk factor, effective inexpensive lifestyle modifications that could favorably alter the risk of developing glaucoma- are welcome. The visual loss due to glaucoma is irreversible, therefore, early detection and timely treatment are crucial in its management.

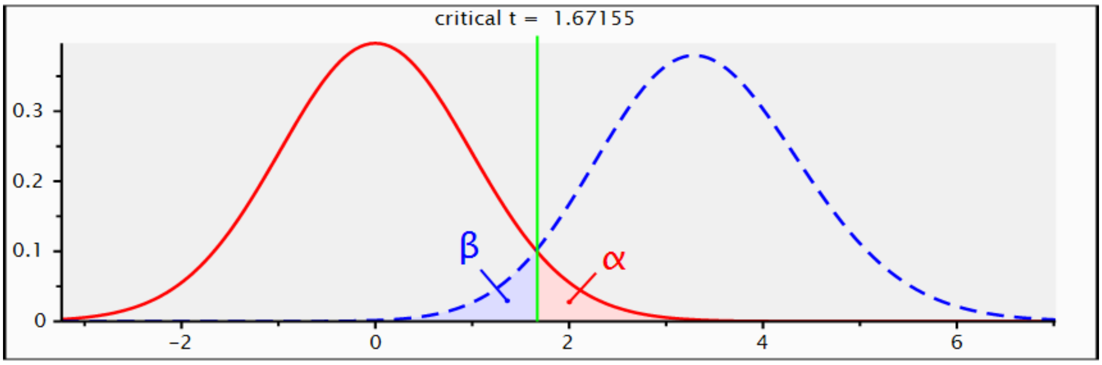

Figure a: T tests - Means: Difference between two independent means (Groups A and B).

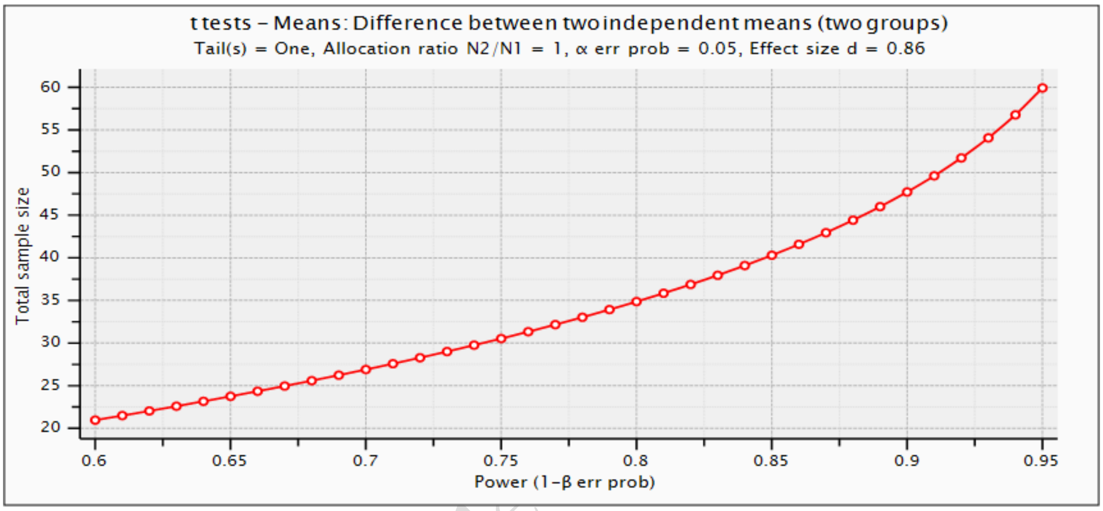

Figure b: T tests - Means: Difference between two independent means (Groups A and B).

Table a: T tests - Means: Difference between two independent means (two groups)

Analysis:	**A priori: Compute required sample size**		
Input:	**Tail(s)**	**=**	**One**
	Effect size d	**=**	**0.86**
	α err prob	**=**	**0.05**
	Power (1-β err prob)	**=**	**0.95**
	Allocation ratio N2/N1	**=**	**1**
Output:	**Non-centrality parameter δ**	**=**	**3.3307657**
	Critical t	**=**	**1.6715528**
	Df	**=**	**58**
	Sample size group 1	**=**	**30**
	Sample size group 2	**=**	**30**
	Total sample size	**=**	**60**

Patient group (Group B): Age: >18 years. Previously diagnosed with primary open angle glaucoma by measuring IOP, fundus examination, visual field test, O.C.T of optic disc and gonioscopy of angle of anterior chamber.

Inclusion criteria:

Control group (Group A): Age: >18 years. No previous history of Intra ocular surgery. No family history of glaucoma. Normal Intra ocular pressure not more than 21 mmHg.

2- Systemic examination: Measure weight/kg. Measure height/m. Calculate BMI = (weight/kg)/(height/m) ^{2}.

Statistical design:

All data were collected, calculated, tabulated, and statistically analyzed using the following statistical tests. A normality test (Shapiro-Wilk) was done to check the normal distribution of the samples. Descriptive statistics were calculated as Mean ± Standard deviation (SD). Independent samples T- test was used to compare between the different two groups. The association between variables was studied by the Pearson correlation coefficient. P value ≤ 0.05 is considered statistically significant. All Statistical analysis was performed using the computer program SPSS software for windows version 26.0 (Statistical Package for Social Science, Armonk, NY: IBM Corp).

Results

Our study included 60 participants above 18 years of age. Among them 30 participants with healthy eyes were selected as a control group (**Group A**). In addition, 30 participants with eyes suffering from primary open angle glaucoma (**Group B**). T-test at P<0.05 was used to compare between Group A and Group B. Regarding the mean age parameter, it was found that mean age of **Group A (**healthy eyes**)** is 54.73± 14.68 years while; mean age of **Group B (**suffering from primary open angle glaucoma) is 56.50± 14.84 years **(Table 1).** There was no significant difference in ages between the two groups **(Fig 1).**

Exclusion criteria for both groups were: Patients on systemic or topical steroid therapy. Undergoing complicated ocular surgery. Patient has systemic disease that affects IOP. Corneal pathology or surgery that might influence the study. Uncontrolled IOP. Any drugs causing elevations of IOP. Allergy to mydriatic agents, topical anesthetic drops.

Each patient was subjected to the following:

Full history taking: Including personal, present, past and family history- as well as- other ocular diseases or operations.

Clinical examination:

1- Ocular examination: Examination of lids, orbit, lacrimal system and ocular motility. Visual acuity assessment: unaided and best corrected. Using Snellen chart to measure VA.

a-Slit-Lamp bio-microscopic examination: Full examination of the anterior segment was performed for cornea, sclera, anterior chamber, iris, pupil and lens.

b-Intra-ocular pressure measurement: Using Goldmann Applanation Tonometer. **c-Fundus examination:** Using indirect ophthalmoscope. Non-contact double aspheric biconvex lens (Volk's lens, +90).

d-Gonioscopic examination: Using Gonioscoy Goldmann 3-mirror lens.

and left eyes (P<0.001). We noticed that the Intraocular Pressure in the obese group (BMI= 30.29%) were 20.10 and 18.47 mmHg compared to 13.37 and 13.47 mmHg obtained from the normal weight group (BMI= 24.9%) in the right and left eyes, respectively **(Fig 3, 4).**

A Pearson correlation coefficient was used to determine the relationship between the variables: body mass index and IOP. Regarding the **Group B** in patients with primary open-angle glaucoma, univariate analysis found a strong positive correlation between BMI and IOP in right eyes (β =0.964, P=0.000) as well as BMI and IOP in left eyes ((β =0.973, P=0.000).

Our results illustrated in **Table (2) and Fig (2)** show that the Body Mass Index in **Group B** which suffering from primary open angle glaucoma was significantly higher than that obtained from the **Group A** of healthy eyes (**30.28** ±**4.50** and **24.90** ±**2.88** %, respectively, P<0.001). We can conclude from our previous results that the **Group A** belongs under the normal weight group while **Group B** under class 1 obese group.

Regarding Intraocular Pressure (mmHg) parameters in **Table (3, 4)**, highly statistically significant differences between the obese individuals and the normal weight group- were found in both the right

Table 1: Comparison of mean ages between 30 participants with healthy eyes (Group A) and 30 suffering from primary open angle glaucoma (Group B).

	Mean (year)	Sd ±	T-test	P value
Group A	54.73	14.68	-0.46	0.645 ns
Group B	56.50	14.84		

ns : no significant difference

Table 2: Comparison of Body Mass Index (%) between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B)

	Mean (kg/m^2)	Sd ±	T-test	P value
Group A	24.90	2.88	-5.51	<0.001**
Group B	30.28	4.50		

**** : Means highly significant difference**

Table 3: Comparison of Intraocular Pressure (mmHg) in right eyes between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B)

	Mean (mmHg)	Sd ±	T-test	P value
Group A	13.37	1.90	-5.27	<0.001**
Group B	20.10	6.73		

**** : Means highly significant difference**

Table 4: Comparison of Intraocular Pressure (mmHg) in left eyes between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B)

	Mean (mmHg)	Sd ±	T-test	P value
Group A	13.47	2.13	-4.99	<0.001**
Group B	18.47	5.06		

**** : Means highly significant difference**

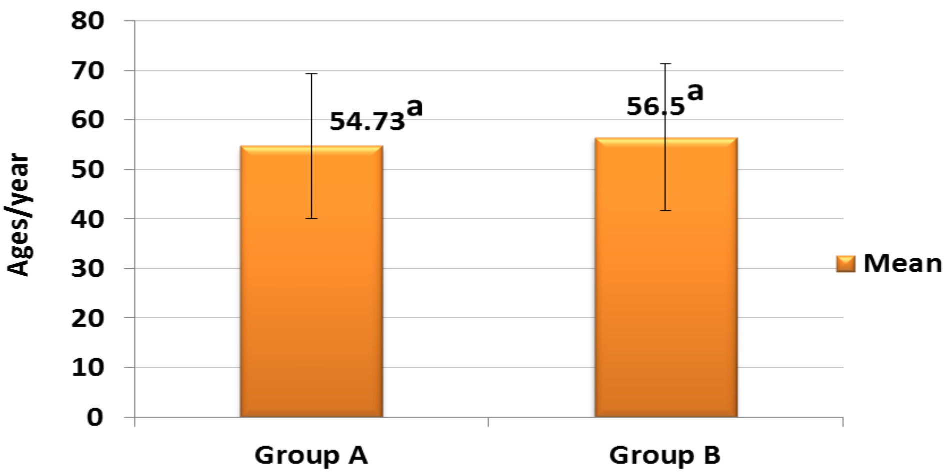

Fig 1: Comparison of mean ages of 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B).

- Means with the same letters are not statistically different.

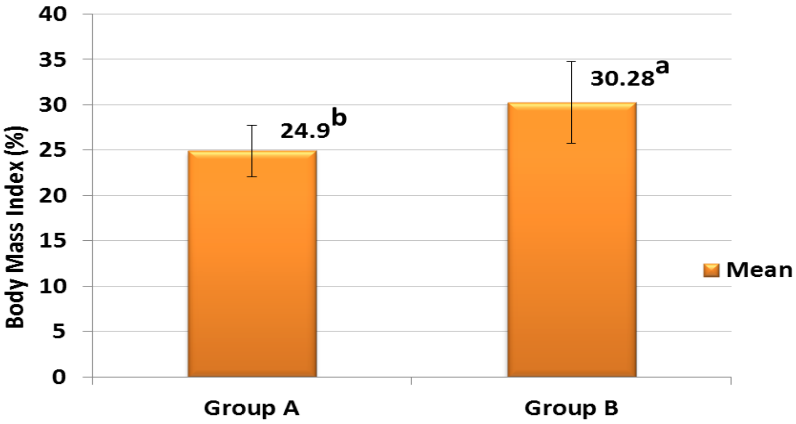

Fig 2: Comparison of Body Mass Index (%) between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B).

-Means with different letters are statistically different.

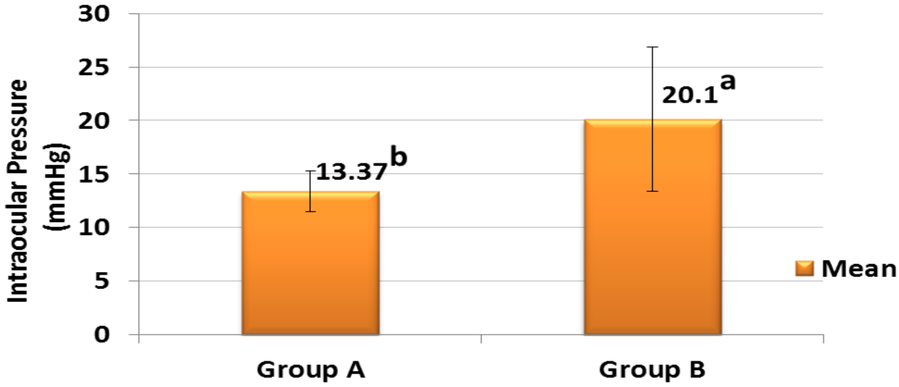

Fig 3: Comparison of Intraocular Pressure (mmHg) in right eyes between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B).

-Means with different letters are statistically different.

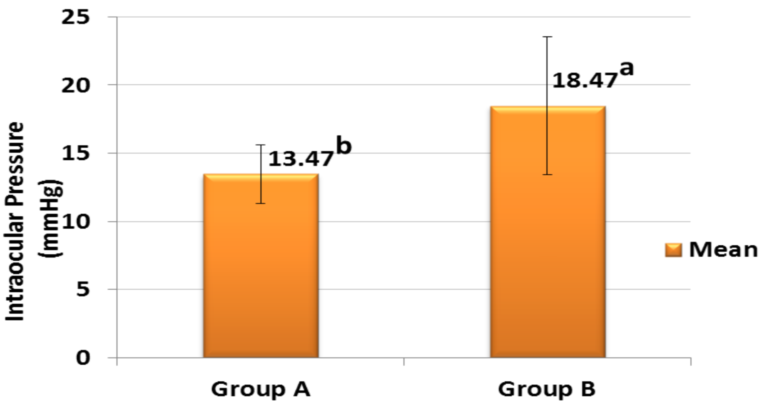

Fig 4: Comparison of Intraocular Pressure (mmHg) in left eyes between 30 participants with healthy eyes (Group A) and 30 suffering from POAG (Group B).

-Means with different letters are statistically different.

Discussion

This research is the first study of body mass index (BMI) and its relationship with intraocular pressure (IOP) in patients with primary open-angle glaucoma, in Faculty of Medicine, Benha University, Egypt. Our results showed no significant age differences between individuals with obesity and normal weight groups **(Figure 1)**. At the same time, the BMI ratio of obese participants was significantly higher than that of normal individuals **(Figure 2)**. We found that IOP in the obese group of POAG was significantly higher than in people of normal weight. Interestingly, BMI significantly correlated with IOP in both eyes in obese individuals **of POAG (Figure 3, 4).**

Our results also indicated that IOP in both eyes increased significantly in obese subjects of POAG and reached 20.1 and 18.47 mmHg compared to 13.37 and 13.47 mmHg obtained in the normal weight group (BMI = 24.9 kg/m^2) in the right and left eyes, respectively. Furthermore, obese participants also had a significant positive correlation between IOP and BMI in the right eye ($\beta = 0.964$, $P = 0.000$) and IOP and BMI in the left eye ($\beta = 0.973$, $P = 0.000$). Our results are consistent with many previous reports [26, 27, 28].

Elevated intraocular pressure in obese participants may be due to several mechanisms. The presence of excess periorbital fat increases pressure and reduces aqueous outflow, which increases IOP [29]. Also, obesity may be associated with increased blood levels of leptin, which may cause oxidative damage to the trabecular meshwork that reduces aqueous outflow [30]. Finally, increased blood viscosity associated with obesity may increase episcleral venous pressure, reducing aqueous outflow and leading to higher IOP [31, 32].

Obesity is a cofactor for vascular dysregulation, such as localized vasospasms and disturbed blood flow autoregulation in the optic nerve head, choroid, and other ocular tissues, contributing to increased intraocular pressure. Increasing the body mass index also leads to the accumulation of fat in the neck area, thus reducing venous return and increasing episcleral venous pressure, thereby increases IOP[23].

On the other hand, it has been found that there is no significant change in IOP after bariatric surgery [33], and others have shown a significant decrease in IOP after weight loss surgery [34]. Our study confirmed that individuals with lower BMI were associated with lower mmHg in IOP.

Similarly, other results reported that a BMI decrease of 10 kg/m^2 was associated with an average IOP decrease of 0.9 and 0.7 mmHg for men and women, respectively [35].These findings are consistent with the tradition that normal weight is more likely to achieve better health outcomes.

Conclusion

Our statistical analysis showed a strong positive correlation between BMI and IOP in POAG patients. The strongest effect on IOP was observed in obese individuals. Also our results are consistent with the convention that normal BMI will likely achieve better health outcomes. The implications for glaucoma prevention in healthy individuals and the potential protective effect in glaucoma patients require further investigation.

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