Effect of Treadmill Exercise on Intraocular Pressure in Normal Subjects

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Abstract

Purpose of this study was to investigate the influence of treadmill exercise on intraocular pressure in normal subjects. Fifteen normal subjects were enrolled in this study (10 women and 5 men) with age ranges between 30-40 years. They performed a supervised treadmill exercise program (3 sessions/week, 40 minutes/session for 3-months) where intraocular pressure was measured before exercise and 30 minutes after exercise, at baseline and after 3-months of training.

Results; showed that there was a significant decrease of the intraocular pressure which scoped in the maintenance of the good nourishment for the eye tissues.

Conclusion; It was concluded that regular treadmill exercise was of great benefit in the preservation of normal intraocular pressure in response to age-related changes of ocular health.

Key Words: Treadmill exercise – Intraocular pressure – Ocular health.

Introduction

EXERCISE induces blood flow changes in all organs in the body, including the eye and the brain that are autoregulated in order to maintain a constant blood supply in the face of metabolic stress or imbalance. Blood flow autoregulation refers to the ability of the vascular bed to maintain a relatively constant flow despite moderate alterations in the perfusion pressure, or in terms of eye, ocular perfusion pressure. Exercise, by its very nature, leads to increase in systolic blood pressure and decrease in the intraocular pressure (IOP). These two components are strongly influenced by the autonomic nervous system, and the result is an increase in ocular perfusion pressure. A normal healthy eye can cope with the stress and altered ocular perfusion pressure, while the diseased eye, or the eye whose vasculature is compromised by a pre-existing systemic state, may not [1].

The normal intraocular pressure is about 10 to 20mmHg. For Caucasian people, the average eye pressure is 16mmHg; this varies slightly with each heartbeat and with respiration. Many factors affect IOP as variation during the course of the day as pressure is highest in early morning before waking but the peak may occur at other times where the difference is usually between 3 and 4mmHg as well as the age changes in the trabecular meshwork and other disease such as Diabetes, Hypertension and glaucoma [2].

Snell and Lamp [3] stated that, there are three chief factors responsible for maintaining a normal intraocular pressure:
- The rate of formation of aqueous humor by the cells of the ciliary processes.
- The rate of drainage of aqueous humor through the trabecular meshwork.
- The pressure in the episcleral veins into which the sinus venosus sclerae (canal of Schlemm) drains.

There are two ways to measure the intraocular pressure either manometrically or tonometrically. Tonometry is the most utilized method in clinical practice as well as in the experimental studies. It is an important test in the evaluation of ocular conditions such as glaucoma as well as conditions such as phthisis bulbi, and iritis. Most tonometers are calibrated to measure pressure in mmHg. [4].

An elevated IOP is the main risk factor for glaucoma, with the degree of risk increasing as the level of IOP increases. Elevated intraocular pressure is known to reduce retinal blood flow, although the effect of intraocular pressure on retinal
vascular pressures is unknown. Researches investigate this relation by direct measurements of intravascular pressures in the cut retina at various intraocular pressures. The results showed that retinal artery pressure depends on both intraocular pressure and mean systemic blood pressure [5].

Many studies explained that the factors associated with high IOP included age, baseline IOP, hypertension, blood pressure as well as wearing a tight necktie could raise IOP. Incidence increased with age, with rates 2.5 times higher at 70 years or older than at ages 40 to 49 years. In addition, older individuals with a higher baseline IOP were more likely to develop elevated IOP after 4 years. Although blood pressure was also associated with high IOP, the relationship may be nonlinear [6].

According to, Koss, [7]; the functional role of nitric oxide in regulation of ocular blood flow is an important subject to be studied. Nitric oxide generated by three distinct enzyme systems appears to play a critical role in many diverse physiological processes. Using both conventional and immunohistochemical techniques, nitric oxide synthases have been identified throughout the body, including all regions of the eye. Nitric oxide is implicated in a variety of ocular pathophysiologic states including uveitis, retinal ischemic disease, diabetes and glaucoma.

Several studies confirm that regular exercise can enhance the release of nitric oxide (NO) that leads to a functional consequence of the good nourishment of the delicate and sensitive tissues to blood deprivation such as EYE and normalize intraocular pressure that will save it from ocular complications as diabetic retinopathy (DR) which is the major cause of blindness in adults aged 25-74 years [8].

The endothelium plays a primary role in the modulation of vascular tone and structure through production of the relaxing factor nitric oxide (NO), which acts by protecting the vessel wall from the development of atherosclerosis and thrombosis. A dysfunctioning endothelium, characterized by reduced NO availability induced by oxidative stress, can in the presence of most of the cardiovascular risk factors, including aging, be a promoter of atherosclerosis [9]. Nitric oxide (NO) is an important regulator of basal choroidal blood flow [10].

Exercise has been repeatedly shown to improve endothelial vasomotor function in healthy subjects and in disease states including hypertension, congestive heart failure, Coronary artery disease (CAD) as well as Diabetics. These effects appear to be mediated in large part by increased NO bioavailability and may be greatest in vascular beds exposed to repetitive increases in blood flow during exercise which includes the coronary circulation for all types of exercise [11].

According to, Singleton et al., [12] the autonomic nervous system contributes to blood flow control to vital organs through autoregulation. Autoregulation involves local myogenic, metabolic, and circulating humoral agents to maintain relatively constant blood flow to tissues despite perfusion pressure fluctuations.

Several studies search the effect of different modes and types of exercises on IOP in healthy and diseased eyes and its effect on the ocular health and overall quality of life on those subjects. The results came to be hopeful that certain exercises not all have good effect on IOP not only in the healthy subjects but also on patients. Intraocular pressure is known to be responsive to the effects of physical exercise. This is usually reflected as a decrease in IOP immediately following exercise, with gradual return to the pre-exercise level over an hour period post-exercise. That was confirmed with a study on the effect of cycling on 10 hypertensive patients that revealed decrease in IOP with exercise which indicates better perfusion of the retina [13].

The effects of physical fitness on intraocular pressure were reviewed in several studies that concluded that physical fitness reduces intraocular pressure in both trained and sedentary life subjects. It would seem reasonable at present not to discourage patients who have glaucoma from light exercise, perhaps; on the contrary, it should be encouraged [14].

The effects of intensity, duration and quantity (intensity x duration) of exercise on the reduction of (IOP) in healthy and physically fit individuals were studied. Five minutes after 15 minutes of exercise at 70%, 55% and 40% of maximum exercise load (%HRmax) decreased IOP by 4.3 ±0.7 mmHg, 2.2±0.7mmHg and 0.6±0.5mmHg, respectively. The magnitude of IOP reduction increased with exercise load. Also running exercises for 7.5 minutes at 70% HRmax decreased IOP comparable to 15 minutes of running at the same exercise load (4.5±0.6mmHg) and also compared by 25 minutes of running at 40% HRmax is almost the same quantity of exercise as 15 minutes of running at 70% HRmax. However, the former did not result in IOP reductions to equal the latter (2.3 ±0.5 Vs. 4.4±0.6mmHg). The amount of IOP reduction after short-term exercise seems to depend on the intensity
of exercise, not on the duration of exercise or the quantity of exercise [15].

Exercise proved to reduce intraocular pressure in healthy subjects. A study designed to evaluate the effect of moderate exercise over a short duration on intraocular pressure and pulsatile ocular blood flow. Thirty-one subjects (20 males and 11 females) ranging in age from 20-60 years had measurements of intraocular pressure and pulsatile ocular blood flow before and after pedaling on a stationary bicycle for 10 minutes. The results gave the evidence that exercise can decrease intraocular pressure and increase pulsatile ocular blood flow [16].

In a study to examine the effects of jogging on intraocular pressure (IOP), blood pressure (BP), and heart rate (HR) on twenty-nine healthy individuals-25 athletes and 4 untrained-were studied. IOP, systolic and diastolic BP, and HR were measured before and just after 20 minutes of jogging (submaximal--70%--aerobic exercise). The results showed that IOP decreased (1 to 8mmHg). BP increased (systolic: 0 to 60mmHg, diastolic: 0 to 15mmHg). HR increased as well (15 to 80 pulses/min). IOP decreases all after the jogging [17].

Dynamic exercise changes Ocular perfusion pressure (OPP), and produces increased tissue blood flow in the retina in the immediate postexercise period, while blood flow increases more persistently in the choroid-retina. Difference in control of blood flow in these two regions may be related to stronger autoregulatory mechanism of blood flow in the retina. Nitric oxide may play a role in the regulation of blood flow [18].

Researchers found that regular physical exercise can reduce IOP by as much as 4mmHg; where this reduction may be enough to protect the retinal ganglion from damage. In addition to the acute-phase IOP lowering effect of exercise, consistent exercise programs decrease ocular pressure in long term [1].

In a recent study, it was observed that people with glaucoma who exercised regularly for three months reduced their IOPs an average of 20%. These people rode stationary bikes 4 times per week for 40 minutes. Measurable improvements in eye pressure and physical conditioning were seen at the end of three months. These beneficial effects were maintained by continuing to exercise at least three times per week; lowered IOP was lost if exercise was stopped for more than two weeks [19].

Hilton (2003) [1] mention that there are two primary responses occur in the eye as a result of exercise: 1) IOP decreases; 2) Ocular blood flow alters. In the eye, exercise is associated with a decrease in IOP and this has been demonstrated by a number of studies.

Material and Methods

Fifteen normal subjects were enrolled in this study, they were chosen from the employees in the Police Hospital in Assuit. (10 women and 5 men), All subjects were with age ranges between 30-40 years, with normal Body Mass Index (BMI) <30 Kg/m².

All the subjects underwent evaluation procedures that include: (BMI) using Weight and Height Scale, Complete eye examination done by ophthalmologist to exclude any ophthalmic condition that might interfere with (IOP) measures. Also measuring (IOP) by using Goldman applanation tonometer.

Procedures: The IOP was measured at baseline and after 3-months of treadmill training in the periods before the exercise and 30 minutes after exercise, where the training program was in the form of controlled walking exercise on the treadmill (Enraf Nonius, EN-TRED) with frequency of 3 sessions/week for 12-weeks. Each training session lasted for 40 minutes; 10 minutes warming up and actual training period for 20 minutes followed by 10 minutes cooling down. The actual training period was in the form of walking with a speed that were be increased slowly on an individual basis until the heart rate reached 140 beats/minute-(by using pulsometer)-that was proved to induce ocular perfusion changes [20].

For each patient, matters to be taken in consideration that the exercise will be stopped when any symptom limiting exercise appears as chest pain, leg pain, fatigue, dyspnea, disturbance in breathing or heart rates.

Results

Table (1): Subject criteria at baseline.

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
</tr>
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<tbody>
<tr>
<td>Number/Sex</td>
<td>15 healthy subjects</td>
</tr>
<tr>
<td></td>
<td>10 women and 5 men</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>36.3±2.2</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>78.4±9.1</td>
</tr>
<tr>
<td>Height (cm.)</td>
<td>162.8±4.7</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>28.42±2.6</td>
</tr>
</tbody>
</table>

BMI: Body mass index.  
SD : Standard deviation.
Table (2): Statistical analysis for Intraocular pressure of the right and left eyes throughout the study.

<table>
<thead>
<tr>
<th></th>
<th>Pre-exercise</th>
<th>After 30min.</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right eye</td>
<td>Left eye</td>
<td>Right eye</td>
<td>Left eye</td>
</tr>
<tr>
<td>At Baseline</td>
<td>15.4±3.4</td>
<td>14.8±3.3</td>
<td>13.2±2.9</td>
<td>13.2±2.6</td>
</tr>
<tr>
<td>After 3-months of training</td>
<td>13.3±2.3</td>
<td>13.7±3.3</td>
<td>12.6±1.9</td>
<td>12.2±2.4</td>
</tr>
<tr>
<td>t-value</td>
<td>–3.993</td>
<td>–2.402</td>
<td>–1.913</td>
<td>–1.329</td>
</tr>
<tr>
<td>p-value</td>
<td>0.000*</td>
<td>0.056</td>
<td>0.001*</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

Min.: Minutes. *: Significant.

Discussion

Here came the importance of (Prevention is better than cure).

In a study by Green et al., [21], findings showed the effect of exercise training on endothelium-derived nitric oxide function in humans where its results clarified that the vascular endothelial function is essential for maintenance of health of the vessel wall and for vasomotor control in both conduit and resistance vessels. Exercise training has been shown to augment endothelial, nitric-oxide-dependent vasodilation in both large and small vessels.

Recent studies also indicate that exercise training may improve endothelial function by up-regulating endothelial nitric oxide (eNOS) protein expression and phosphorylation. While improvement in NO vasodilator function has been less frequently found in healthy subjects, a higher level of training may lead to improvement [21].

On comparing the findings of the present study about the effect of exercise on mean arterial blood pressure and its direct relation with IOP it came in consistent with the findings of Ismail et al., 1998 [13] that declared that exercise lead to significant decrease in IOP in normal and hypertensive patients which in turn returned to its initial value within 60 minutes.

In the present study, the impact of 3-months treadmill exercise is the most important variable that plays an important role in adjusting intraocular pressure. That was in consistent with the results of a study by Silver and coworkers, [22] that reported an increase in blood flow of the ophthalmic artery, which is accompanied by a decrease in IOP following acute exercise.

In contrast, a separate study by Nemesure, et al., [6] which used color Doppler ultrasound imaging to measure blood flow velocities of the ophthalmic artery and central retinal artery in healthy volunteers before and after exercise, showed decreased blood flow in the ophthalmic artery, while blood flow in the central retinal artery remained stable. The authors concluded that efficient autoregulatory mechanisms existed for retinal blood flow, which was kept constant during the altered cardiac state, but not for the ophthalmic artery.

It was evident that there were many factors that determine the decrease in intraocular pressure (IOP) that occurs during dynamic exercise as mentioned by Harris et al., [23] in a study about correlated factors that involved in the decrease in IOP during acute dynamic exercise and with comparison
of the IOP response of trained and sedentary subjects, where the results declared that: Acute dynamic exercise lowers IOP in a graded fashion proportional to relative, not absolute, work load. The IOP decline is correlated with blood lactate but not with PCO₂ or plasma osmolality changes.

On the other hand, many studies regarded the relationship between physical fitness and IOP as claimed by Dane et al., [24] that acute exercise increased IOP in male athletes, but had no effect in sedentary men. Also, it decreased IOP in sedentary women, but had no effect in female athletes. Sex and physical fitness both were significant factors influencing the changes in IOP due to exercise. These results suggest that acute dynamic exercise is useful to decrease IOP in sedentary women, but not in male athletes.

Hilton, [1], claimed that the reason why exercise results in reduced IOP in terms of the eye, this correlation offers three explanations for the reduced IOP.

1- Ocular dehydration may occur through osmotic changes in the retinal and uveal vasculature.

2- An increase in colloid osmotic pressure may reduce aqueous formation via reduced ultrafiltration and hence IOP.

3- Altered colloid osmotic pressure could act directly on the hypothalamus resulting in IOP reductions through an unspecified reflex response.

In one study, jogging for 20 minutes lowered IOP by 1mmHg to 8mmHg. In another, weight lifting also led to decreases in IOP, with IOP dropping by 14.5% after the third set of chest presses and 13.2% after the third set of leg presses. While the jogging and weight training studies were conducted in healthy, athletic people without glaucoma, exercise has also been found to benefit sedentary people with ocular hypertension. For instance, three months of moderate exercise for nine sedentary people suspected of having glaucoma decreased mean IOP by 4.6mmHg (20% for these particular patients). Simply going for a walk three or more times a week is all you need to protect against glaucoma progression [25].

Conclusion: Overall, exercise has been found to lower IOP. Studies also have found that it improves blood flow to the retina and optic nerve.

References


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