Magnitude of Decrease in Intraocular Pressure Depends upon Intensity of Exercise

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The present study was planned to investigate the relationship between the magnitude of intraocular pressure (IOP) reduction after short-duration exercise and the intensity, duration and quantity of exercise in healthy subjects. Twenty-five healthy, sedentary male of the same age group, performed exercises at the levels of 80%, 60%, and 40% maximum heart rate (HRmax) for 15 minutes, 80%HRmax for 7.5 minutes, 60%HRmax for 10 minutes, and 40%HRmax for 30 minutes. IOP was measured with the Goldmann applanation tonometer. The IOP reduction at 5 minutes after 15 minutes of exercising at 80%HRmax, 60%HRmax, and 40%HRmax were 4.7 ± 0.9, 3.5 ± 0.7, and 0.9 ± 0.4 mmHg, respectively. At five minutes, after exercising 7.5 minutes at 80%HRmax, 10 minutes at 60%HRmax, and 30 minutes at 40%HRmax, IOP reduced by 4.5 ± 0.7, 3.3 ± 0.9, and 2.9 ± 1.1 mmHg, respectively. This study concludes that intensity of exercise seems responsible for the magnitude of the initial IOP decrease after short-term exercise. Furthermore, it seems that other factors such as duration of exercise or quantity of exercise, blood pressures, body mass index are not related to the amount of the initial fall in IOP.

Key words: exercise, exercise intensity, exercise quantity, intraocular pressure, tonometry.

INTRODUCTION

Endurance physical training such as cycling, swimming and running increases a persons maximum capacity for aerobic exercise and causes adaptations in different systems of the body. In recent years it has been noted that intraocular pressure is a dynamic function and is subject to changes occurring in many body systems. Intraocular pressure (IOP) is known to be sensitive to changes occurring in many body systems. In the results of previous studies, may be due to negligence of above mentioned factors. Exercise can be measured in terms of intensity and duration. The

varies with age, sex, and diurnally. It has been reported that drinking of water, coffee, or alcohol before measurement significantly increases IOP. It has been shown that IOP is positively related with systemic blood pressure. Acute hyperglycaemia decreases, while chronic hyperglycaemia in diabetes increases IOP. Moreover, seasonal variations also have significant effects on intraocular pressure.

Several studies have shown that intraocular pressure decreases in response to short term exercise. However, the amount of decrease differs from study to study. The variability in the results of previous studies, may be due to negligence of above mentioned factors. Exercise can be measured in terms of intensity and duration. The

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quantity of exercise is expressed as exercise intensity times exercise duration. The present study was planned to investigate the relationship between the magnitude of IOP reduction after short-duration exercise and the intensity, duration and quantity of exercise in healthy subjects, after taking into account the above mentioned factors. Moreover, we also investigated whether or not any relation between exercise induced IOP change and other physiological factors exist.

**MATERIALS AND METHODS**

All experimental procedures adhered to the Declaration of Helsinki of the World Medical Association. Twenty-five healthy male volunteers, aged 21 to 26 years (mean 23.4 years, SEM 0.6), were recruited from the Karachi University. They have not done any regular exercise for the last three months. The criteria met by all the participants of this study were: absence of ocular complaints including refractive errors; absence of any history of eye surgery and diabetes; normal body temperature and blood pressure. The effect of cigarette smoking on IOP is less clearly established. Mehra et al. reported an acute rise of intraocular pressure, but Bahna and Bjerkedahl failed to find any effect of cigarette smoking on IOP. To exclude any possible effect of cigarette smoking, we chose those subjects that have not smoked at least from last six months. All the subjects were in good health and no one was taking any medicine. A transport service was provided to each subject to avoid any delay or exertion and they were asked not to do any hard work after awakening. To avoid the effect of acute hyperglycemia, the subjects were asked not to have breakfast or any form of drink before the test. Each subject was tested between 08:00 and 09:00 hours to minimize the effect of diurnal variations. Testing was performed after a complete rest of 15 minutes in supine posture. Before the start of test, resting blood pressure and heart rate were measured in sitting position. After instillation of 0.25% fluorescein sodium and 0.4% benoxinate hydrochloride (fluress) eye drops, IOP was measured with the Goldmann applanation tonometer (Goldmann Topocon, Germany), first in the right eye and then in the left. Three consecutive readings of each eye were taken, as has been previously described.

The percentage of maximum heart rate (%HRmax) was used to determine the difficulty level of the exercise. The %HRmax was expressed as follows:

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\%HR_{\text{max}} = \frac{HR \text{ during exercise} - HR \text{ at resting}}{\text{Maximum HR} - HR \text{ at resting}} \times 100
\]

Maximum heart rate was obtained from 190 minus age. The laboratory temperature was 20°C. In the present study riding a bicycle ergometer was chosen for two reasons: the feasibility of examining the heart rates during exercise, and because this form of activity is well accepted as a means for calibrated levels of physical exercise. Each subject was tested six times by different exercise tests at an interval of one week. The tests were applied in the same order. Each subject performed exercises at the levels of 80%, 60%, and 40%HRmax for 15 minutes, 80%HRmax for 7.5 minutes, 60%HRmax for 10 minutes, and 40%HRmax for 30 minutes. During exercise, heart rates were measured by palpation for 20 seconds and exercise load was increased until the individually prescribed heart rate was achieved. During the exercise, heart rates were confirmed three times. Blood pressures and heart rates were measured immediately after exercise. A compulsory five-minute cool down period was given to all subjects followed by IOP measurements.

Maximal oxygen uptake (VO₂ max) represents the maximal circulatory transport of oxygen from the lungs to the metabolically active tissues. Because the circulatory transport of oxygen is achieved both by cardiac output and by peripheral extraction, VO₂ max is the best physiological reference for functional capacity of the circulation and is a standard measure of cardiovascular fitness. In this study physical fitness was evaluated by the measurement of maximum oxygen uptake (ml/kg/min) with a Beckman O₂ analyzer (Beckman Instruments Inc. Irvine, Calif. U.S.A.), as described by Astrand and Rodahl.

**Statistical Analyses**

The mean of the three readings was computed separately for each eye. For all variables descriptive
statistics (mean, standard deviation, standard error of mean) were calculated by Statistical Analysis System 76. All data are expressed as mean and standard error of the mean. The mean IOP difference from the baseline IOP value was compared at each measurement point using the two-tailed paired t-test. Analysis of variance (ANOVA) was used to compare results between experiments. Differences are regarded as significant when the P value was less than 0.05. Actual P values are also given. Multiple linear regression analysis was used to assess correlations between IOP changes and other physiologic factors.

RESULTS

All of the subjects completed all the six experiments. Resting IOP levels, resting heart rates, and blood pressure before and after exercises of different intensities are displayed in the Table 1. The mean resting heart rates of subjects showed no significant change during this study. As compared to baseline, systolic blood pressure was significantly higher after 15 minutes of exercising at 80%HRmax. Blood pressure under other exercise conditions showed no significant difference between the baseline and immediately after exercise. The maximal \(O_2\) uptake were found to be 39.2 ± 4.7 and 39.6 ± 4.4 ml/kg/min, before and after study periods respectively. As assessed by maximal \(O_2\) uptake, the physical fitness of the subjects did not change during study period.

The effects of exercises on IOP are shown in Figures 1-4. The effects of exercise were found to be similar on two eyes of each pair, therefore, the data of only right eyes is given. The IOP reduction at 5 minutes after 15 minutes of exercising at 80%HRmax, 60%HRmax, and 40%HRmax were 4.7 ± 0.9, 3.5 ± 0.7, and 0.9 ± 0.4 mmHg respectively. At five minutes, after exercising 7.5 minutes at 80%HRmax, 10 minutes at 60%HRmax, and 30 minutes at 40%HRmax, IOP reduced by 4.5 ± 0.7, 3.3 ± 0.9, and 2.9 ± 1.1 mmHg, respectively.

In every subject tested, aerobic exercise produced an acute drop in intraocular pressure, although there was a considerable variation in the amount of fall and duration of post-exercise recovery. Changes in magnitude of systolic or diastolic blood pressures did not correlate with the changes in the level of intraocular pressure. No relation between decreased intraocular pressures and body weight or body mass index was found.

DISCUSSION

This paper reports a rarely studied phenomenon and the results are relevant to planning trials in glaucoma where intraocular pressure is a major outcome measure. In the present study, IOP

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<th>Table 1. Resting intraocular pressure and physical characters before and after exercises of different intensities.</th>
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<tr>
<td>Intensity (%HRmax)</td>
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<td>duration (min)</td>
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<td>Resting intraocular pressure (mmHg)</td>
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All values are expressed as mean ± s.e.m., *p <0.01 as compared to pre-exercise level.
reduction at 5 minutes after 15 minutes of exercising at 80% HRmax, 60% HRmax, and 40% HRmax were found to be 4.7 ± 0.9, 3.5 ± 0.7, and 0.9 ± 0.4 mmHg, respectively. This clearly shows that with the increase of exercise intensity, magnitude of IOP reduction also increases. Decrease in IOP was found to be 4.5 ± 0.7 mmHg, after exercising for 7.5 minutes at 80% HRmax. This IOP reduction is statistically the same as after 15 minutes of exercising at 80% HRmax, i.e., 4.7 ± 0.9 mmHg. Exercising at 60% HRmax for 15 and 10 minutes, decreased IOP 3.5 ± 0.7 and 3.3 ± 0.9 mmHg, respectively. Although, durations are different, but decreases are statistically the same.

Thus, when the exercise intensity is unchanged, exercise duration may not have any effect on IOP reduction.

Since the quantity of exercise is expressed as exercise intensity times exercise duration, thus, exercising for 7.5 minutes at 80% HRmax, 10 minutes at 60% HRmax, and 15 minutes at 40% HRmax, are the same quantities of exercise. All consume the same amount of energy. But in the present study, after exercising 7.5 minutes at 80% HRmax, 10 minutes at 60% HRmax, and 15 minutes at 40% HRmax, IOP reduced by 4.5 ± 0.7, 3.3 ± 0.9, and 0.9 ± 0.4 mmHg, respectively. The results of present study showed that among these

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**Fig 1.** Intraocular pressure reduction after 15 minutes of exercising at 80% HRmax (A), 60% HRmax (B), and 40% HRmax (C). Symbol (●) corresponds to the mean and the vertical lines above and below the symbol represent one standard error of mean.
Fig 2. Intraocular pressure reduction after exercising of 7.5 minutes at 80%HRmax.

Fig 3. Intraocular pressure reduction after exercising of 10 minutes at 60%HRmax.

Fig 4. Intraocular pressure reduction after exercising of 30 minutes at 40%HRmax.

three conditions of the same quantity of exercise, the IOP changes were significantly different. The difference between IOP change after exercising 7.5 minutes at 80%HRmax and 10 minutes at 60%HRmax was significant at the level of p < 0.05. The difference between IOP change after exercising 10 minutes at 60%HRmax and 15 minutes at 40%HRmax was found to be significant at the level of p < 0.001. Similarly, exercising for 15 minutes at 80%HRmax and 30 minutes at 40%HRmax are the same quantities of exercise. exercising for 15 minutes at 80%HRmax decreased 4.7 ± 0.9 mmHg, while exercising for 30 minutes at 40%HRmax decreased 2.9 ± 1.1 mmHg. The difference between IOP change after exercising 15 minutes at 80%HRmax and 30 minutes at 40%HRmax was significant at the level of p < 0.001. Therefore, these results of present study clearly showed that quantity of exercise does not determine the magnitude of IOP decrease. This study concludes that intensity of exercise alone is responsible for the magnitude of the initial IOP decrease after short-term exercise. Moreover, results of this study support the idea that factors such as duration of exercise or quantity of exercise is not related to the amount of the initial fall in IOP.18

Pasco et al.,19 had demonstrated that physical fitness significantly reduces resting IOP level and attenuates the hypotensive response to short-duration maximal aerobic exercise. VO2 max is the best physiological reference for functional capacity of the circulation and is a standard measure of physical fitness.16 Our results were not influenced by physical fitness, because the VO2 max remained the same before and after the study periods. Numerous studies have demonstrated that intraocular pressure in normal volunteers decreases after exercise.8-12, 19 The amount of decrease reported differs from study to study because of several variables, including age,2 diurnal,3 and
seasonal variations. This study concludes that intensity of exercise also plays a very important role in determination of IOP decrease and needs to be controlled in future research.

In every subject tested, aerobic exercise produced an acute drop in intraocular pressure, although there was a considerable variation in the amount of fall and duration of post-exercise recovery. We attempted to associate decreased intraocular pressures with pre- and post-exercise hemodynamic factors such as heart rate or maximum systolic or diastolic blood pressure, but no such relationship has been confirmed. This result is the same as reported by Passo et al. We also attempted to associate decreased intraocular pressures with body weight and body mass index, but failed to find any such relation.

The physiological mechanism responsible for the decrease of intraocular pressure during exercise is not clearly known. Although we did not measure the hormonal changes before and after short duration aerobic exercise, but the existing literature shows the influence of hormones upon intraocular pressure. There is evidence that corticotropin vasopressin, thyroxin, insulin, growth hormone, progesterone, estrogen, chorionic gonadotropin and relaxin glucocorticoids and mineralocorticoids may play a role in the physiologic regulation of intraocular pressure. Some of these hormones increase, while other decrease intraocular pressure. Stimulation of the sympathetic nervous system in anticipation of and during the stress of exercise is well documented. This causes release of large quantities of epinephrine and norepinephrine from adrenal medulla. Epinephrine, an adrenergic agonist, is widely used as an ocular hypotensive drug for the treatment of glaucoma. The fact that epinephrine lowers intraocular pressure in humans is undisputed. Epinephrine produces many of its effects by stimulating the synthesis of cyclic adenosine monophosphate (c-AMP). Although there is controversy about the effect of c-AMP on the aqueous humor production, but it has been shown that activation of c-AMP decreases intraocular pressure. It is amazing that almost any type of stress, whether physical or neurogenic, will cause an immediate and marked increase in ACTH secretion. Even a small amount of ACTH is enough to permit the adrenal glands to secrete whatever amount of aldosterone is required. The effects of ACTH, aldosterone and important catecholamines, including norepinephrine on IOP have not been investigated.

We consider it quite possible that a decrease in intraocular pressure during exercise is effected through hormonal mechanism; an effect on electrolytes or electrolyte transport enzymes may be involved. Two enzyme systems are involved in the aqueous humor secretion, which are Na/K-ATPase and carbonic anhydrase. Therefore, the antagonists of these enzyme systems can reduce the aqueous formation and hence, lower the IOP. Hormonal changes and metabolites produced during exercise can act as the antagonists of these enzyme systems. Among possible antagonists ACTH, aldosterone, and norepinephrine seem most important, since exercise changes their concentrations in blood, therefore, they are more likely to affect intraocular pressure. At this time investigation to elucidate such factors may prove a fruitful area for ophthalmic research.

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REFERENCES


