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THE EFFECTS OF AEROBIC EXERCISE ON INTRAOCULAR PRESSURE

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Abstract

Intraocular pressure (IOP) measurements were taken on nine subjects at rest and at two standardised workload levels after aerobic exercise was performed on a bicycle ergometer. The mean resting IOP was 15.22 mmHg and after four minutes of cycling at 55% of the subjects maximal aerobic capacity (VO2 max), the mean IOP dropped to 12.25 mmHg. A further four minutes of cycling at 75% of VO2 max showed a further drop to a mean IOP of 10.30 mmHg. The results of this study confirm the observation of other studies, that moderate aerobic exercise significantly lowers IOP. The implications of aerobic exercise reducing IOP in glaucoma patients is discussed.

Key words: *Non-contact tonometry, submaximal workload, glaucoma, workload intensity.*

INTRODUCTION

Reduction in intraocular pressure (IOP) related to physical exertion has been well documented.[1-6,8] It has been shown that this effect is inversely proportional to the workload intensity.[1,6] Krejci[8] reported on 17 subjects pedalling at four progressive workloads (25%, 50%, 75%, 100% of maximal aerobic exercise capacity). IOP measurements were taken when a standard heart rate level was reached for each subject. The IOP was shown to decrease from 16.6 mmHg to 12.1 mmHg in the right eye and from 17.3 mmHg to 13.3 mmHg in the left eye. Other studies have found that IOP can change with body position,[9] varies diurnally[10] and that the numerical value can be altered by the tonometry technique itself.[11]

Shapiro and Shoenfeld[7] stated that many earlier studies disregarded the influence of body position, diurnal variation, and tonometry techniques on IOP values. They concluded that when these factors are taken into consideration, and only the exercise workload level is considered, there is only a relatively small and insignificant decrease in IOP secondary to aerobic exercise.

The purpose of this study is to examine the effect of aerobic exercise on intraocular pressure using an experimental design that standardises the variables that influence IOP and also the intensity of physical exercise.

This paper was based on a research project completed as part of an undergraduate degree by Pierre Elmurr in the School of Orthoptics, Faculty of Health Sciences, University of Sydney in 1992.

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METHOD

Five male and four female sedentary students aged between 20-31 years (mean age 22.4) from Sydney University were voluntarily recruited to the study. After consenting to the experiment all subjects completed a health status questionnaire (parQ test). This questionnaire is designed to identify people for whom physical activity is inappropriate. All nine subjects were able to participate in the study and none had been previously involved in a regular exercise programme.

Aerobic exercise was performed on a bicycle ergometer. This was chosen because this form of activity is well accepted as a means of calibrating levels of physical exercise and has the flexibility of examining intraocular pressure during exercise.[7] The first two stages of the experiment were designed to ensure that each subject exercised at a standardised level. Intraocular pressure measurements were taken in the final third stage using a Keelar Pulsair non-contact tonometer.

Stage 1: Determination of relationship between heart rate, volume of oxygen, and power output (watts).

Subjects were required to perform an incremented exercise test on a ergoline cycle ergometer (model 800s) for 12 minutes. Four power outputs were used increasing by 25 watts every three minutes after commencing at 50 watts. The subjects were required to cycle at 60 RPM at all times. The heart rate was measured at rest, and every three minutes in conjunction with the increasing power output. Electrocardiograph (ECG) and respiratory gas exchange were monitored throughout testing. Figure 1 illustrates the exercise physiology set-up. Gas analysis for concentration of carbon dioxide (CO2) and oxygen (O2) in expired gas was measured using amateur gas analysers and were recorded on a online computer system.

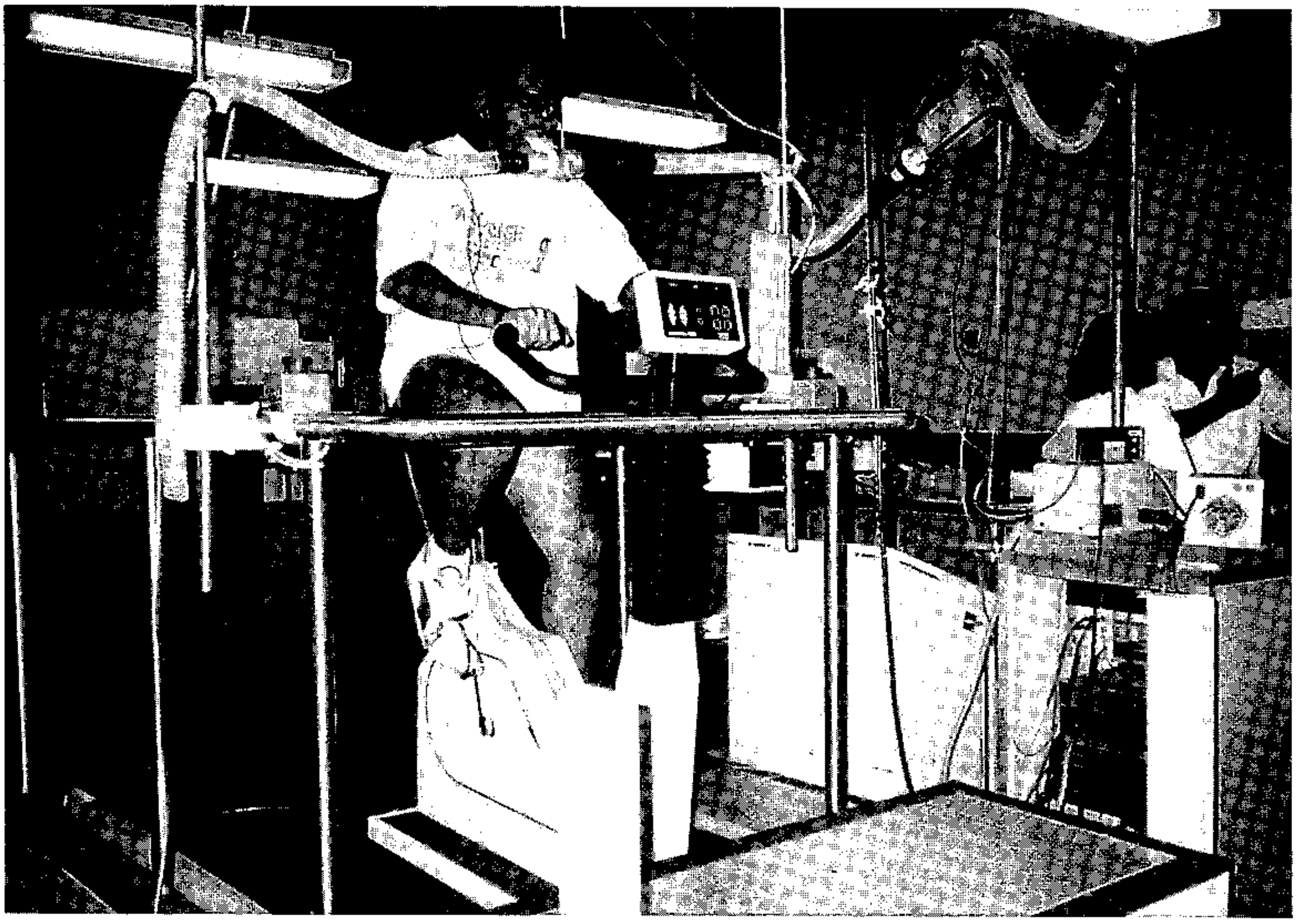

Figure 1. Stage 1 & 2: Exercise physiology set up for determination of maximal oxygen uptake (VO2 max).

Stage 2: Determination of maximal oxygen uptake. (VO2 max)

A two minute rest period was allowed, then another incremented procedure was performed. Subjects cycled with power output increased by 25 watts every minute, after commencing at 50 watts until volitional fatigue occurred. Heart rate was monitored every minute to coincide with incrementation. ECG and respiratory gas exchange were monitored as mentioned above. This procedure determines the VO2 max, which is the maximal aerobic capacity that an individual can sustain under exercise conditions before volitional fatigue. Calculations of VO2 max were performed on an online computer system.

The results from the first two stages were correlated graphically to determine the two submaximal workload intensities to be adopted in stage 3, and were set at 55% and 75% of VO2 max. Figure 2 demonstrates how these levels were determined for one subject. The four VO2 numerical values taken in stage one, every three minutes, were plotted against the equivalent power output (A at 3 min, B at 6 min, C at 9 min and D at 12 min). The VO2 max value determined in stage two was also plotted on the graph. (Figure 2 VO2 max = 26.2) The workload levels to be used in stage three were determined by calculating 55% and 75% of the VO2 max and reading from the graph the equivalent power output. For example in figure 2, 75% of 26.2 is 19.65 which corresponds to a workload level of 100 watts for that subject. This procedure was followed for all nine subjects.

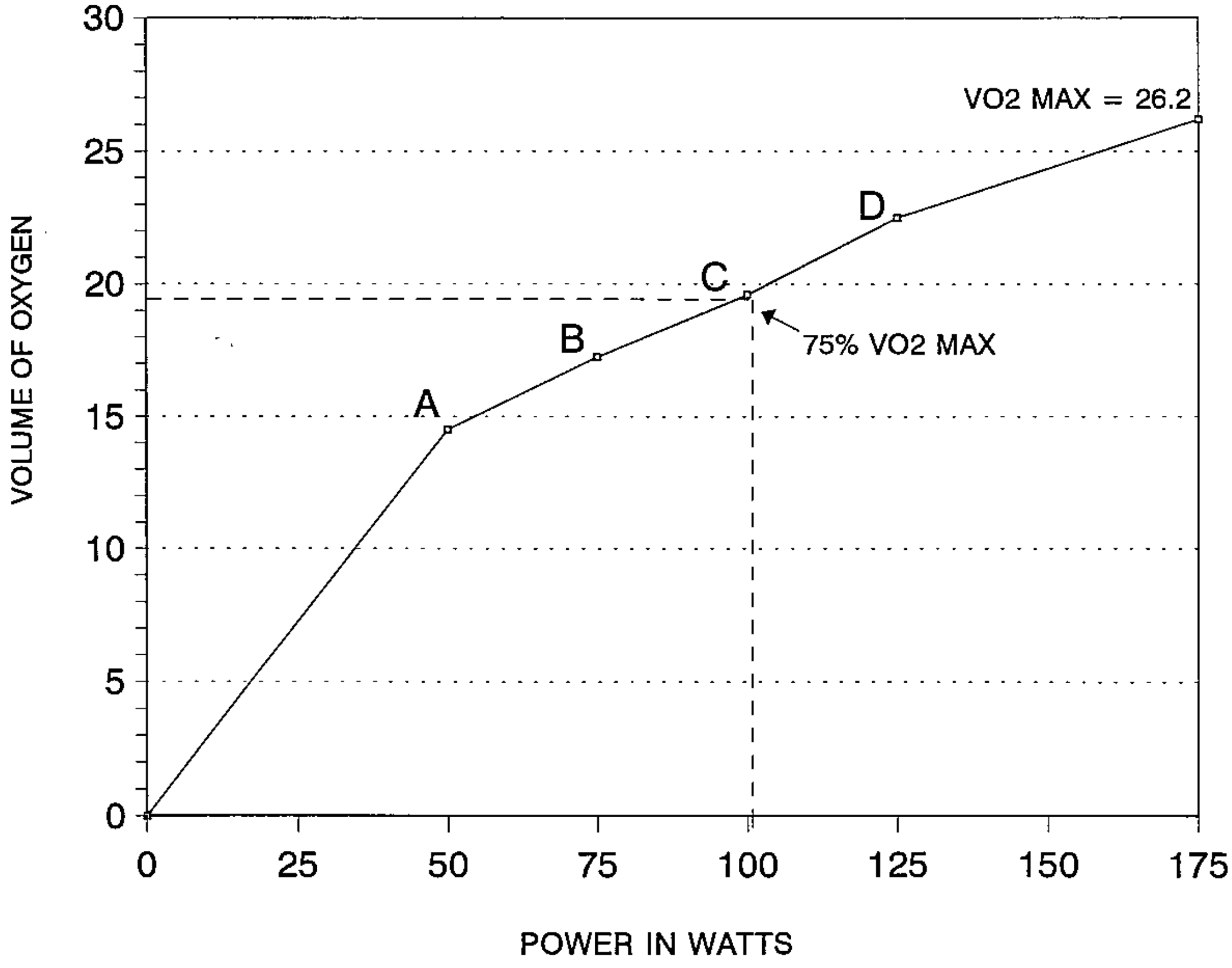

Figure 2: Determination of submaximal workloads.

Stage 3: IOP measurement.

One week later subjects were required to sit on the ergoline bike and IOP measurements were taken at rest. Four minutes of cycling was commenced with a workload equivalent to 55% of each subject's VO2 max. Four consecutive IOP measurements were taken at the end of the 4th minute. A rest period was allowed until heart rate came within 15 bpm of resting heart rate then another four minutes of cycling was commenced with a workload set at 75% of each subject's VO2 max. IOP measurements were again taken at the end of the 4th minute. Figure 3 demonstrates how the IOP measurements were taken.

The above procedure took 15 minutes to complete and all subjects were tested at the same time of day. Heart rate was monitored every minute, blood pressure before and after each four minute interval, and ECG was monitored throughout the procedure.

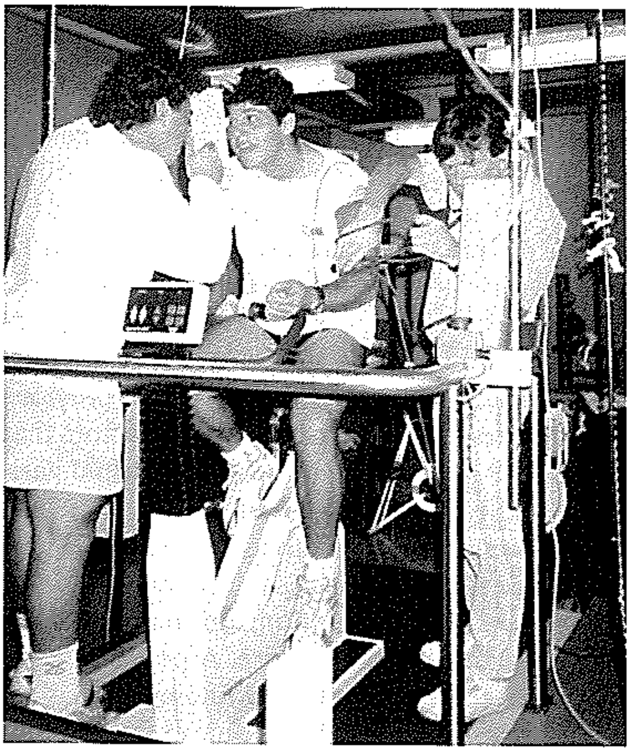

Figure 3: Measurement of IOP during stage 3.

RESULTS

The mean heart rate and blood pressure levels obtained in stage three indicated that an appropriate level of aerobic exercise was achieved for the testing procedure.

When IOP was compared between eyes of the same subject no statistical difference was found. This enabled the measurement of IOP for right and left eyes to be combined for each subject in the statistical analysis. A two paired T test was used and alpha was set at the conventional level of .05.

Mean resting IOP was 15.22 mmHg. At the end of the first workload level (55% of VO2 max) the mean IOP had dropped to 12.25 mmHg. At the end of the second workload level (75% of VO2 max) the mean IOP had dropped to 10.30 mmHg. Table 1 tabulates these results. The decrease in IOP from rest to the first workload level: 55% VO2 max ($t = 6.49$), from rest to the 2nd workload level: 75% VO2 max ($t = 10.61$), and from the first to the second workload level ($t = 7.91$) were all found to be statistically significant ($p < .0001$ level).

DISCUSSION

It is well known that a change in body position can cause a change in IOP.[9] All measurements in this study were taken in the sitting position whilst the exercise was performed so that the effect of body position on IOP was controlled.

Over the course of the day IOP varies an average of 3 mmHg to 6 mmHg in normal individuals.[13,14] These diurnal changes can occur over as short a period as 20 minutes.[15] All measurements were taken at the same time of day for all subjects and the testing procedure took no longer than 15 minutes to complete. Taking four consecutive measurements of each eye has been shown to produce accurate and precise results.[16] Non-contact tonometry was used in preference to contact tonometry as the latter tends to distort

TABLE 1
Mean IOP measurement at rest, 55% and 75% of VO2 max

Exercise Intensity	Mean IOP (mmHg)	Standard Deviation	Difference in IOP (mmHg)
Rest	15.22	2.34	2.97
55% VO2 max	12.25	2.13	
Rest	15.22	2.34	4.91
75% VO2 max	10.30	1.94	
55% VO2 max	12.25	2.13	1.94
75% VO2 max	10.30	1.94	

results because the instrument itself alters the steady state condition of the eye during repeated IOP measurements.[17,18]

Reduction of IOP following aerobic exercise noted in this study confirms previous findings.[1-6,8] A quantitative comparison between the results of this study with previous work is difficult because of the differences in methods used. The form of aerobic activity, workload intensities used, and type of tonometry measurement vary in each study. Additionally some previous research designs have not controlled factors that affect IOP levels, such as posture, diurnal variation and tonometry technique.

It is interesting to note that Shapiro et al.[7] who controlled similar variables to this study, did not find a significant relationship between IOP reduction and aerobic exercise. A possible explanation for these contradictory findings is that the intensity levels set for the aerobic exercise workload were too low to produce a significant drop in IOP. This highlights the apparently important relationship between IOP and aerobic exercise intensity.

Passo, Goldberg, Elliot, and Buskirk[19] investigated the implication of a reduction in IOP with exercise. Nine sedentary subjects suspected of having glaucoma were observed before and after three months of aerobic exercise training. The mean IOP had decreased by 4.6 mmHg at the end of the conditioning period. With cessation of exercise IOP returned to elevated preconditioned levels by three weeks. They concluded that regular aerobic exercise is associated with a reduction in elevated IOP and may represent an effective non-pharmacologic intervention for patients suspected of having glaucoma. It is important to recognise that recent physical exertion may mask increased IOP in patients presenting for routine examination. They suggest that an exercise history be taken to determine IOP dynamics more accurately. Changes in exercise status should also be monitored in routine glaucoma care, just as changes in pharmacologic therapy are made.

The physiological mechanisms responsible for the reduction of IOP are not clear. It has been suggested[2-4,6-8] that IOP decreases when blood pH and venous pressure decrease and CO2, lactate and osmolarity increase. Aerobic training has been shown to reduce catecholamine levels, especially norepinephrine concentrations.[20] Regular exercise also enhances the parasympathetic-sympathetic input ratio at rest, increasing relative acetylcholine-norepinephrine release.[20-22] These autonomic changes that accompany regular exercise may favour reduced IOP. These two mechanisms appear to be related to improved facility of outflow through the anterior chamber within the eye.

CONCLUSION

It appears that some physiological mechanism is responsible for IOP reduction immediately following aerobic exercise. Further study is required to understand the mechanism of action of this acute change and the role of aerobic exercise as a non-pharmacological alternative therapy to lowering IOP in glaucoma patients.

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