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The effect of dynamic and isometric exercise on refractive state, accommodation and intra-ocular pressure

Abstract

Introduction: Several studies have demonstrated that an increase in the number of hours children spend outdoors is associated with reduced myopia progression One suggestion is that physical exercise could affect refractive development, either through a change in the accommodative response or IOP. This study evaluated the effect of both isotonic and isometric exercise on these ocular parameters.

Methods: 20 young, healthy subjects participated in 3 trials. In the first trial, subjects spent 10 minutes exercising on a stair climbing machine while in the second session, they were required to maintain an unsupported squat position for a continuous 2 minute period. In a control condition, subjects watched television in a seated position for 10 minutes. Before and immediately after each trial, the following parameters were measured: (i) systolic and diastolic BP, (ii) heart rate, (iii) distance refractive state, (iv) accommodative response to 3, 4 and 5D stimuli and (v) IOP. In a second study, IOP was assessed both before and during (while the subject was still in the squatting position) 1 minute of isotonic exercise in 14 young, healthy subjects.

Results: A significant increase of 32 mmHg in systolic BP was observed following the stair climbing exercise while significant increases in heart rate were recorded following both the stair climbing and squatting trials. However, no significant changes in IOP, distance refractive state or accommodative response were noted following any of the 3 conditions. In the second study, mean IOP before and during the squatting exercise was 14.6 and 19.1 mm Hg, respectively ($p < 0.0001$).

Conclusion: Brief periods of exercise do not produce significant changes in refractive state, accommodation or IOP. Although a significant change in IOP was observed during the course of isometric exercise, this effect dissipated rapidly. While a cumulative effect may exist following longer or multiple exercise sessions, there is no support for the proposal that physical exercise will alter refractive state development or progression.

Keywords: exercise, refractive state, accommodation, intra-ocular pressure, myopia, glaucoma

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Abbreviations: IOP, intra-ocular pressure; BP, blood pressure

Introduction

Myopia occurs in approximately 41.6% of adults in the United States,[1] and the associated costs of examination and treatment per annum between 1999 and 2002 were estimated to be between \$3.9 and \$7.2 billion.[2] It is likely that this number has now increased significantly. When considering the high prevalence and associated costs, together with ocular conditions such as glaucoma, cataract and retinal detachment that are associated with myopia,[2] it is clearly important to find preventative or therapeutic modalities that may slow or stop the development and progression of this refractive condition.

A number of studies have suggested that participation in physical endeavors may have a limiting effect on myopia development and progression.[3–7] For example, Jones et al.[3] compared eventual myopes (as determined by parental surveys) and non-myopes within a group of third grade children (around 9 years of age), noting that the mean amount of sports and outdoor activities performed by the future myopes and non-myopes was 7.98 hours per week and 11.65 hours per week, respectively ($p<0.0001$). In addition, Deere et al.[7] compared physical activity and refractive error in children and found that myopes spent significantly less time undertaking moderate to vigorous physical activity when compared with non-myopic children. Similarly, Jacobsen et al.[6] noted that the mean amount of physical activity undertaken by groups of myopic and non-myopic students was 51 and 60 min/day, respectively ($p=0.05$). These authors suggested that the protective effect of 1 hour of physical activity was equivalent to the detrimental effect of 3 hours of studying.

However, the mechanism underlying this negative association is unclear. One possibility is that physical exercise could affect refractive development, either through a change in the accommodative response or IOP. For example, Read and Collins[8] observed a significant decrease in axial length ($P<0.0001$) and IOP ($P<0.0001$) following dynamic exercise (10 minutes on a bicycle ergometer). In addition, a significant positive association was found between the changes in axial length and IOP ($P<0.0001$).

The effect of exercise on IOP has been well studied.[8–24] Although the majority of studies agree that dynamic exercise produces a decrease in IOP,[8–13] no consensus was found for the effect of isometric exercise (i.e., static strength training where the joint angle and muscle length do not change during the contraction). Previous reports have observed either a significant increase,[14–19] decrease[11,20] or no change in IOP[21–24] following isometric exercise. As noted earlier, increased IOP has also been associated with axial growth, with scleral creep possibly resulting from an inability to resist these intra-ocular forces. As an alternative hypothesis, sustained accommodation may lead to increased IOP and ultimately axial elongation.[25–42] It is also of interest that improved physical fitness is associated with lower baseline IOP as well as decreased exercise-induced reduction in IOP.[11] Accordingly, the aim of the present study was to evaluate the effect of both dynamic and isometric exercise on a range of ocular parameters, including refractive state, accommodation, and IOP.

Methods

20 healthy subjects (4 male, 16 female) between 22 and 28 years of age (mean age=24 years) participated in the first study. The gender imbalance reflects the composition of the student body at the SUNY College of Optometry. Any subject with a history of cardiovascular disease, high BP or having been advised not to undertake strenuous exercise was excluded. Subjects provided written consent to participate after a full explanation of the study objectives and risks involved. The protocol was approved by the Institutional Review Board at the SUNY College of Optometry.

Each subjects participated in 3 trials, namely: aerobic exercise, isotonic exercise, and a control condition. The trial order was randomized, and each trial was separated by a 10 minute rest period. In the aerobic exercise trial, subjects spent 10 minutes exercising on a stair climbing machine, namely the Phoenix Denise Austin 99120 Mini Stepper Plus (Phoenix Health & Fitness, Inc., Rancho Cucamonga, CA), while watching television at a viewing distance of 3 meters. Subjects were instructed to keep moving and exercise as rigorously as they could on the stair climber throughout the 10 minute period. For the isotonic exercise trial, subjects maintained an unsupported static squat position with knees flexed to a 90° angle for a continuous 2 minute period while watching television at 3 meters. In the control condition, subjects watched television at 3 meters while seated for a 10 minutes. For all 3 trials, subjects watched clips of a movie of their choice.

Before and immediately after each trial, the following parameters were measured: heart rate, systemic and diastolic BP, IOP, distance refractive state, and the accommodative response to 3, 4 and 5D stimuli. For all trials these parameters were measured in the order indicated above (although heart rate and BP were measured simultaneously). All ocular measurements were taken from the right eye only. These same measurements were repeated immediately after each trial. Given that it took approximately 3 minutes to complete all measurements, the accommodative findings were recorded approximately 1-2 minutes after the exercise period was concluded.

Heart rate and BP were assessed using an automatic Omron HEM-432CN2 digital BP monitor (Omron Healthcare, Bannockburn, IL) positioned on the subject's right arm. All measurements were recorded while subjects were seated. Both distance refractive state and accommodation to 3D, 4D, and 5D stimuli were measured objectively using a Grand Seiko WAM-5500 auto refractor (Grand Seiko, Hiroshima, Japan). Subjects were instructed to fixate the lowest line they could read correctly on a Snellen acuity chart (under binocular viewing conditions) at viewing distances of 6 m, 33 cm, 25 cm, and 20 cm. 20 readings were recorded from the right eye at approximately 0.5s intervals over a 10 second period. These readings were converted to spherical equivalent (i.e., sphere + ½ cylinder power) and subsequently averaged to obtain the mean refractive state. The accommodative response was quantified as the difference between the refractive findings for the distance and near conditions.

IOP was assessed with a handheld Tonopen tonometer (Reichert Technologies, Depew, NY). One drop of 0.5% proparacaine hydrochloride was instilled in the subject's right eye prior to the IOP assessment. Measurements were taken approximately 30s following instillation of the topical anesthetic agent. The tonometer takes 10 measurements and averages them to give both a mean IOP measurement as well as a confidence interval for the findings. Values having confidence intervals below 90% were rejected and re-measured. In a second study, IOP was assessed both before and during the isotonic exercise trial. 14 healthy subjects between 23 and 28 years of age (mean age=24 years) participated. The isotonic exercise (maintained an unsupported static squat position) and method of measuring IOP was identical to that described above. However, IOP was measured both before and after 1 minute of isotonic exercise (i.e., while the subject was still in the squatting position).

Results

Measurements obtained before and following a 10 minute period of aerobic exercise are shown in (Table 1). A significant increase in systolic BP (t=10.28;df=17; p< 0.0001) and heart rate (t=9.93;df=17;p<0.0001) was observed following the aerobic exercise trial. No significant change in any of the other parameters measured was found. With regard to the isotonic exercise trial, a significant increase in heart rate (t=4.41; df=17; p=0.05) was observed. No significant change in any of the other parameters measured was found. Additionally, no significant changes were recorded following the control condition. In the second study, mean IOP before and during the squatting exercise was 14.6 mm Hg (SD=2.31) and 19.1 mm Hg (SD=2.93), respectively. This difference was significant (t=5.70; df=13; p<0.0001).

Table 1 Pre- and post-task measurements following either: (i) a 10 minute period of exercise on a stair climbing machine (stairs), a 2 minute period maintaining an unsupported squat position (squats), and a 10 minute control period of watching television while seated (TV). Figures in parentheses indicate 1 SEM

	Pre-stairs	Post stairs	p=	Pre-squats	Post squats	p=	Pre-TV	Post-TV	p=
Systolic BP (mm Hg)	110.8 (2.89)	143.2 (3.12)	<0.0001	114.4 (3.35)	119.2 (2.92)	0.17	110.9 (3.54)	108.4 (2.47)	0.23
Diastolic BP (mm Hg)	67.2 (2.08)	73.2 (3.1)	0.09	67.7 (2.11)	68.7 (2.60)	0.68	69.4 (2.71)	70.4 (2.47)	0.49
Heart Rate (beats per minute	64.4 (2.71)	104.2 (4.11)	<0.0001	72.9 (3.22)	82.7 (4.04)	0.05	74.6 (3.32)	70.3 (2.44)	0.14
Distance refractive error (D)	-0.1 (0.16)	-0.1 (0.15)	0.34	-0.1 (0.16)	-0.1 (0.16)	0.47	-0.2 (0.17)	-0.1 (0.15)	0.25
IOP (mm Hg)	16.8 (0.98)	16.4 (0.77)	0.45	17.4 (0.85)	16.6 (0.90)	0.17	16.3 (0.95)	17.8 (0.96)	0.1
Accom. response to 3D stimulus (D)	2.1 (0.16)	2.1 (0.15)	0.4	2.1 (0.17)	2.0 (0.13)	0.98	2.0 (0.17)	2.0 (0.14)	0.43
Accom. response to 4D stimulus (D)	3.0 (0.16)	2.9 (0.16)	0.51	2.7 (0.137)	3.0 (0.15)	0.28	2.9 (0.19)	3.1 (0.14)	0.1
Accom. response to 5D stimulus (D)	3.9 (0.18)	3.9 (0.16)	0.73	3.9 (0.17)	4.0 (0.14)	0.21	3.7 (0.18)	4.0 (0.17)	0.13

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Discussion

This study found that brief periods of exercise do not produce significant changes in refractive state or accommodation. These results are consistent with the findings of Woods and Thomson,[26] who demonstrated that 20 minute periods of cycling, jogging or stair running did not result in a significant change in visual acuity, refractive state, dark focus, amplitude of accommodation or pupil size. In the present investigation, both the aerobic exercise and isotonic exercise trials produced significant increases in heart rate, indicating that the exercises were sufficiently demanding to produce systemic changes. However, it is possible that the duration of the task, while being long enough to alter heart rate, was too short to affect the refractive state of the eye. Additionally, it took approximately 3 minutes to complete all of the measurements. For all subjects, heart rate, BP and IOP were recorded first, followed by the refractive measurements. Therefore, any changes in the power of the eye may have dissipated by the time the optical parameters were quantified (approximately 2 minutes after the exercise period was concluded). It would be valuable to repeat the study and record both accommodation and refractive state as close to the end of the exercise period as possible.

While a significant change in IOP was observed during the course of isometric exercise, this change dissipated rapidly following completion. These findings are in line with previous studies that observed a significant increase in IOP during isometric exercise, which decreased back to baseline[22–23] or even below baseline within a minute following the exercise.[14–19] Movaffafhy et al.[14] and Riva et al.[15] observed that an increase in blood volume within the large choroidal vessels could explain the increase in IOP during squatting. In addition, noted that isometric exercises cause an increase in mean perfusion pressure, which induces a rise in choroidal vascular resistance. This limits the increase in choroidal blood flow. Thus, choroidal blood flow may have a regulatory effect that can minimize IOP fluctuations during and/or following exercise. Although the effect of isometric exercise on IOP dissipates rapidly after exercise is completed, the significant spike in IOP during isometric exercise suggests that patients with glaucoma should avoid isometric exercises such as squatting and weight lifting.

While a cumulative effect may occur following longer or multiple exercise sessions, these data do not support the proposal that increased physical exercise will alter the development or progression of refractive error. A number of recent studies have suggested that it is the time spent outdoors rather than physical activity, which may have a greater protective effect on myopia development.[34–38] For example, Rose et al.[35] found that although there were significant protective associations of increased outdoor activity with the reduced myopia progression in children between 6 and 12 years of age, there was no association between the performance of indoor sports and myopia. The authors suggested that the level of light intensity experienced outdoors, rather than the physical activity, is the factor that retards myopia progression.

Support for this proposal comes from Cohen et al.[43] who examined both myopia development and retinal dopamine concentrations in chickens raised in low (50 lux), medium (500 lux) or high (15,000 lux) light levels for 90 days. They found that low light levels were associated with decreased concentrations of retinal dopamine and myopia development. Accordingly, refractive development may be associated with the release of retinal dopamine, a hormone whose concentration is regulated by the intensity of ambient light.

Further, exposure to bright light has been found to suppress deprivation myopia in many animal models, including chickens,[38,44–49] tree shrews,[44–47] and monkeys.[45] These findings also imply a protective effect of light exposure on myopia development. Sherwin et al.[37] measured conjunctival auto fluorescence (UVAF), a biomarker of outdoor light exposure, in humans and found that prevalence of myopia decreased with increased UVAF, thereby indicating a protective association between increased UVAF and myopia.[50] Accordingly, there is strong evidence to support the proposal that refractive development is retarded by light exposure.

Summary

Both the results of the present study and others do not support that proposal that physical exercise will retard the development or progression of myopia. Rather, prolonged light exposure seems to be a more likely mechanism for altering refractive development. However, the short duration of the exercise trials used here, both in terms of the length of each session and the lack of multiple trials does weaken the validity of the findings. Further studies using a larger number of subjects performing exercise trials that are both longer in duration and repeated on multiple occasions would be valuable to confirm the effect of physical exercise on the eye. Longitudinal studies on the effect of light exposure on myopia progression may be more valuable in determining the mechanism by which outdoor activity reduces myopia progression.

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None.

Conflicts of interest

Author declares that there is no conflict of interest.

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