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Resistance Training Exercises Acutely Reduce Intraocular Pressure in Physically Active Men and Women

JOSEPH A. CHROMIAK,[1] BEN R. ABADIE,[1] RONALD A. BRASWELL,[2] YUN S. KOH,[1] AND DANIEL R. CHILEK[1]

[1]*Department of Health, Physical Education, Recreation, and Sport, Mississippi State University, Starkville, Mississippi 39762; and* [2]*Departments of Ophthalmology and Neurology, University of Mississippi School of Medicine, Jackson, Mississippi 39216.*

ABSTRACT

Our purpose was to examine the effect of the chest press and leg press exercises on intraocular pressure (IOP) in physically active, college-aged students. Fifteen healthy males and 15 females performed 3 sets of 10 repetitions of the chest press or leg press with 70% 1 repetition maximum (1RM). IOP was measured using applanation tonometry with a Tono-PenXL prior to exercise, following each set and 5 minutes after the third set. Data were analyzed with a repeated-measures two-way analysis of variance and paired *t*-tests when necessary. A $p < 0.05$ was accepted as statistically significant. For the chest press, IOP was reduced 8.0% after the first set, up to 14.5% after the second and third sets, and remained depressed 5 minutes post exercise. For the leg press, IOP was reduced 6.9% after the second set and 13.2% after the third set. IOP began to return to the pre-exercise value during 5 minutes post exercise. Males and females had similar IOP responses to the chest press and leg press exercise. Dynamic resistance exercises induce modest postexercise decreases in IOP.

Key Words: strength training, eyes, glaucoma

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Introduction

Intraocular pressure (IOP) is the internal pressure within the eye that is determined by the balance between the rate of aqueous humor production, the resistance to outflow of aqueous humor through the trabecular meshwork, and the level of episcleral venous pressure. In most cases, chronic elevations in IOP are due to an increased resistance to outflow of the aqueous humor (25). The numerical values signifying elevated IOP have been set at slightly different values in various studies, although values of 18 to 21 mm Hg are most often used. The reported incidence of elevated IOP ranges from 4.5% to 9.4% in individuals over 40 years of age across studies (12). Chronic elevations in IOP can result in degeneration of the optic nerve and declining visual acuity.

Glaucoma is a disturbance of the structural or functional integrity of the optic nerve, which usually can be attenuated by reducing IOP. Glaucoma of all types is the second leading cause of legal blindness (26), and an additional 5,500 people become legally blind from glaucoma annually (7). It is estimated that 2.25 million people in the United States over the age of 40 years have primary open-angle glaucoma (26). An additional 10 million Americans are estimated to have IOP values greater than 21 mm Hg. Although the relationship between IOP and glaucoma including optic nerve damage is complex, a higher IOP is related to an increased risk of primary open-angle glaucoma.

Although it has been clearly demonstrated that aerobic exercise reduces IOP, the effect of resistance training exercise on IOP is not entirely clear. Aerobic exercise decreases IOP both immediately following a single bout of exercise (4, 8, 10, 18, 20, 22, 23) and after aerobic exercise training (21, 23) in healthy individuals. For example, IOP was reduced 28% immediately after cycling at a low intensity for 1 hour in sedentary subjects (23). IOP was decreased 9% after 16 weeks of running or cycling at moderate to high intensity for 3 days per week (20). In individuals with elevated IOP (18 mm Hg or greater), IOP is reduced following a single bout of aerobic exercise (9, 11, 21, 22) and by aerobic exercise training (21, 24). IOP was decreased 30% following an incremental cycle test to exhaustion in subjects with IOP values of 22 mm Hg or greater (21). IOP was reduced 20% after 12 weeks of aerobic exercise

Table 1. Descriptive characteristics for males and females, including 1 repetition maximum (1RM) leg press and chest press strength.*

Sex	Age (yr)	Height (cm)	Weight (kg)	1RM chest press (kg)	1RM leg press (kg)
Male	22.5 ± 1.7	181.0 ± 4.4	81.6 ± 16.5	97.9 ± 19.6	153.7 ± 35.0
Female	20.9 ± 0.9	164.3 ± 6.0	66.7 ± 14.6	51.5 ± 9.5	110.6 ± 24.3

* Data are mean ± standard deviation for men (n = 15) and women (n = 15).

training performed by cycling at moderate intensity, 4 days per week, in these same subjects (21). Reductions in IOP because of exercise training may retard the progression of glaucoma.

The effects of resistance exercises on IOP are less straightforward. An early study reported that resistance training induced an increase in IOP (2, as reported in 11). However, IOP was decreased following static muscular actions, such as handgrip exercise in subjects with normal IOP values (13) and in subjects with IOP values greater than 18 mm Hg (6). However, an increase in IOP of 30% was reported immediately following a static squat done until voluntary termination (17). IOP then declined to 14% less than the preexercise value during the postexercise period. A dramatic increase of IOP was observed in experienced strength trained subjects during a maximal static muscle contraction combined with Valsalva maneuver (3). IOP was not assessed during the postexercise period. The only study that incorporated dynamic muscular contractions reported that IOP was reduced 40% following a series of isokinetic muscular actions in subjects with normal IOP (1). Based on the reports of increases in IOP during or immediately after static muscle contractions in some studies and decreases in other studies, there is a need for additional research. The purpose of this study was to examine the acute effect of either a single upper- or lower-body resistance training exercise using Cybex variable resistance machines on IOP in recreationally active, college-aged students. A secondary purpose was to determine whether males and females had similar IOP responses to resistance training exercise. We hypothesized that IOP would be decreased by performing multiple sets of a single resistance exercise, and there would be no difference in the IOP response to resistance exercise between men and women.

Methods

Experimental Approach to the Problem

Because there is a lack of data regarding the acute effects of resistance training exercises on IOP and it is possible that resistance exercises may increase IOP (3, 17), subjects with normal IOP values rather than subjects with glaucoma or elevated IOP were used for this study. To test the hypotheses, a repeated-measures design in which IOP was measured in men and women prior to and immediately following the first, second, and third set of resistance exercise as well as 5 minutes after the exercise was established. The chest press and leg press exercises were selected for several reasons: (a) to determine whether IOP was altered by resistance exercise, relatively large muscle mass exercises were selected; (b) these are upper and lower body exercises that are often included in resistance exercise programs; and (c) the seated upright posture during the performance of these exercises was similar to the posture of the subject during measurement of IOP, and, therefore, postural changes would not affect IOP.

Subjects

Healthy, recreationally active subjects (15 men and 15 women), as determined from a medical history and physical activity questionnaire, were recruited from physical education classes at a large university. Recreationally active was defined as engaging in physical activity a minimum of 2 days per week for a minimum of 20 minutes. Activities included intramural sports, aerobic activities, and resistance training. Subject characteristics, including 1 repetition maximum (1RM) strength for the Cybex VR chest press and leg press exercises, are shown in Table 1.

Subjects with health problems that limited their ability to perform resistance exercise or that could confound the results of the study were excluded. Also, subjects with IOP values of > 20 mm Hg when tested initially or those who noted eye problems other than the need for corrective lenses were excluded from participation. The study was reviewed and approved by the Institutional Review Board at Mississippi State University.

Study Design

Subjects reported to the exercise science laboratory on 3 separate occasions with a minimum of 48 hours between testing sessions. Subjects were tested at approximately the same time each day because IOP may be affected by diurnal variation (9). Subjects were instructed not to exercise during the day prior to testing and were asked to refrain from nicotine, consumption of caffeine, large quantities of beverages, or a large meal within 1 hour prior to testing. On the first day of testing, 1RM strength for the seated leg press (model 4860) and chest press exercises (model 4800) were determined on Cybex VR equipment (Cybex International, Medway, MA) using standard testing procedures. Subjects started the concentric phase of the leg press at 90° knee flexion and were required to extend the leg completely to complete the concentric phase. For the chest press, subjects were in a seated position. Subjects initiated the concentric phase of the lift with the handle arms of the chest press machine at chest level and were required to move the arms to full extension. For the following testing sessions, subjects performed 3 sets of 10 repetitions of either the leg press or chest press exercise using a resistance of ~70% of 1RM in random order. (The resistance used was as close as possible to the calculated 70% of 1RM without being less than the calculated value.)

Determination of the Acute IOP Response to Resistance Exercise

Subjects reported to the exercise science laboratory and were asked to relax while seated. After 5 minutes, the first IOP measurements were obtained using the right eye of the subject. IOP was measured using applanation tonometry with a Tono-Pen XL (Medtronics/Solan, Jacksonville, FL). The Tono-Pen XL is a handheld, portable device. Before the initial series of IOP measurements, 1 drop of the anesthetic Alcaine (proparacaine) was administered to the right eye of the subject. (Following the initial administration of anesthetic, additional anesthetic was given on an as-needed basis. Subjects typically required 1 additional drop of anesthetic, although 2 drops were needed in some cases.) To obtain an IOP measurement, the tip of the device is tapped lightly against the pupil 3 times. The device presents a value from the mean of the 3 readings. Three consecutive sets of IOP readings were obtained and the mean of these measurements accepted as the measured value.

After the initial IOP measurement, subjects performed 1 warm-up set of 10 repetitions with a resistance of 60% of the weight that would be used for testing. Subjects were permitted to stretch but were asked not to perform any vigorous warm-up exercise that might alter IOP. Subjects performed 3 sets of 10 repetitions of the leg press or chest press using a resistance of ~70% of 1RM with 2 minutes of seated rest between each set. Immediately after each set, subjects were asked to move slowly from the exercise apparatus to a seat beside it, and IOP was measured. After the third set, subjects remained seated for 5 minutes, and a final series of IOP measurements were made. If the subject could not complete 10 repetitions during the first or second sets of leg press exercise, the resistance was decreased 4.5 kg for subsequent sets. If a subject could not complete 10 repetitions of the chest press exercise, resistance was decreased 2.8 kg (if subject completed 7–9 repetitions) to 5.7 kg (if subject completed fewer than 7 repetitions) for subsequent sets.

Table 2. Effect of repeated applanation tonometry measurements using the TonoPen XL on intraocular pressure (IOP).*

Time	IOP (mm Hg)
Initial	14.0 ± 1.5
3 Minutes	14.1 ± 1.9
5 Minutes	14.4 ± 2.7
7 Minutes	14.7 ± 2.5
12 Minutes	14.4 ± 2.8

* Data are mean ± standard deviation, n = 8. IOP was not significantly different at any time point compared to the initial value.

Determination of the Effect of Repeated IOP Measurements on IOP

Because repeated applanation tonometry measurements may reduce IOP (16), the effect of repeated IOP measurements using the Tono-Pen XL was examined on a separate group of subjects. After the initial IOP measurement, IOP was measured every 3 minutes until the final measurement, which was 5 minutes later. These times were selected to mimic the time points used when subjects performed the resistance exercises.

Statistical Analyses

IOP data were analyzed with a two-way analysis of variance (ANOVA) with repeated measures on time using the SPSS 8.0 statistics package (SPSS, Chicago, IL). A $p \leq 0.05$ was accepted as statistically significant. Because there were no statistically significant differences between males and females and no time × sex interaction, data for males and females were pooled to identify differences over time. A one-way ANOVA with repeated measures and paired least significant differences *t*-tests were used to identify differences across time. Intraclass R values (Ri) and effect sizes also were calculated. For the repeated tonometry measurements without exercise, data were analyzed with a one-way repeated-measures ANOVA. For all analyses, $p \leq 0.05$ was accepted as statistically significant.

Results

Effect of Repeated IOP Measurements With the Tono-Pen XL

IOP was not altered by repeated applanation tonometry measurements using the Tono-Pen XL (Table 2).

Leg Press Exercise

The intraclass reliability (Ri) of the measurements for the leg press exercise was 0.91. ANOVA showed that IOP declined as a result of performing leg press exercise. Because there were no statistically significant

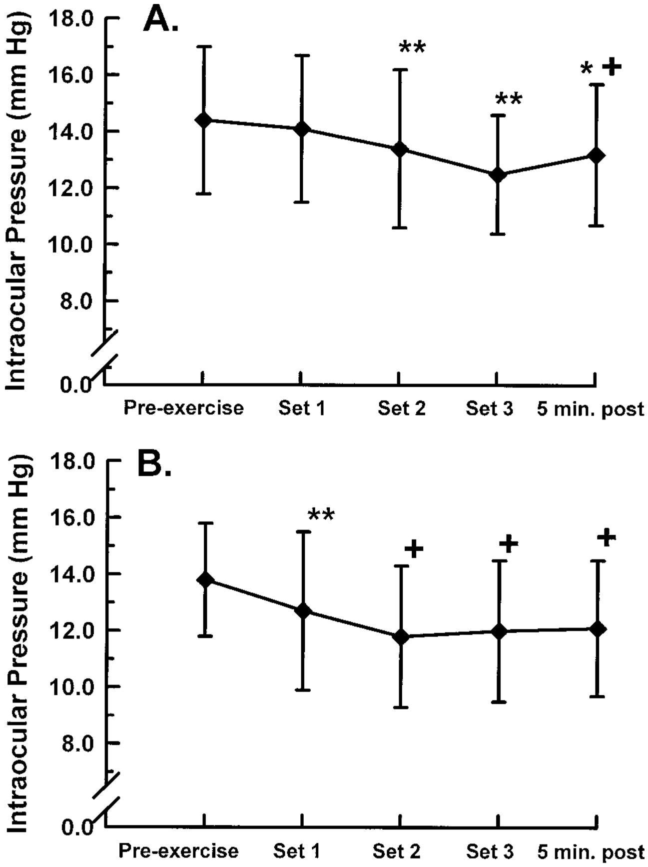

Figure 1. Resistance training exercises reduce intraocular pressure (IOP). IOP was measured using applanation tonometry with a Tono-Pen XL prior to the first set, after each set, and 5 minutes after the third set of either leg press (A) or chest press (B) exercise using Cybex VR equipment. Subjects attempted to complete 3 sets of 10 repetitions with ~70% of their 1RM. Data are the mean ± *SD*; $*p < 0.05$ vs. set 3; $**p < 0.01$ vs. pre-exercise (rest); $+p < 0.001$ vs. pre-exercise (rest). $N = 30$ subjects for the leg press and 29 subjects for the chest press exercises.

differences between males and females, and no time × sex interaction, data for males and females were pooled for further analysis. IOP after the first set was not different from the pre-exercise IOP value (pre-exercise: 14.4 ± 2.6 mm Hg; Figure 1A). IOP was reduced 6.9% following the second set and 13.2% after the third set. Five minutes following exercise, IOP was elevated slightly, compared with immediately after the third set, but was still less than the pre-exercise IOP. The effect size (Eta² [η^2]) was 0.227.

Chest Press Exercise

The Ri of the measurements for the chest press exercise was 0.90. ANOVA showed that IOP changed as a result of performing chest press exercise. Because there was no difference between males and females, and no IOP × sex interaction, data for males and females were pooled for further analysis. IOP was reduced 8.0% after the first set (pre-exercise: 13.8 ± 2.0 mm Hg; Figure 1B). After the second and third sets, IOP was reduced up to 14.5%. Five minutes after exercise, IOP remained significantly lower than the pre-exercise IOP value. The Eta² (η^2) was 0.237.

One subject had an initial IOP value of 20.7 mm Hg when he reported to the laboratory on the day that he was scheduled to do the chest press exercise. On a prior day, his IOP was 18.0 mm Hg before performing the leg press exercise. His data are included for the leg press but excluded for the chest press exercise. Exclusion of the data for this subject did not alter the statistical significance of the results for the chest press exercise.

Discussion

The results of this study, based on repeated applanation tonometry measurements, demonstrate that IOP declines after one or more sets of chest press and leg press exercise performed at moderate intensity using variable resistance machines. Although it has been reported that repeated tonometry measurements decrease IOP (16), data from this study show that repetitive measurements with the Tono-Pen XL do not alter IOP. Repeated IOP measurements with Goldman and Shiotz tonometers may induce small declines in IOP, whereas repeated readings with the Tono-Pen XL and noncontact tonometers do not alter IOP (18). The decreases in IOP following 1 or more sets of dynamic resistance exercise are due to the exercise and are not an artifact of measurement.

Only one other study (1) has examined the acute effects of dynamic resistance exercise on IOP. Although that study reported a 41% decrease in IOP following isokinetic leg extension and leg flexion exercise, which was much greater than the 13% decline following 3 sets of leg press exercise in the present study, the warm-up protocol used in that study likely confounded the results. In the study of Avunduk et al. (1), 15 minutes of cycle ergometer warm-up exercise was performed between the initial IOP reading and initiation of isokinetic exercise. Short to moderate duration cycling has been shown to reduce IOP by approximately 30% (9). In the current study, subjects performed 1 warm-up set of 10 repetitions with a resistance of 60% of the weight that would be used for testing, so that IOP would not be affected. The difference in the magnitude of response between the present study and the study using isokinetic exercise (1) likely is due to different warm-up protocols.

Several studies have demonstrated declines in IOP following static muscle contractions (1, 6, 13). The postexercise reduction in IOP appears to be related to both the duration and intensity of the static muscle exercise. A static hand grip contraction at 20% of maximal voluntary contraction (MVC) until force declined 50% (duration 4–5 minutes) did not alter IOP (13).

However, a static hand grip contraction at 20% MVC until fatigue (~9 min.) resulted in a 3 mm Hg decline in IOP after exercise. A static hand grip contraction at 55% of MVC induced a 4 mm Hg decline during the postexercise period (13). The amount of muscle mass used also may affect the IOP response to resistance exercise. A 30% increase in IOP was reported immediately after subjects performed a static squat until voluntary termination. IOP declined to 14% lower than the pre-exercise levels further into the postexercise period (17).

Although the current study is consistent with the majority of other studies using static or dynamic contractions in demonstrating a decline in IOP postexercise (1, 6, 13), the IOP response during resistance exercise requires additional study. Although studies have reported no change in IOP during static handgrip contractions of low to moderate intensity (13), static contractions of maximal intensity involving a large muscle mass, especially combined with a Valsalva maneuver, may contribute to elevations in IOP (3). IOP was elevated 115% in highly trained weight lifters during a maximal static contraction coupled with a Valsalva maneuver (3). Seated subjects attempted to maximally contract much of the musculature of the body while grasping both sides of a bench. Performance of a Valsalva maneuver simultaneously may have contributed in whole or part to the increased IOP during the contraction. Mean IOP during the static contraction was 28 mm Hg, with IOP reaching 46 mm Hg in 1 subject. The variable resistance chest press and leg press exercises in the current study use a moderate to fairly large amount of muscle mass. The possibility remains that IOP increased during the chest press or leg press in our study but declined to less than the pre-exercise level by the time IOP was measured. Current technology does not permit accurate measurement of IOP during dynamic resistance exercise.

It has been suggested that the very large increases in blood pressure during some resistance training exercises result in venous outflow obstruction leading to elevated IOP (3). Both static and dynamic muscle contractions can dramatically increase blood pressure, and the performance of a Valsalva maneuver during muscle contractions exacerbates the increases in blood pressure (5, 14, 15, 19). Although increases in systolic and diastolic blood pressure to greater than 160 mm Hg and 105 mm Hg (values estimated from graphs), respectively, were not associated with alterations in IOP during static handgrip exercise (13), it is possible that extremely large increases in blood pressure overcome the ability of the eye to maintain a relatively constant IOP. The ability to continuously monitor IOP during and following exercise would assist in clarifying the IOP response to different types of exercise and of various intensities. However, no device has achieved widespread use (7).

Regardless of the effect of resistance exercise on IOP while performing the muscle contractions, IOP declines during the postexercise period. The cause of this decline is not entirely known, although there is research evidence suggesting that increases in blood osmolality and lactate and decreased blood pH (13) and blood CO_2 (6) contribute to the decline. It is also possible that changes in blood flow to the eye may alter IOP postexercise. These data show that 3 sets of chest press or leg press exercise at moderate intensity induce a modest decrease in IOP and suggest a need for additional research regarding the effects of resistance exercise on IOP.

Practical Applications

These data demonstrate that performing up to 3 sets of dynamic strength training exercises at moderate intensity reduce IOP during the postexercise period in healthy subjects with normal IOP. At the present time, caution must be used in generalizing the results of the present study and recommending resistance exercise to individuals with elevated IOP. This first study suggests that resistance exercise at moderate intensity does not elevate IOP in individuals with normal IOP and indeed induces a reduction in postexercise IOP. Individuals with glaucoma or elevated IOP should use resistance of low to moderate intensity and avoid performing a Valsalva maneuver during the resistance exercise. Also, resistance exercise training may result in a chronic reduction in IOP (21). Future study should examine the effect of dynamic resistance exercise of various intensities on IOP, the effect of resistance training on IOP, and the effects of resistance exercise on individuals with glaucoma or elevated IOP. In addition, the ability to continuously monitor IOP during and following exercise would assist in clarifying the IOP response to different types and intensities of exercise.

References

1. Avunduk, A.M., B. Yilmaz, N. Sahin, Z. Kapicioglu, and V. Dayant. The comparison of intraocular pressure reductions after isometric and isokinetic exercises in normal individuals. *Ophthalmologica* 213:290–294. 1999.
2. Biro, I., and F. Botar. Ueber das verhalten den augendrucks bei verschiedenen sportsleistugen. *Klin. Monatsbl. Augenheilkd.* 140:123. 1962.
3. Dickerman, R.D., G.H. Smith, L. Langham-Roof, W.J. McConathy, J.W. East, and A.B. Smith. Intra-ocular pressure changes during maximal isometric contraction: Does this reflect intra-cranial pressure or retinal venous pressure? *Neurol. Res.* 21:243–6. 1999.
4. Era, P., O. Parssinen, M. Kallinen, and H. Suominen. Effect of bicycle ergometer test on intraocular pressure in elderly athletes and controls. *Acta Ophthalmol. (Copenh.)* 71:301–307. 1993.
5. Gotshall, R.W., J. Gootman, W.C. Byrnes, S.J. Fleck, and T.C. Valovich. Noninvasive characterization of the blood pressure response to the double-leg press exercise. *J. Exerc. Pysiol.* online:2. 1999.

6. Harris, A., V.E. Malinovsky, L.B. Cantor, P.A. Henderson, and B.J. Martin. Isocapnia blocks exercise-induced reductions in ocular tension. *Invest. Ophthalmol. Visual Sci.* 33:2229–2232. 1992.
7. Hoskins, H.D. Jr.,and M. Kass. Introduction and classification of the glaucomas. In: *Beckers-Shaffer's Diagnosis and Therapy of the Glaucomas* (6th ed.). Baltimore: C.V. Mosby Co., 1989. pp. 2–9.
8. Keilar, R.A., P. Teraslinna, D.G. Rowe, and J. Jackson. Standardized aerobic and anaerobic exercise. Differential effects on intraocular tension, blood pH, and lactate. *Invest. Ophthalmol. Vis. Sci.* 14:782–794. 1975.
9. Krejci, R.C., R.B. Gordon, C.T. Moran, R.G. Sargent, and J.C. Magun. Changes in intraocular pressure during acute exercise. *Am. J. Optom. Physiol. Optics* 58:144–148. 1981.
10. Leighton, D.A., and C.I. Phillips. Effect of moderate exercise on the ocular tension. *Br. J. Ophthalmol.* 54:599–605. 1970.
11. Lempert, P., K.H. Cooper, J.F. Culver, and T.J. Tredici. The effect of exercise on intraocular pressure. *Am. J. Ophthalmol.* 63: 1673–1676. 1967.
12. Leske, M.C. The epidemiology of open-angle glaucoma: A review. *Am. J. Epidemiol.* 118:166–191. 1983.
13. Marcus, D.F., H.F. Edelhauser, M.G. Maksud, and R.L. Wiley. Effects of a sustained muscular contraction on human intraocular pressure. *Clin. Sci. Mol. Med.* 47:249–257. 1974.
14. MacDougall, J.D., R.S. McKelvie, D.E. Moroz, D.G. Sale, N. McCartney, and F. Buick. Factors affecting blood pressure during heavy weight lifting and static contractions. *J Appl. Physiol.* 73:1590–1597. 1992.
15. MacDougall, J.D., D. Tuxen, D.G. Sale, J.R. Moroz, and J.R. Sutton. Arterial blood pressure response to heavy resistance exercise. *J. Appl. Physiol.* 58:785–790. 1985.
16. Moses, R.A. and C. Liu. Repeated applanation tonometry. *Am. J. Ophthalmol.* 66:89–91. 1968.
17. Movaffaghy, A., S.R. Chamot, B.L. Petrig, and C.E. Riva, C.E. Blood flow in the human optic nerve head during isometric exercise. *Exp. Eye. Res.* 67:561–568. 1998.
18. Myers, K.J. The effect of aerobic exercise on intraocular pressure. *Invest. Ophthalmol.* 13:74–76. 1974.
19. Narloch, J.A., and M.E. Brandstater. Influence of breathing technique on arterial blood pressure during heavy weight lifting. *Arch. Phys. Med. Rehabil.* 76:457–462. 1995.
20. Passo, M.S., L. Goldberg, D.L. Elliot, and E.M. Van Buskirk. Exercise conditioning and intraocular pressure. *Am. J. Ophthalmol.* 103:754–757. 1987.
21. Passo, M.S., L. Goldberg, D.L. Elliot, and M. Van Buskirk. Exercise training reduces intraocular pressure among subjects suspected of having glaucoma. *Arch. Ophthalamol.* 109:1096–1098. 1991.
22. Qureshi, I.A. The effect of mild, moderate, and severe exercise on intraocular pressure in glaucoma patients. *Jpn. J. Physiol.* 45: 561–569. 1995.
23. Qureshi, I.A. The effects of exercise on intraocular pressure in physically fit subjects. *Clin. Exp. Pharmacol. Physiol.* 23:648–652. 1996.
24. Sargent, R.G., S.N. Blair, J.C. Magun, R.C. Krejci, C. Sacoco, T.D. Langley, and R.L. Taylor. Physical fitness and intraocular pressure. *Am. J. Optom. Physiol. Optics* 58:460–466. 1981.
25. Stamper, R.L., M.F. Lieberman, and M.V. Drake. Intraocular pressure. In: *Beckers-Shaffer's Diagnosis and Therapy of the Glaucomas* (7th ed.). St. Louis: Mosby Inc., 1999. p. 74.
26. Stamper, R.L., M.F. Lieberman, and M.V. Drake. Introduction and classification of the glaucomas. In: *Becker's-Shaffer's Diagnosis and Therapy of the Glaucomas* (7th ed.). St. Louis: Mosby Inc., 1999. pp. 2–9.

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Address correspondence to Dr. Joseph A. Chromiak, jchrom@colled.msstate.edu.