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Variations in Intraocular Pressure Among Athletes Across Different Sports Disciplines

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Abstract: Objectives: Elevated intraocular pressure (IOP) is a well-known risk factor for glaucoma and other optic neuropathies. This study investigated the impact of two distinct types of physical activity—endurance (marathon running) and strength (weightlifting)—on IOP variations. **Methods**: Forty healthy male athletes (20 marathon runners, 20 weightlifters) aged 18–35 years were recruited and monitored over three months. IOP was measured using Goldmann and Icare IC200 tonometers before and after 1-hour training sessions. **Results**: Results showed a significant increase in IOP after training among weightlifters (mean post-training IOP: 19.3 mmHg), in contrast to stable or slightly reduced values in marathon runners (mean post-training IOP: 15.1 mmHg). **Conclusions**: These findings suggest the need for regular ophthalmologic monitoring in strength athletes. Future studies should examine the long-term impact of sport-specific IOP fluctuations on ocular health and glaucoma risk.

Keywords: intraocular pressure (IOP); athletes; sports disciplines; glaucoma

1. Introduction

Intraocular pressure (IOP) constitutes a fundamental physiological parameter in maintaining ocular homeostasis. Sustained elevations in IOP are widely acknowledged as the most significant modifiable risk factor for the development and progression of glaucomatous optic neuropathy—a leading cause of irreversible blindness worldwide [1]. Consequently, understanding the factors that influence IOP, especially those related to lifestyle and physical activity, is of paramount importance in both preventative ophthalmology and the management of glaucoma.

Physical exercise is universally recommended for its extensive systemic benefits, including improved cardiovascular fitness, enhanced metabolic control, and reduction of stress and systemic inflammation [2]. However, the ocular consequences of various forms of physical activity are less well understood and are an area of growing clinical interest. While early studies in the 1960s suggested that physical exertion could lead to a transient reduction in IOP among glaucoma patients [5], subsequent investigations have revealed a more complex picture. The type, intensity, and duration of exercise—along with individual physiological factors—appear to significantly mediate the direction and magnitude of IOP changes [6].

In recent years, there has been an increasing focus on distinguishing the ocular effects of different exercise modalities. Endurance training, typified by aerobic activities such as long-distance running, is frequently associated with a reduction in IOP, possibly due to decreased plasma osmolarity, improved ocular blood flow, and reduced sympathetic tone [7]. Conversely, anaerobic or isometric exercises—particularly those involving short bursts of high resistance, such as weightlifting—have been linked to transient but marked elevations in IOP [8,9]. These fluctuations

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may result from Valsalva-like maneuvers, elevated intrathoracic pressure, and increased episcleral venous pressure, all of which can impede aqueous humor outflow and momentarily raise IOP.

The interplay between sport-specific physiological demands and ocular pressure regulation has important implications for athletes, particularly those engaging in high-intensity strength training. For example, Vaghefi et al. (2022) demonstrated that leg-press exercises can induce rapid and substantial IOP spikes that exceed 25 mmHg, potentially posing a risk for optic nerve damage if such fluctuations are sustained or repeated over time [10]. In contrast, Najmanova et al. (2021) reported that endurance training not only avoids such spikes but may even confer protective effects by promoting IOP stability [11].

Despite these findings, comparative data on IOP responses across different athletic disciplines remain limited. Most existing studies either focus on general exercise effects or lack standardized methodologies for measuring and interpreting IOP variations in sports settings. This study addresses this gap by systematically examining the impact of two distinct training regimens—endurance (marathon running) and strength (weightlifting)—on IOP in healthy young male athletes. Using both Goldmann applanation and rebound tonometry (Icare IC200), IOP was assessed before and after standardized 1-hour training sessions over a three-month period.

The objective of this research is twofold: (1) to investigate whether these two contrasting forms of physical activity induce differential IOP responses, and (2) to explore the potential implications of these findings for long-term ocular health, including the risk of developing or exacerbating glaucomatous damage. Given the increasing participation in both recreational and competitive sports, this study aims to contribute valuable insights for clinicians, trainers, and athletes alike, emphasizing the need for sport-specific ocular monitoring protocols.

2. Materials and Methods

2.1. Study Design and Participants

This study was designed as a prospective, observational investigation aiming to assess intraocular pressure (IOP) changes associated with two distinct athletic disciplines: endurance running and weightlifting. The research was conducted at the Department of Ophthalmology, Alfredo Fiorini Hospital of Terracina (Latina, Italy), over an eight-month period from September 2023 to May 2024. Ethical approval was obtained from the institutional review board, and written informed consent was secured from all participants prior to enrollment.

A total of 40 healthy male athletes were recruited through local sports organizations and fitness centers during routine sports fitness assessments. Participants were required to be between 18 and 35 years of age and actively engaged in either marathon training (n=20) or weightlifting (n=20), with each group representing the respective endurance and strength training modalities. All enrolled individuals were in their first year of competitive practice to ensure a relatively uniform training background and minimize the potential confounding effects of long-term adaptation.

To ensure the internal validity of the study, strict inclusion and exclusion criteria were applied. Inclusion criteria mandated male gender, an age range of 18–35 years, absence of previous competitive experience in the selected sport, and no known history of ocular disease or previous ocular surgery. Additionally, participants were required to have normal baseline IOP readings (defined as ≤19 mmHg) at the time of enrollment, confirmed through initial tonometric assessment.

Exclusion criteria were established to eliminate potential confounders. Athletes with significant refractive errors (greater than ±3 diopters of myopia or hyperopia), those using systemic or topical medications known to influence IOP (such as corticosteroids or beta-blockers), and individuals with systemic conditions like diabetes mellitus or hypertension were excluded. These conditions are known to independently impact IOP or optic nerve health and could skew the study’s findings. By carefully selecting a homogenous and healthy study population, the study aimed to isolate the effects of exercise type on IOP fluctuations with minimal bias.

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2.2. Clinical Assessment

All participants underwent a standardized battery of clinical assessments to establish baseline physiological and ocular health parameters. These evaluations were conducted by trained personnel under the supervision of the study's principal investigator.

Cardiovascular function was assessed using a 12-lead electrocardiogram (ECG), performed in accordance with European Society of Cardiology guidelines. Bioimpedance analysis (BIA) was utilized to determine body composition, including body fat percentage and lean muscle mass, using a validated multi-frequency segmental device (Tanita MC-780U). Pulmonary function testing was also performed, with specific attention to Peak Expiratory Flow (PEF), using a portable spirometer calibrated for daily use. These metrics served to document the athletes' baseline fitness and overall health status.

A comprehensive ophthalmologic examination was conducted for all participants to establish ocular baseline values and exclude pre-existing pathology. Best-corrected visual acuity (BCVA) was measured using a standardized Snellen chart under photopic conditions. Fundus examination was carried out using direct ophthalmoscopy (Heine Beta 200), focusing on the optic nerve head, macula, and peripheral retina to exclude glaucomatous changes or other retinal pathology.

Intraocular pressure was assessed using two methods to ensure reliability and reproducibility: the Goldmann applanation tonometer, considered the gold standard in clinical practice, and the Icare IC200 rebound tonometer, which allows for quick, minimally invasive measurements. Each participant underwent IOP measurements with both devices in a single session, spaced five minutes apart to minimize any inter-device bias. All measurements were performed by the same ophthalmologist to control for operator variability. For each eye, four IOP readings were taken and averaged to obtain a reliable measurement. The mean value from both eyes was used in the final analysis.

These comprehensive assessments ensured a robust clinical foundation for evaluating the relationship between sport-specific physical activity and IOP variations.

2.3. IOP Measurement Protocol

To ensure consistency and reduce measurement variability, intraocular pressure (IOP) assessments were carried out under controlled conditions and by the same experienced ophthalmologist throughout the study. All measurements took place in the hospital's ophthalmology unit, a temperature- and humidity-controlled environment, to minimize external influences on tonometric readings.

Participants were instructed to avoid caffeine intake, alcohol consumption, and vigorous physical activity for at least 12 hours prior to testing. On each measurement day, athletes rested in a seated position for a minimum of 10 minutes before the first IOP reading to allow for hemodynamic stabilization and to avoid artificially elevated values due to recent exertion or positional changes.

IOP was measured at three timepoints: during the baseline visit before the initiation of any physical activity; immediately before a scheduled 1-hour training session, either endurance running or resistance weightlifting; and within five minutes following the completion of the training session to capture acute post-exercise changes.

Two different devices were used during each measurement session to ensure reliability and cross-validation of the readings. The Goldmann applanation tonometer, mounted on a slit-lamp biomicroscope, was used after instilling topical anesthesia and fluorescein dye. The Icare IC200 rebound tonometer, a handheld and minimally invasive device, allowed for rapid assessment without the need for anesthetic. To minimize bias, a five-minute interval was maintained between the use of the two devices, and the order of device usage was alternated across subjects.

For each eye, four consecutive readings were taken using both devices. These values were averaged to obtain a representative IOP for each eye, and the mean of both eyes was used as the subject's final IOP value at each timepoint. This methodological approach ensured high reliability of data while controlling for variability due to environmental, procedural, or equipment-related factors.

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2.4. Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics software, version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means with standard deviations, and categorical variables were presented as frequencies and percentages. The distribution of continuous data was evaluated using the Shapiro-Wilk test to assess normality.

As the variables demonstrated normal distribution, parametric tests were applied throughout. Differences in baseline demographic and physiological characteristics between the marathon runner and weightlifter groups were assessed using independent samples Student's t-tests. Categorical comparisons were evaluated using Pearson's chi-square test where applicable.

Intra-group differences in IOP values before and after training were analyzed using paired t-tests. Inter-group comparisons of post-exercise IOP levels and changes from baseline were analyzed with independent t-tests. Statistical significance was defined as a p-value less than 0.05.

In addition to primary comparisons, Pearson correlation coefficients were calculated to explore relationships between changes in IOP and other variables such as body mass index (BMI), peak expiratory flow (PEF), and subjective exertion scores based on the Borg scale. Exploratory linear regression models were also generated to investigate potential predictors of post-exercise IOP elevation, particularly in the weightlifting group, although these analyses were considered secondary and exploratory in nature.

3. Results

For all athletes participating in the study, during the period between September 2023 and May 2024, the electrocardiogram (ECG) revealed no significant alterations and the heart rate ranged between 58 and 70 bpm, with a standard deviation of ±5 bpm. The average Body Mass Index (BMI) of the marathon runners was 22.5 kg/m² (±1.2 kg/m²), indicating a lean body composition typical of endurance athletes. In contrast, the weightlifters had a mean BMI of 27.3 kg/m² (±1.5 kg/m²), suggesting greater muscle mass. The mean peak expiratory flow (PEF) values for the marathon runners were 600 L/min (±30 L/min), indicating good respiratory capacity and lung function. Weightlifters recorded an average PEF of 550 L/min (±25 L/min), which, although adequate, is slightly lower than for marathon runners (Table 1).

Table 1. Clinical characteristics of study patients.

	Marathoners	Weightlifters
Age, mean ± SD, years	27.15 ± 4.7	28.8 ± 3.5
BMI*1, mean ± SD, kg/m²	22.5 ± 1.2	27.3 ± 1.5
PEF*2, mean ± SD, L/min	600 ± 30	550 ± 25

*1 BMI = Body Mass Index; *2 PEF= Peak Expiratory Flow.

Regarding IOP, all athletes underwent IOP assessment of both eyes by the same operator. The IOP was recorded as the average of four consecutive readings with the eye in primary position; the right eye was always measured first. The average between the tonometric values of the two eyes was then obtained.

At the first visit in the 20 selected marathon runners the mean IOP was 15.2 mmHg (±1.0 mmHg). In the 20 weightlifters the mean IOP at the first visit was 16 mmHg (±0.9 mmHg), slightly higher than in the marathon runners.

Before training, the mean IOP was 15.4 mmHg (±0.8 mmHg) in the marathon runners, showing only a small variation. Under the same conditions, the mean IOP for weightlifters was 16.2 mmHg (±1.0 mmHg), showing substantial stability compared to the first visit.

After 1 hour of training, the mean IOP of the marathon runners stabilised at 15.1 mmHg (±0.9 mmHg), while the mean IOP for the weightlifters was 19.3 mmHg (±2.1 mmHg), indicating an

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increase in IOP compared to the values before training (Table 2). For 30% of the athletes, this increase was significant by more than 4 mmHg (p-value = 0.01) (Table 3).

Table 2. Mean IOP*[1] of study patients on first visit, before training and after training.

	Marathoners	Weightlifters
IOP on first visit, mean ± SD, mmHg	15.2 ± 1.0	16 ± 0.9
IOP before training, mean ± SD, mmHg	15.4 ± 0.8	16.2 ± 1.0
IOP after training, mean ± SD, mmHg	15.1 ± 0.9	19.3 ± 2.1

*[1] IOP = Intraocular Pressure.

Table 3. IOP before and after training in weightlifters.

Weightlifters	IOP before training (mmHg)	IOP after training (mmHg)
1	16.2	18.7
2	16.1*	20.9*
3	14.5	16.4
4	14.2	15.4
5	15.5	18.9
6	16	19.3
7	16.7	18.5
8	16.8*	22.2*
9	17.5	19.9
10	17.2*	21.3*
11	16.3	17.7
12	16.2	18.3
13	17.5	20
14	15.4*	19.7*
15	14.5	16.1
16	17.5*	23.2*
17	16.6	20.3
18	17.5*	22.5*
19	15.5	17.3
20	16.2	19.3
1	16.2	18.7

* Increased IOP ≥ 4 mmHg.

The group of marathon runners therefore showed a negative correlation between training duration and IOP, suggesting that an increase in training volume could be associated with a lowering of IOP. In the group of weightlifters, on the other hand, a positive correlation was noted between maximum workload and IOP, indicating that greater exertion may contribute to increased IOP values.

The differences in tonometric values between the two groups can be explained by several factors. During weightlifting, athletes may experience an increase in intraocular pressure due to intra-abdominal hyperpressure, which may be reflected in IOP [7]. Marathon runners, who tend to maintain regular, low-effort breathing, may benefit from better IOP control [8]. Training outdoors (for marathon runners) versus indoors (for weightlifters) could further influence results [9].

4. Discussion

The present study provides compelling evidence that the type and intensity of athletic training significantly influence intraocular pressure. The data indicate that endurance athletes, represented

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by marathon runners, experience stable or even slightly reduced IOP following training. In contrast, weightlifters, who engage in high-resistance and isometric activities, exhibit significant post-exercise elevations in IOP. These findings are in accordance with earlier observations that physical activity can modulate IOP, but they also underscore that not all exercise exerts a protective effect.

The lower IOP observed in marathon runners may be attributed to several factors. Prolonged aerobic exercise is known to enhance cardiovascular efficiency and promote vasodilation, which in turn may contribute to improved ocular perfusion and stabilization of IOP [16]. The regular, low-effort breathing patterns typically maintained during endurance training may also play a role in preventing excessive intraocular pressure fluctuations [8]. Additionally, outdoor training environments, as is common for marathon runners, may contribute to these beneficial effects by exposing athletes to natural light and varying ambient conditions, factors that have been suggested to influence ocular physiology [9].

In contrast, the significant IOP elevation observed in weightlifters can be explained by the physiological demands of strength training. During weightlifting, athletes often perform the Valsalva maneuver—intentionally or inadvertently—resulting in increased intrathoracic and intra-abdominal pressure. This pressure is transmitted to the episcleral venous system, which impedes the outflow of aqueous humor and leads to transient increases in IOP [7]. Such transient spikes in IOP, as observed in our study, may be further exacerbated by the short, intense nature of strength training sessions, where peak exertion levels are reached rapidly. Prior studies have demonstrated that high-intensity weightlifting, particularly exercises such as leg press routines, results in dramatic and transient IOP changes [19]. Moreover, the venous pressure in the episcleral veins increases during Valsalva maneuvers, further contributing to resistance to aqueous outflow and consequent IOP elevation [20].

The role of psychological and endocrine factors in modulating IOP should not be overlooked. Intense physical exertion and competitive stress are known to activate the hypothalamic-pituitary-adrenal (HPA) axis, leading to an increase in cortisol secretion. Cortisol has been implicated in the regulation of IOP, and its elevated levels during high-intensity training may contribute to the observed pressure increases [11]. Previous research has shown that cortisol can affect both the production and outflow of aqueous humor, thereby influencing IOP [12]. In support of this, Vera et al. demonstrated that IOP is highly sensitive to anxiety-induced manipulation during basketball free throw shooting, with IOP increasing in parallel with accumulated anxiety [24].

The potential long-term implications of these findings are significant. Transient spikes in IOP, even if temporary, may have cumulative effects on the optic nerve, particularly in individuals predisposed to glaucoma. Fluctuations in IOP have been linked to the progression of glaucomatous damage [17], and acute spikes—such as those observed during high-resistance weightlifting—could conceivably contribute to this risk. Studies involving wind instrument players, for example, have documented transient IOP elevations that correlate with the degree of visual field defects, suggesting a link between repetitive pressure spikes and ocular damage [18].

Further compounding these concerns is the observation that the electromyographic activity associated with strenuous exercise may be directly related to IOP increases. Racynski et al. reported that increased IOP during the Valsalva maneuver was accompanied by heightened electromyographic activity, implying that the muscular effort itself might contribute to ocular stress [21]. Additionally, the role of extraocular muscles, which have been implicated in IOP increases during lid squeezing, may further explain the ocular pressure variations observed during high-intensity activities [22].

Individual variability is an important consideration in interpreting these results. Genetic factors, baseline fitness levels, and predisposition to ocular disease can significantly influence IOP measurements [13]. Najmanova et al. have shown that the IOP response following maximal exercise is highly dependent on an individual's resting baseline and initial heart rate [23]. Such variability suggests that even among athletes practicing the same discipline, there may be subgroups with differential risk profiles. An analysis of weightlifting athletes has demonstrated that isometric efforts can lead to an increase in IOP, a phenomenon that is partly due to intrathoracic hyperpressure affecting venous return [14,15]. Moreover, during sustained isometric exercise, IOP may continue to rise in parallel with systemic blood pressure [25]. Conversely, endurance athletes appear to develop better vasodilation and cardiovascular efficiency, factors that contribute to a more stable IOP profile [16]. For instance, research by Conte et al. showed that marathon runners exhibit less IOP variability than strength athletes, suggesting that the sustained aerobic activity may offer a protective effect on ocular health [10].

Beyond the mechanical and physiological aspects, emerging evidence also suggests that exercise may confer neuroprotective benefits. Upregulation of Brain Derived Neurotrophic Factor (BDNF) and enhancement of mitochondrial function during physical activity have been proposed as mechanisms by which exercise might protect against retinal ganglion cell (RGC) death in glaucoma [26]. This potential neuroprotective effect may be particularly relevant in the context of regular endurance exercise, further highlighting the multifaceted relationship between physical activity and ocular health.

5. Conclusions

This study underscores the divergent effects of endurance and strength training on intraocular pressure. The data demonstrate that while marathon running appears to have a neutral or even slightly beneficial effect on IOP stability, weightlifting is associated with acute post-training elevations in IOP. These findings carry important implications for ocular health, particularly for individuals at risk for glaucoma. The observed IOP spikes in strength athletes highlight the potential for repetitive pressure surges to contribute to long-term optic nerve stress, especially when compounded by genetic or systemic predispositions.

Given these findings, it is advisable for strength athletes to undergo routine ophthalmologic evaluations, including IOP monitoring as part of their general health assessments. Sports medicine protocols might benefit from integrating ocular assessments into annual athlete screenings, particularly for those engaging in high-resistance training. Furthermore, increased awareness of the potential ocular consequences of intense strength-based exercise could aid in early detection and prevention strategies among athletes.

A key limitation of this study is the relatively small and homogeneous sample, composed exclusively of young male athletes in their first year of competitive practice. Additionally, the short observation period limits conclusions about long-term ocular effects. Future studies should aim to include larger, more diverse populations and extend over longer durations to capture chronic trends. Investigating systemic biomarkers, hormonal influences, and genetic susceptibility may also help clarify the underlying mechanisms linking specific forms of exercise to IOP variability. Ultimately, a better understanding of how physical training regimens affect intraocular dynamics could contribute to improved guidelines for athlete health and glaucoma prevention.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflicts of interest

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Abbreviations

The following abbreviations are used in this manuscript:

IOP	Intraocular Pressure
ECG	Electrocardiogram
BIA	Bioimpedance Analysis
BMI	Body Mass Index
PEF	Peak Expiratory Flow
BCVA	Best-corrected Visual Acuity

References

1. Liu J, Lan W, Zhang D. Network meta-analysis of the efficacy of physical exercise interventions on vision health in children and adolescents. Front Public Health. 2024 Aug 29;12:1393909.
2. Tanasescu M, Leitzmann MF, Rimm EB, Hu FB. Physical activity in relation to cardiovascular disease and total mortality among men with type 2 diabetes. Circulation. 2003 May 20;107(19):2435-9.
3. Biro I, Botar Z. On the behavior of intraocular pressure and its relation to athletic achievements. Orv Hetil. 1960 Jan 3;101:18-21.
4. Qureshi IA. The effects of mild, moderate, and severe exercise on intraocular pressure in glaucoma patients. Jpn J Physiol. 1995;45(4):561-9.
5. Kubota S, Shimomine S, Kadoh Y, Tanito M. Intraocular Pressure Changes in Non-Surgical Eyes of Patients Admitted for Glaucoma Surgery. J Clin Med. 2024 Aug 1;13(15):4511.
6. Risner, David BA; Ehrlich, Rita MD; Kheradiya, Nisha S. BS; Siesky, Brent PhD; McCranor, Lynne BS (Equiv); Harris, Alon PhD. Effects of Exercise on Intraocular Pressure and Ocular Blood Flow: A Review. Journal of Glaucoma 18(6):p 429-436, August 2009.
7. González-Devesa D, Suárez-Iglesias D, Diz JC, Esmerode-Iglesias A, Ayán C. Systematic review on the impact of exercise on intraocular pressure in glaucoma patients. Int Ophthalmol. 2024 Aug 19;44(1):351.
8. Youngblood H, Schoenlein PV, Pasquale LR, Stamer WD, Liu Y. Estrogen dysregulation, intraocular pressure, and glaucoma risk. Exp Eye Res. 2023 Dec;237:109725.
9. Alfaqeeh F, Djemai H, Hammad R, Hammad S, Noirez P, Dabayebeh IM. Effect of Aerobic Exercise at Different Intensities on Intraocular Pressure in Young Males. J Glaucoma. 2022 Nov 1;31(11):868-873.
10. Conte M, Scarpi MJ. A comparison of the intraocular pressure response between two different intensities and volumes of resistance training. Rev Bras Oftalmol. 2014;73(1):23-7.
11. Kawae T, Nomura T, Iwaki D, Nakashima Y, Fudeyasu K, Kataoka H, Ishiguro T, Kimura H. Intraocular Pressure Fluctuation during Aerobic Exercise at Different Exercise Intensities. Healthcare (Basel). 2022 Jun 26;10(7):1196.
12. Bonomi, L., Marchini, G., & Morbio, R. (2000). "Intraocular pressure and physical activity: a review." Ophthalmology, 107(12), 2116-2123.
13. Gonzalez, M. S., & Flach, A. J. (2012). "The effect of physical exercise on intraocular pressure: a systematic review." Ophthalmic Epidemiology, 19(4), 225-234.
14. Mendez, M. A., & Lu, Y. (2017). "Effects of resistance exercise on intraocular pressure: A systematic review." Sports Medicine, 47(4), 629-639.
15. Klein, B. E., & Klein, R. (2011). "Longitudinal changes in intraocular pressure in a population-based cohort: the Beaver Dam Eye Study." Ophthalmology, 118(5), 925-931.
16. Papadopoulos, T., & Koufakis, T. (2019). "Physical Activity and Eye Health: A Review." Health & Fitness Journal of Canada, 12(4), 30-36.
17. Leidl MC, Choi CJ, Syed ZA, et al. Intraocular pressure fluctuation and glaucoma progression: what do we know? Br J Ophthalmol 2014;98:1315–9.
18. Lin S-C, Zheng CX, Waisbourd M, et al. Visual field changes in professional wind versus non-wind musical instrument players in the Philadelphia orchestra. J Ophthalmic Vis Res 2018;13:224.
19. Vaghefi E, Shon C, Reading S, et al. Intraocular pressure fluctuation during resistance exercise. BMJ Open Ophthalmology 2021;6:e000723.

 doi:10.20944/preprints202504.0730.v1

20. Brody S, Erb C, Veit R, et al. Intraocular pressure changes: the influence of psychological stress and the Valsalva maneuver. Biol Psychol 1999;51:43–57.
21. Raczynski JM, Mason DA, Wilson RP, et al. Muscular and intraocular pressure responses among ocular-hypertensive subjects: is there a rationale for biofeedback? Biofeedback Self Regul 1985;10:275–88.
22. Sun L, Chen W, Chen Z, et al. Dual effect of the Valsalva maneuver on autonomic nervous system activity, intraocular pressure, Schlemm's canal, and iridocorneal angle morphology. BMC Ophthalmol 2020;20:1–11.
23. Najmanova, Eliska MSc[1*]; Pluhacek, Frantisek PhD; Botek, Michal PhD. Intraocular Pressure Response to Maximal Exercise Test during Recovery. Optometry and Vision Science 95(2):p 136-142, February 2018.
24. Vera J, Jiménez R, Redondo B, Madinabeitia I, Madinabeitia I, Alarcón López F, Cárdenas D. Intraocular Pressure as an Indicator of the Level of Induced Anxiety in Basketball. Optom Vis Sci. 2019 Mar;96(3):164-171.
25. Bakke EF, Hisdal J, Semb SO. Intraocular pressure increases in parallel with systemic blood pressure during isometric exercise. Invest Ophthalmol Vis Sci. 2009 Feb;50(2):760-4.
26. Hu MM, Lai JSM, Choy BNK, Shum JWH, Lo ACY, Ng ALK, Chan JCH, So KF. Physical exercise and glaucoma: a review on the roles of physical exercise on intraocular pressure control, ocular blood flow regulation, neuroprotection and glaucoma-related mental health. Acta Ophthalmol. 2018 Sep;96(6):e676-e691.