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REVIEW ARTICLE

The impact of physical activity on intraocular pressure: a review of the literature

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Summary

Glaucoma is a chronic, progressive optic neuropathy and one of the leading causes of irreversible blindness worldwide. Intraocular pressure (IOP) remains the most important and only proven modifiable risk factor for the development and progression of glaucoma. At the same time, current pharmacological, laser, and surgical interventions primarily aim to lower IOP. Physical activity exerts a wide range of systemic effects that may directly or indirectly influence IOP and ocular perfusion. The effect of physical activity on IOP depends on the type, intensity, and duration of exercise, as well as individual patient characteristics.

Aerobic exercise is consistently associated with acute IOP reductions of 1 to 5 mmHg, mediated by increased aqueous humor outflow, osmotic shifts, and sympathetic modulation of aqueous production. Long-term aerobic training may produce sustained baseline IOP reductions of approximately 2 to 4 mmHg, with concurrent improvements in ocular perfusion pressure. In contrast, high-intensity anaerobic and isometric exercise, as well as inverted body positions such as specific yoga postures, can transiently elevate IOP to clinically concerning levels, primarily through Valsalva maneuver-induced increases in episcleral venous pressure. The relationship between physical activity and ocular perfusion pressure further underscores the complexity of exercise-ocular interactions.

The clinical significance of these findings lies in the potential application of physical activity as an adjunctive strategy in glaucoma management. Moderate aerobic exercise should be encouraged in most patients, while certain high-intensity activities and inverted positions should be carefully considered. Further research is needed to establish standardized guidelines and to understand better the long-term impact of physical activity on glaucoma progression.

Keywords: intraocular pressure, glaucoma, physical activity, aerobic exercise, ocular perfusion pressure

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INTRODUCTION

Glaucoma is a chronic, progressive optic neuropathy and one of the leading causes of irreversible blindness worldwide, affecting an estimated 80 million individuals globally (1). It is characterized by structural damage to the optic nerve head and corresponding visual field defects that, once established, cannot be reversed with current therapeutic strategies. Intraocular pressure (IOP) remains the most important and only proven modifiable risk factor in glaucoma development and progression. Current pharmacological, laser, and surgical interventions primarily aim to lower IOP (2). However, disease progression has been documented even in patients who achieve target IOP levels, suggesting that additional systemic and environmental factors contribute to glaucomatous optic nerve damage (3). Previous work has demonstrated that vascular and hemodynamic factors play a key role in this context: changes in retrobulbar hemodynamic parameters following IOP reduction in primary open-angle glaucoma (POAG) patients confirm the vascular component of glaucomatous damage (4), and ambulatory blood pressure monitoring has revealed important associations between systemic hypertension and normal-tension glaucoma (5).

Among lifestyle-related factors, physical activity has attracted growing scientific interest in recent years. Physical activity exerts wide-ranging systemic effects, including improvements in cardiovascular function, metabolic regulation, vascular reactivity, and autonomic nervous system tone, all of which may directly or indirectly influence IOP and optic nerve perfusion (6, 7). The relationship between exercise and IOP is complex and multidirectional, depending on the type, intensity, duration, and biomechanical characteristics of the exercise performed, as well as individual patient factors such as baseline IOP, cardiovascular fitness, and glaucoma subtype (8).

Understanding these interactions has direct clinical relevance, as patients with glaucoma are frequently advised regarding lifestyle modifications, yet evidence-based exercise-specific recommendations remain limited in most clinical guidelines. Early investigations into the effect of exercise on IOP date back to the 1960s, and over half a century of subsequent research has substantially advanced our understanding of the acute and chronic ocular responses to physical exertion (9). More recently, systematic reviews and randomized controlled trials have begun to provide higher-quality evidence to support clinical practice (10, 11).

This review synthesizes the current evidence on the effects of various forms of physical activity on IOP, examines the underlying physiological mechanisms, and discusses the practical implications for the management of patients with glaucoma, with particular attention to the differential effects of aerobic versus anaerobic exercise, body position, and the distinction between acute and chronic adaptations.

MATERIAL AND METHODS

A comprehensive literature search was conducted using the PubMed/MEDLINE, Scopus, and Google Scholar databases. The search included English-language articles published between January 1995 and February 2026. The following keywords and keyword combinations were used: “intraocular pressure”, “glaucoma”, “physical activity”, “exercise”, “aerobic exercise”, “resistance training”, “weightlifting”, “ocular perfusion pressure”, “yoga”, and “Valsalva maneuver”.

Additional relevant articles were identified through manual screening of the reference lists of selected publications. Priority was given to systematic reviews, meta-analyses, randomized controlled trials, and clinically relevant observational studies addressing the effects of physical activity on intraocular pressure and ocular perfusion pressure in healthy subjects and glaucoma patients.

Publications not directly related to intraocular pressure or glaucoma, duplicate studies, conference abstracts without full text, and non-English articles were excluded from the review.

PHYSIOLOGICAL REGULATION OF INTRAOCULAR PRESSURE

IOP is determined by the dynamic equilibrium between continuous aqueous humor production and its drainage from the anterior segment of the eye. Aqueous humor is actively secreted by the non-pigmented epithelium of the ciliary body and drains primarily via two pathways: the conventional trabecular route, comprising the trabecular meshwork, Schlemm’s canal, and the episcleral venous system; and the unconventional uveoscleral pathway, through which fluid diffuses across the ciliary muscle into the suprachoroidal space (12, 13). In POAG, the predominant pathological change is an increase in outflow resistance at the juxtacanalicular trabecular meshwork and the inner wall of Schlemm’s canal, resulting in elevated IOP (14).

Beyond local ocular mechanisms, IOP is influenced by systemic factors. Episcleral venous pressure is a particularly important determinant, as any increase in venous pressure is directly transmitted to the outflow system and tends to raise IOP proportionally (12). Systemic arterial blood pressure, autonomic nervous system activity, particularly via adrenergic receptors on the ciliary epithelium, and circulating hormones, including cortisol and prostaglandins, all modulate aqueous humor dynamics (15). Circadian rhythmicity further contributes to IOP variation, with pressures typically peaking in the early morning hours and declining in the afternoon and evening (16). Previous work has demonstrated that central corneal thickness is another important modulator of IOP measurement across various age groups, and this must be accounted for when interpreting exercise-related IOP changes in clinical settings (17).

Physical activity can simultaneously influence multiple components of this regulatory system. Exercise-induced changes in systemic hemodynamics, including increases in cardiac output, arterial blood pressure, and peripheral vascular resistance, alter ocular blood flow and episcleral venous pressure. Neurohumoral responses during exercise, particularly sympathetic nervous system activation, modify aqueous humor secretion via beta-adrenergic pathways. Additionally, metabolic byproducts of exercise, including lactic acid, carbon dioxide accumulation, and osmotically active metabolites, may alter aqueous humor composition or affect the permeability of ocular tissues (7, 8). The net effect of these overlapping mechanisms on IOP depends heavily on the type and intensity of exercise performed.

EFFECTS OF AEROBIC EXERCISE ON INTRAOCULAR PRESSURE

Acute responses

Aerobic exercise has been consistently associated with a reduction in IOP in both healthy individuals and patients with glaucoma across a wide range of studies. Activities such as walking, jogging, running, and cycling have been shown to reduce IOP by 1 to 5 mmHg, with the effect most pronounced immediately after exercise and gradually diminishing over the subsequent 30 to 60 minutes (9, 10). A 2022 controlled study examining the effects of aerobic exercise at different intensities on a cycle ergometer found a significant IOP reduction specifically at high-intensity exercise corresponding to 85% of peak power, underscoring exercise intensity as a key modulating variable (18).

A 2024 systematic review by González-Devesa et al., conducted according to PRISMA guidelines and encompassing 15 studies with 388 participants in a meta-analysis, confirmed that both aerobic and resistance training led to an immediate IOP reduction following a single exercise session, with a moderately significant pooled effect size (Hedges' $g = -0.81$, $p = 0.022$) (10). Notably, the review identified a strong inverse association between baseline IOP and the magnitude of the exercise-induced reduction ($R^2 = 0.626$), suggesting that individuals with higher baseline pressures may derive greater benefit, with direct implications for glaucoma management. The same meta-analysis found that the IOP-lowering effect appeared independent of exercise intensity across subgroup analyses. However, this finding should be interpreted with caution, given the high heterogeneity ($I^2 = 96.7\%$) across included trials (10).

Mechanisms of IOP reduction

The mechanisms underlying the IOP-lowering effect of aerobic exercise are multifactorial. One of the most consistently cited explanations involves an increase in aqueous humor outflow facility, potentially mediated by biomechanical and biochemical changes within the trabecular meshwork. Nitric oxide (NO), a potent vasodilator released during aerobic exercise, relaxes trabecular meshwork cells and increases the permeability of Schlemm's canal, thereby reducing outflow resistance (19). Structural expansion of the Schlemm's canal lumen during exercise may further facilitate aqueous drainage (6).

The second proposed mechanism involves suppression of aqueous humor production. Sympathetic nervous system activation during aerobic exercise stimulates beta-adrenergic receptors on the ciliary body epithelium, reducing aqueous secretion rate, a mechanism analogous to that of topical beta-blocker medications (7, 8). Additionally, exercise-induced increases in plasma osmolarity, resulting from lactate accumulation, carbon dioxide production, and fluid redistribution to exercising muscles, create an osmotic gradient that draws fluid from the intraocular space into the systemic circulation (15). Improvements in ocular perfusion and vascular autoregulation, mediated by endothelial function and increased ocular blood flow in the post-exercise period, may also contribute (6).

ANAEROBIC AND ISOMETRIC EXERCISE

In contrast to the IOP-lowering effects of aerobic exercise, anaerobic and isometric activities, including weightlifting, resistance training, and sustained muscle contraction, can produce transient, sometimes substantial increases in IOP. A central mechanism is the Valsalva maneuver, which involves forced expiration against a closed glottis and is commonly performed, often inadvertently, during high-intensity resistance exercise. This maneuver sharply increases intrathoracic pressure, which is transmitted to the central venous system and subsequently elevates episcleral venous pressure, impairing aqueous outflow and raising IOP (7, 20).

A 2025 comprehensive review confirmed that resistance training causes short-term increases in IOP and systemic blood pressure, while noting that the net effect on ocular perfusion pressure (OPP) may also transiently increase, reflecting the complex interplay between systemic and ocular hemodynamics (11). Whether these acute IOP spikes translate into cumulative optic nerve damage over time remains unclear. Studies examining the immediate and cumulative effects of isometric squat exercise across varying loads have demonstrated consistent IOP elevations proportional to the applied load, with the highest pressures recorded at near-maximal effort (20). The emerging data on blood flow restriction training suggest it may offer a safer alternative for patients who wish to engage in resistance exercise, as low-load resistance training combined with moderate blood flow restriction produced IOP responses comparable to those of standard resistance exercise without Valsalva provocation (11).

Patients with advanced glaucoma, compromised nerve fiber layers, or already elevated IOP are at the greatest risk of harm from repeated acute IOP spikes during anaerobic exercise. Exfoliative glaucoma, a subtype characterized by particularly high IOP levels and rapid progression, presents distinctive clinical features that may render these patients especially vulnerable to exercise-induced pressure fluctuations (21, 22). Individualized counseling on exercise type and technique is therefore essential in this population.

ROLE OF BODY POSITION AND YOGA

Body position is an independent and clinically significant determinant of IOP. The transition from an upright to a supine position is associated with an IOP increase of approximately 1 to 2 mmHg in healthy eyes, with larger effects in glaucomatous eyes, attributed to increased episcleral venous pressure and redistribution of ocular blood volume (23). Inverted body positions, as used in certain yoga practices, produce substantially greater IOP elevations through the same mechanism, amplified by gravity-driven cephalic fluid displacement.

The landmark prospective observational study by Jasien et al. (2015), conducted at the New York Eye and Ear Infirmary of Mount Sinai, evaluated IOP changes in 10 POAG patients and 10 healthy controls during four common head-down yoga postures (23). Both groups demonstrated significant IOP elevations across all four positions, with the greatest increase in the downward-facing dog (Adho Mukha Svanasana) posture. Importantly, IOP remained slightly elevated even after returning to a seated position and waiting ten minutes, suggesting that recovery may not be immediate and that the clinical impact of repeated posture practice may accumulate. A more recent study using the iCare HOME2 self-tonometer across four inverted yoga postures in 25 healthy subjects and 25 glaucoma patients found acute IOP elevations of up to 31 mmHg in head-down positions, with no statistically significant difference in the magnitude of elevation between the two groups (24). These data are particularly concerning given that the sirsasana (headstand) posture has previously been shown to approximately double baseline IOP values in some individuals (25).

Importantly, the picture with yoga is not entirely negative. A systematic review and meta-analysis examining structured yoga-based interventions, including pranayama breathing and meditation practices, with exclusion of overtly inverted postures, found statistically significant IOP reductions of approximately 1.3 to 1.5 mmHg compared to non-yoga controls in glaucoma patients (26). These findings suggest that yoga, when practiced with appropriate modifications, may contribute to IOP management. Clinicians should advise patients to inform yoga instructors of their glaucoma diagnosis and to request modifications that avoid sustained head-down positions.

ACUTE VERSUS CHRONIC EFFECTS OF PHYSICAL ACTIVITY

The effects of physical activity on IOP are usefully distinguished as acute responses occurring during or immediately after a single session of exercise and chronic adaptations associated with sustained participation in a regular training program. Acute aerobic exercise produces a transient IOP reduction that typically begins within minutes of activity onset, peaks at cessation, and returns to baseline within approximately 30 to 60 minutes. Anaerobic or isometric exercise may produce transient IOP elevations that similarly resolve within a short period following cessation (9, 10).

The chronic effects of regular aerobic exercise on baseline IOP have been investigated in several prospective studies, with increasingly robust evidence supporting a modest but meaningful sustained reduction. A randomized controlled trial enrolling 123 POAG patients on prostaglandin analog therapy found that three months of regular morning jogging at moderate intensity produced a significant reduction in the 24-hour IOP curve compared to a non-exercising control group (27). The mean baseline IOP decreased by approximately 4.6 mmHg in the exercise group, with a concurrent significant increase in OPP. Critically, this reduction was reversible upon exercise cessation, with IOP returning to pre-training levels within approximately three weeks (9). This finding underscores the need to maintain physical activity as an ongoing component of glaucoma management rather than viewing it as a short-term intervention.

A 2025 review corroborated these findings, reporting that long-term aerobic conditioning produces sustained baseline IOP reductions of approximately 2 to 4 mmHg and improvements in OPP, suggesting potential neuroprotective benefits extending beyond IOP lowering alone (11). Whether these hemodynamic improvements translate into measurable visual field preservation over longer time horizons remains an important area for future investigation. Physical fitness level may further modulate the acute IOP-lowering response, with evidence suggesting that fitter individuals exhibit smaller acute reductions, possibly because their baseline IOP is already lower due to chronic training adaptation (28).

IMPACT ON OCULAR PERFUSION PRESSURE

Ocular perfusion pressure, defined as the difference between mean arterial pressure and IOP (OPP = 2/3 MAP – IOP), is a critical determinant of optic nerve head blood supply and metabolic support (27). Epidemiological studies have identified low OPP as an independent risk factor for POAG, separate from absolute IOP levels, highlighting the importance of ocular vascular health in the pathogenesis of glaucomatous optic neuropathy (29). Physical activity can simultaneously influence both components of OPP, with consequences that depend on the relative magnitudes of changes in blood pressure and IOP.

Aerobic exercise generally increases systemic blood pressure, primarily systolic, and reduces IOP, both of which increase OPP and thereby enhance optic nerve perfusion (27). Significant increases in OPP following aerobic exercise have been reported in POAG patients, with some studies documenting increases of 21.7% to 43% above baseline (9). However, autoregulatory mechanisms governing ocular blood flow introduce additional complexity: while increased OPP may theoretically enhance optic nerve perfusion, a proportionate increase in vascular resistance within the ocular circulation may attenuate the actual increase in retinal blood flow, particularly during high-intensity exertion. Pathological states, including advanced glaucoma with compromised autoregulation, may further disrupt this compensatory response (9). Previous research has demonstrated that lowering elevated IOP in POAG patients results in measurable changes in retrobulbar hemodynamic parameters, confirming the close relationship between pressure and perfusion in glaucomatous eyes (4).

Research involving individuals with a family history of glaucoma has demonstrated that this population may exhibit lower OPP at rest and an attenuated OPP response to isometric exercise compared to controls, suggesting an underlying vascular susceptibility that precedes manifest disease (29). These observations reinforce the concept that vascular factors play an independent role in glaucoma pathophysiology and that exercise prescriptions for at-risk individuals should consider not only IOP effects but also systemic hemodynamic responses.

CLINICAL IMPLICATIONS FOR GLAUCOMA PATIENTS

The collective evidence has direct practical implications for the counseling and management of patients with glaucoma. Moderate aerobic exercise, including brisk walking, jogging, cycling, and swimming at low to moderate intensity, can be recommended as part of a healthy lifestyle, as it may contribute to both acute and sustained IOP reductions, improvements in OPP, and potential neuroprotective effects through enhanced ocular perfusion and neuronal plasticity (9, 11, 27). Additionally, exercise has well-documented benefits for anxiety and depression, both prevalent comorbidities in chronic glaucoma that may independently worsen IOP control and reduce quality of life (9).

Caution is warranted, however, when advising patients about activities involving heavy lifting, prolonged breath-holding, or inverted body positions. These activities carry a risk of significant acute IOP elevation and should be approached with particular care in patients with advanced glaucomatous damage or poor baseline IOP control. In patients with pigmentary glaucoma, a recognized subtype in which exercise-induced pigment dispersion can paradoxically raise IOP with aerobic activity, even conventional aerobic recommendations require modification (9). Patients with advanced or juvenile-onset glaucoma should be advised that reports of transient vascular steal phenomena and visual symptoms during high-intensity exercise have been documented and warrant clinical awareness.

Practical guidance should be individualized and account for disease severity, baseline IOP, current medications, cardiovascular fitness, and the patient's habitual physical activities. Clinicians should specifically discuss avoiding the Valsalva maneuver during resistance training achievable through a controlled breathing technique, and avoiding sustained inverted postures in yoga. Current evidence-based recommendations suggest that glaucoma patients wishing to engage in resistance training should use lower loads with higher repetitions, avoiding near-maximal efforts, and should practice diaphragmatic breathing throughout exercise sets (11). The use of blood flow restriction at moderate occlusion pressures may represent a promising alternative resistance-training strategy that produces muscular adaptations without eliciting the degree of IOP elevation associated with high-load conventional resistance exercise (11).

CONCLUSION

Physical activity exerts a complex, bidirectional, and clinically significant influence on IOP, with effects that vary substantially depending on exercise type, intensity, duration, body position, and individual patient characteristics. The most consistent and clinically relevant finding across the literature is that moderate aerobic exercise produces acute IOP reductions mediated by increased outflow facility, osmotic mechanisms, and sympathetic suppression of aqueous production effects that, with sustained training, may translate into meaningful reductions in baseline IOP and improvements in OPP.

Resistance exercise and inverted body positions carry a risk of acute IOP elevation that is of clinical concern in patients with advanced glaucomatous damage, particularly in those with exfoliative glaucoma or other high-pressure subtypes where baseline IOP is already substantially elevated (21, 22). Yoga, when practiced with attention to problematic postures, may offer a net benefit for IOP control through its non-inverted breathing and meditation components.

Taken together, the available evidence supports the incorporation of individualized exercise counseling into the comprehensive management of glaucoma. Regular, moderate aerobic activity should be actively encouraged in most patients, while specific contraindications, including Valsalva-intensive resistance training and sustained head-down postures, should be clearly communicated. Further prospective, controlled studies with longer follow-up periods and standardized exercise protocols are needed to clarify dose-response relationships, identify which glaucoma subtypes benefit most, and determine whether exercise-mediated IOP reductions meaningfully alter long-term rates of visual field progression.

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UTICAJ FIZIČKE AKTIVNOSTI NA VREDNOST INTRAOKULARNOG PRITISKA: PREGLED LITERATURE

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Sažetak

Glaukom predstavlja hroničnu, progresivnu optičku neuropatiju i jedan je od vodećih uzroka ireverzibilnog slepila u svetu. Intraokularni pritisak (IOP) ostaje najvažniji i jedini dokazano promenljiv faktor rizika u nastanku i progresiji glaukoma. Fizička aktivnost ispoljava brojne sistemske efekte koji mogu direktno ili indirektno uticati na intraokularni pritisak i očnu perfuziju. Uticaj fizičke aktivnosti na IOP zavisi od tipa, intenziteta i trajanja vežbanja, kao i od individualnih karakteristika pacijenta.

Aerobne vežbe povezane su sa akutnim smanjenjem intraokularnog pritiska u rasponu od 1 do 5 mmHg, što se objašnjava pojačanim oticanjem očne vodice, osmotskim promenama i uticajem simpatičkog nervnog sistema na njeno stvaranje. Dugotrajna i redovna aerobna aktivnost može dovesti i do trajnog smanjenja bazalnog intraokularnog pritiska za približno 2 do 4 mmHg, uz istovremeno poboljšanje očnog perfuzionog pritiska.

Nasuprot tome, anaerobne i izometrijske vežbe visokog intenziteta, kao i položaji tela sa spuštenom glavom, uključujući pojedine položaje u jogi, mogu dovesti do prolaznog porasta intraokularnog pritiska, ponekad i do klinički značajnih vrednosti. Ovaj efekat se prvenstveno objašnjava porastom episkleralnog venskog pritiska, najčešće usled izvođenja Valsalvinog manevra.

Klinički značaj ovih nalaza ogleda se u mogućnosti primene fizičke aktivnosti kao dopunske strategije u lečenju glaukoma. Umerena aerobna aktivnost može se preporučiti većini pacijenata, dok aktivnosti visokog intenziteta, naročito one koje uključuju izometrijski napor ili položaje sa spuštenom glavom, zahtevaju poseban oprez i individualizovan pristup. Dalja istraživanja su neophodna radi definisanja standardizovanih smernica i boljeg razumevanja dugoročnog uticaja fizičke aktivnosti na tok i progresiju glaukoma.

Ključne reči: intraokularni pritisak, glaukom, fizička aktivnost, aerobne vežbe, okularni perfuzioni pritisak

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