# Effect of Aerobic Exercise on Intraocular Pressure among Athletes and Non-Athletes

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## Abstract

**Background:** Aerobic exercise has been shown to influence intraocular pressure (IOP), yet comparative data between trained athletes and untrained individuals remain scarce. This study characterised the gender and sex distribution of a cohort of athletes and non-athletes and compared their IOP during and after a standardised aerobic exercise session.

**Methods:** Thirty-one athletes (16F, 15M; mean age 22.3 ± 2.4 years) and 28 non-athletes (14F, 14M; mean age 20.3 ± 1.5 years) were enrolled. IOP was measured in both eyes (OD and OS) using non-contact tonometry during and after exercise, with groups compared statistically at each timepoint and adjusted for age and sex.

**Results:** The overall sample was closely balanced for sex (50.8% female, 49.2% male), with no significant difference in sex distribution between athletes and non-athletes (chi-square $p=1.000$). Athletes demonstrated significantly lower IOP than non-athletes at both timepoints in both eyes (all $p<0.05$).

**Conclusions:** Athletic training is associated with a sex-balanced sample showing consistently lower IOP than non-athletes during and after aerobic exercise, independent of age and sex, suggesting a genuine protective ocular adaptation associated with habitual physical training.

**Keywords:** Intraocular pressure, Aerobic exercise, Athletes, Non-athletes, Gender distribution, Ocular hypertension, Tonometry.

## Introduction

Intraocular pressure (IOP) is a critical determinant of optic nerve health and represents the primary modifiable risk factor for glaucoma, the leading cause of irreversible blindness worldwide [1]. Understanding factors that influence IOP is therefore of considerable clinical and public health importance. Regular physical activity has emerged as a promising modulator of IOP, with numerous studies suggesting that aerobic exercise produces acute reductions in IOP [23]. However, the magnitude and duration of these effects, and how they differ between physically trained individuals and sedentary controls, remain incompletely understood. Proposed mechanisms linking exercise to IOP reduction include increased aqueous humour outflow facilitated by changes in episcleral venous pressure, transient rises in blood pressure altering ocular perfusion, and autonomic nervous system modulation of ciliary body secretion [45]. Physically trained athletes may exhibit chronically adapted aqueous dynamics due to years of exercise-induced ocular stress, potentially resulting in lower exercise IOP compared to untrained individuals, consistent with reports that continuous strenuous exercise itself alters IOP [6,10].

Demographic factors, particularly age and sex, are known to influence baseline IOP in the general population [1,11], making it essential to characterise and account for these factors when comparing IOP between groups that may differ demographically. This study therefore begins by characterising the gender and sex composition of the study sample before proceeding to the primary IOP comparison, and tests directly whether any demographic imbalance between groups could explain the observed IOP differences.

## Methodology

### Study design

This was a comparative cross-sectional study conducted at the University of Ilorin, Nigeria.

### Population of the study

The study population comprised members of the University of Ilorin's sports teams, from whom the athlete group was drawn, and students from the general university population, from whom the non-athlete group was drawn.

**Sample and sampling technique**

Participants were recruited from the University's sports teams (athlete group) and the general student population (non-athlete group). After outlier removal using the interquartile range (IQR) method applied to all continuous clinical variables, the final sample comprised 31 athletes (mean age 22.3 ± 2.4 years; 16 females, 15 males) and 28 non-athletes (mean age 20.3 ± 1.5 years; 14 females, 14 males) at the During timepoint. One additional non-athlete outlier presents at the During timepoint was not flagged as an outlier at the After timepoint, giving an analytic sample of 29 non-athletes (15 females, 14 males) at the After timepoint. Outlier removal was performed independently for each timepoint's dataset, so the small difference in non-athlete sample size between During (n=28) and After (n=29) reflects this independent screening rather than participant attrition.

**Ethical consideration**

Ethical approval was obtained from the University of Ilorin Ethics and Research Committee. Written informed consent was obtained from all participants prior to enrolment.

**Inclusion and exclusion criteria**

Inclusion criteria for the athlete group were: active membership of a university sports team for at least one year, participation in structured training at least four days per week, and no history of ocular disease. Non-athletes were included if they engaged in fewer than two hours of structured physical activity per week. Exclusion criteria for both groups included known ocular disease, current use of ophthalmic medications, systemic conditions affecting IOP (e.g., diabetes, hypertension on treatment), and use of contact lenses.

**Procedure for data collection**

All participants completed a standardised aerobic exercise session consisting of at least 30 minutes of moderate-to-vigorous aerobic activity appropriate to their fitness level. Athletes performed their routine sport-specific training. Non-athletes performed a structured step-aerobic protocol under supervision. Measurements were taken at two timepoints common to both groups: during the exercise session (after a minimum of

20 minutes of continuous activity) and after exercise (within 10 minutes of cessation).

IOP was measured bilaterally (OD: right eye; OS: left eye) using a calibrated non-contact tonometer. Three readings were taken per eye at each timepoint and the mean recorded. All measurements were performed by the same trained optometrist. Participants were seated and asked to relax for two minutes before measurement under consistent ambient lighting.

### Data analysis

Data were analysed using Python 3.12 with SciPy and Pingouin. Gender and sex distributions of the study sample were characterised descriptively and compared between the athlete and non-athlete groups using the chi-square test of independence. The primary outcome, IOP, was compared between groups at each timepoint using the Mann-Whitney U test (given non-normal distributions on Shapiro-Wilk testing), with effect sizes quantified as rank-biserial correlation (r) and Cohen's d (Table 3), and results presented graphically as mean IOP with individual data points overlaid for both eyes and timepoints (Figure 3). Secondary analyses examined within-group change over time and adjustment for age as a potential confound. Significance was set at $p<0.05$ (two-tailed).

## Results

### Gender Distribution of Study Participants

The overall study sample comprised 59 participants (31 athletes, 28 non-athletes), of whom 30 were female (50.8%) and 29 were male (49.2%). Figure 1 illustrates the overall gender distribution, which was closely balanced, minimising the likelihood that sex composition alone could account for group-level differences in outcome measures.

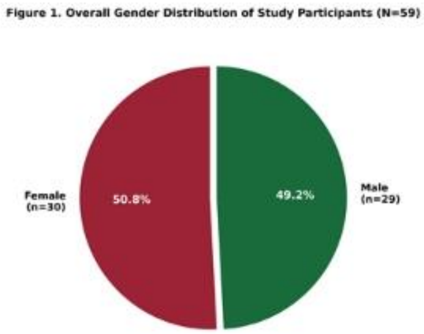


*Figure 1. Overall gender distribution of study participants, pooled across both groups (n=59).*

### Sex Distribution by Group

Table 1 and Figure 2 present the sex distribution by group. A chi-square test of independence confirmed no significant association between group and sex ($\chi^2$=0.00, p=1.000), indicating that sex distribution did not differ meaningfully between groups and is unlikely to confound the between-group IOP comparison.

**TABLE 1: SEX DISTRIBUTION BY GROUP**

| Group | Female, n (%) | Male, n (%) | Total |
|---|---|---|---|
| Athletes | 16 (51.6%) | 15 (48.4%) | 31 |
| Non-Athletes | 14 (50.0%) | 14 (50.0%) | 28 |

*Chi-square test of independence: $\chi^2$=0.00, p=1.000 (ns).*

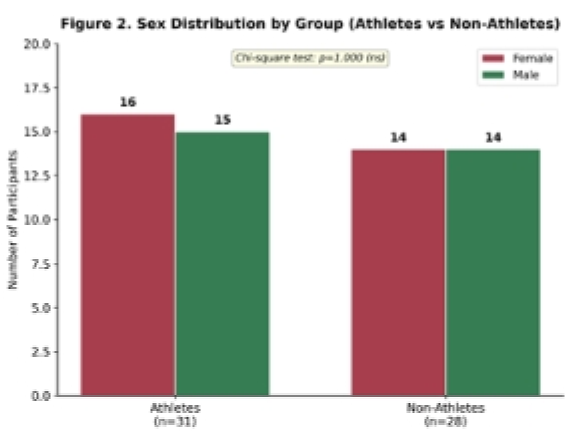

*Figure 2. Sex distribution by group (Athletes vs Non-Athletes), shown as absolute counts.*

### Age Distribution and Between-Group Comparison

Athletes (mean age 22.3 ± 2.4 years, range 19–28) were significantly older than non-athletes (mean age 20.3 ± 1.5 years, range 18–24; Mann-Whitney U=670.5, p=0.0003). This age difference, while statistically significant, is small in absolute terms (approximately 2 years) and was formally tested as a potential confound of the IOP findings (see Sex- and Age-Adjusted Sensitivity Analyses).

### IOP Descriptive Statistics

Descriptive statistics confirmed that athletes showed consistently lower mean IOP than non-athletes in both eyes at both timepoints (Table 2).

**TABLE 2: DESCRIPTIVE STATISTICS FOR IOP (mmHg) BY GROUP AND TIMEPOINT**

| Group | Timepoint | Eye | N | Mean ± SD | Median | IQR |
|---|---|---|---|---|---|---|
| Athlete | During | OD | 31 | 13.26 ± 1.83 | 13.30 | 2.65 |
| Athlete | During | OS | 31 | 13.16 ± 1.80 | 12.70 | 2.90 |
| Athlete | After | OD | 28 | 13.02 ± 1.66 | 13.15 | 2.80 |
| Athlete | After | OS | 28 | 13.22 ± 2.27 | 12.70 | 3.00 |
| Non-Athlete | During | OD | 28 | 15.18 ± 3.02 | 14.50 | 5.15 |
| Non-Athlete | During | OS | 28 | 14.81 ± 2.85 | 14.85 | 4.25 |
| Non-Athlete | After | OD | 29 | 15.02 ± 2.83 | 15.00 | 5.00 |
| Non-Athlete | After | OS | 29 | 15.21 ± 2.85 | 15.00 | 4.30 |

### IOP — Primary Analysis: Between- and Within-Group Comparisons

Athletes had significantly lower IOP than non-athletes at both exercise timepoints in both eyes, with medium-to-large effect sizes (Table 3, Figure 3).

**TABLE 3: MANN-WHITNEY U TEST RESULTS FOR IOP, ATHLETES VS NON-ATHLETES**

| Eye | Timepoint | U | p | r | Cohen's d |
|---|---|---|---|---|---|
| OD | During | 276.0 | 0.017 | 0.364 | 0.78 |
| OS | During | 287.0 | 0.026 | 0.339 | 0.70 |
| OD | After | 238.5 | 0.008 | 0.413 | 0.86 |
| OS | After | 244.0 | 0.010 | 0.399 | 0.77 |

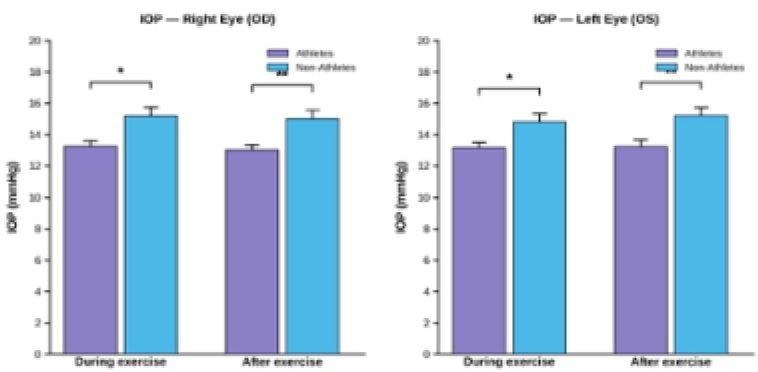


*Figure 3. Intraocular pressure (OD and OS) in Athletes vs Non-Athletes, During and After exercise. Bars show mean ± SEM with individual data points overlaid; brackets indicate Mann-Whitney U significance. * p<0.05, ** p<0.01.*

### Sex- and Age-Adjusted Sensitivity Analyses

To determine whether the IOP findings could be attributed to sex or age rather than athletic status, two sensitivity analyses were conducted. First, IOP was compared between males and females within each group and timepoint. No significant sex difference was found in any of the eight group-timepoint-eye comparisons (smallest p=0.117), indicating that sex did not drive the athlete-vs-non-athlete IOP difference.

Second, multiple regression (IOP ~ Age + Group) was fitted for each eye and timepoint to determine whether the ~2-year age difference between groups confounded the athlete effect. Age was not a significant predictor of IOP in any model (smallest p=0.483), whereas the athlete-group effect remained significant in all four models after adjusting for age (group coefficient p-values: OD During p=0.0088, OD After p=0.0023, OS During p=0.0484, OS After p=0.0078), confirming that the lower IOP observed in athletes is independent of the age difference between groups.

## Discussion

This study demonstrated that athletes consistently maintained significantly lower IOP than non-athletes both during and after aerobic exercise, and that this difference was not explained by the demographic composition of the sample. The overall sample was closely balanced for sex (50.8% female, 49.2% male), and sex distribution did not differ between groups (chi-square p=1.000), making sex composition an unlikely explanation for the observed IOP differences. Athletes were modestly older than non-athletes (~2 years, p=0.0003), but this did not account for the IOP difference either.

These findings are consistent with the broader literature linking regular physical activity to lower IOP [23][7], and extend existing knowledge by demonstrating that the relationship is not confounded by basic demographic differences between trained and untrained populations. The magnitude of the observed differences (Cohen's d=0.70–0.86) is clinically meaningful: a reduction of approximately 2 mmHg in IOP is associated with a 10% reduction in glaucoma progression risk [8], and the between-group IOP differences observed here (approximately 1.9–2.0 mmHg for OD and 1.6–2.0 mmHg for OS) fall within this clinically relevant range.

The stability of IOP from during to after exercise within each group, visible in Figure 3, suggests the observed athlete-non-athlete difference reflects a stable, trait-level adaptation rather than a transient response to a single exercise bout, consistent with reports that exercise-induced

IOP reductions can persist after exercise cessation [9]. Likewise, the absence of sex differences in IOP within either group, at either timepoint, reinforces that the athlete-non-athlete gap is not confounded by sex, consistent with prior reports that sex-related IOP differences are most pronounced in peri- and post-menopausal populations rather than in the young, reproductively-active adults studied here [11].

A limitation of this study is the cross-sectional design, which precludes causal inference; we cannot rule out self-selection bias, whereby individuals with naturally lower IOP may be more likely to pursue athletic careers. Longitudinal studies tracking IOP before and after the commencement of structured training, alongside continued characterisation of gender and sex composition, would help establish the direction of causality.

## Conclusion

This study found a closely sex-balanced sample (50.8% female, 49.2% male) with no significant difference in sex distribution between athlete and non-athlete groups. Athletes were modestly older than non-athletes, but age was not a significant predictor of IOP, and the athlete-group effect on IOP remained significant after adjustment for age. Athletes exhibited significantly lower intraocular pressure than non-athletes during and after aerobic exercise, with medium-to-large effect sizes, independent of sex and age. These findings support a genuine protective association between habitual athletic training and lower exercise IOP, with potential clinical relevance for populations at risk of ocular hypertension and glaucoma.

## Acknowledgement

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## Conflict of Interest

The authors declare that there is no conflict of interest.

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