Inner ocular blood flow response to exercise in healthy humans

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Abstract  Inner ocular circulation consists of choroidal and retinal circulation. The inner ocular blood flow nourishes the retina, which plays an important role in vision. It had been thought that inner ocular circulation kept its blood flow constant against circulatory challenges during exercise. Recent studies, however, have revealed that inner ocular blood flow changes during exercise, and that retinal and choroidal circulations show different responses depending on the manner of exercise. This review provides an overview of the responses in inner ocular blood flow to exercise and its relevant factors.

Keywords : ocular circulation, ocular blood flow, exercise

Introduction

The inner ocular circulation consists of the choroidal and retinal circulation, both of which contribute to the nutrition of retinal tissue¹ (Fig. 1). Physiological and pathophysiological studies have demonstrated that adequate inner ocular circulation is essential to visual function²⁵). The regulatory mechanisms of inner ocular blood flow and outer ocular blood flow, i.e., the ophthalmic artery that supplies blood to inner ocular circulation, are different, despite the fact that the inner ocular vessels branch from the ophthalmic artery⁶). In addition, retinal and choroidal circulations have different regulatory mechanisms⁹).

The inner ocular blood flow response to exercise is an important target to be regulated, since the status of the inner ocular vessels directly reflects circulation to retinal tissue. The inner ocular blood flow dynamics during exercise have long been unclear, since few studies have reported on inner ocular blood flow, and such earlier studies only reported on after exercise. More recently, inner ocular blood flow responses to several exercise conditions have been reported. This short review deals with the current evidence on inner ocular blood flow dynamics during exercise.

Inner ocular blood flow during dynamic exercise

Inner ocular blood flow changes according to the intensity of dynamic exercise and/or perfusion pressure. It has long been believed that inner ocular blood flow could be kept at a constant level of resting baseline during exercise, as inner ocular circulation had an autoregulation against changes in perfusion pressure²⁰). Retinal and choroidal blood flow, however, increase during submaximal dynamic exercise, even with mild increases of ocular perfusion pressure (< 10%)¹¹). Consistent with this observation, the authors also reported that choroidal blood flow increased concomitantly with an increase in mean arterial pressure (MAP) during incremental cycling exercise (Fig. 2)¹²). These findings suggested that inner ocular circulation is not constant during exercise, and that its blood flow is reflected by changes in perfusion pressure.

Retinal and choroidal blood flow show different dynamics during both submaximal and exhaustive exercises. Retinal blood flow was maintained during submaximal dynamic exercise (Fig. 2)¹²). Choroidal blood flow also kept a constant value during low intensity exercise (< 100 bpm); however, it increased significantly during mild-to-moderate intensity exercise (100-140 bpm) accompanied by an increase in MAP¹²). During exhaustive exercise, choroidal blood flow decreased to almost baseline, whereas retinal blood flow was less than the resting baseline, despite an increase in MAP (Fig. 3)¹³).

The decreased and/or suppressed blood flow in inner ocular circulation during maximal exercise can be explained by the decrease in arterial partial pressure of CO₂ (Paco₂)¹³). The authors reported that inner ocular blood flow decreased and/or was suppressed with a decrease in Paco₂ during exhaustive exercise. This is similar to the decrease in blood velocity in the middle cerebral artery observed during exhaustive exercise⁴⁰). Inner ocular blood vessels have been known to be highly sensitive to variations in Paco₂.¹¹ A mild increase in Paco₂ by adding CO₂ to inspired gas increased both retinal and choroidal blood flows¹⁵,¹⁶). Choroidal blood flow was also increased by inhaling 95% O₂ + 5% CO₂ gas¹⁶). Inner ocular blood flow is strongly influenced by changes in Paco₂ during exercise as well as resting.

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Inner ocular blood flow during static exercise

Limited information has been obtained about choroidal blood flow response to static exercise. Previous studies have reported that choroidal blood flow did not increase against an increase in MAP or ocular perfusion pressure of up to 60-70% during squatting exercise\(^9,17,18\). The authors, in turn, observed that an increase in choroidal blood flow occurred concomitantly with an increase in MAP by roughly 15% during handgrip exercise (Fig. 4)\(^9\). These inconsistent results can be due to different types of exercise. Thus, the choroidal blood flow dynamics during static exercise needs to be elucidated.

Only one study reported on the retinal blood flow during static exercise. The retinal blood flow increased with an increase in MAP (< 15%) during handgrip exercise (Fig 4)\(^9\). This result was surprising, as the contribution of autoregulation to retinal circulatory control has been thought to be powerful enough to stabilize the flow against such an increase in perfusion pressure, as shown in the submaximal dynamic exercise mentioned above. In fact, however, an increase in MAP accompanied with an increase in retinal blood flow. The mechanism inducing different retinal blood flow responses to static and dynamic exercise is unclear.
Limited effects of autoregulation on ocular circulation

Choroidal circulation does not seem to be able to stabilize its blood flow, though autoregulation in choroidal circulation is still controversial.\textsuperscript{1, 18, 19} No change was reported in retinal blood flow despite an increase in MAP during a cold pressor test, whereas choroidal blood flow increased.\textsuperscript{19} Choroidal blood flow increased with an increase in MAP during dynamic exercise, while retinal blood flow remained at resting baseline level.\textsuperscript{12} There are differences between retinal circulation and choroidal circulation in inner ocular blood flow response to submaximal dynamic exercise. The former can be attributed to an effect of autoregulation and the latter can be attributed to pressor response.

The existence of an autoregulation response within several seconds is unclear in ocular circulation. The authors observed the nature of inner ocular blood flow during an acute decrease in MAP obtained immediately after a release of thigh occlusion, to assess the magnitude of autoregulation in a short period in the inner ocular circulation as used to assess it in cerebral circulation.\textsuperscript{20} Vasodilation should have to be obtained as to keep blood flow constant, if the inner ocular circulation had had an autoregulation. We did not observe any sign of vasodilation, either in retinal or choroidal circulation.\textsuperscript{20} Thus we cannot support explicit autoregulation in a short period, based on our finding.

Effects of ambient temperature

Inner ocular blood flow is influenced by ambient environment during dynamic exercise. The decrease in inner ocular blood flow during exhaustive exercise was greater under hyperthermic conditions (35 °C) than in normothermic conditions (20 °C) without any difference in PaCO\textsubscript{2}.\textsuperscript{21} We also reported that inner ocular blood flow decreases during passive heat stress, even without a change in PaCO\textsubscript{2}.\textsuperscript{22} Heat stress itself decreases inner ocular blood flow.

Conclusions

Inner ocular blood flow changes during exercise, according to changes in perfusion pressure and PaCO\textsubscript{2}. The choroidal and retinal blood flows showed different responses to dynamic exercise, despite the fact that both of them are components of inner ocular circulation. We were not able to conclude whether the autoregulation of a short period in inner ocular circulation works; however, retinal circulation can relatively stabilize the blood flow against a change in perfusion pressure within a few minutes at least. The inner ocular blood flow response is influenced by exercise intensity and ambient temperature. Types of exercise may also have an influence on inner ocular blood flow response, while the inner ocular blood flow response to static exercise is still controversial.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

References


