

The Effect of Short Intense Exercise on Pupillary Size

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Abstract

This study evaluated the effects of short, intense exercise on pupillary size. The subjects were 14 young, healthy male volunteers with no history of optic nerve disease (n=14, age: 19.5 ± 1.0 years). The subjects were initially placed in a dark room for 10 minutes before performing two types of exercise. In Experiment I, subjects pedaled an ergometer with maximum effort for 30 seconds. In Experiment II, subjects performed isometric knee extension for 10 seconds. Pupillary diameters were measured with an infrared pupilometer at rest, during exercise, and during the recovery phase. There was significant pupillary dilation during both maximum-effort pedaling and isometric knee extension compared with the size of the pupils at rest. There was also significant pupillary constriction 3 minutes after the isometric exercise. High-intensity exercises may cause transient reflexive mydriasis, which could be due to the ciliospinal reflex.

Keywords : pupillary size, exercise intensity, reflexive mydriasis

1. Introduction

Observation of pupillary size, which has traditionally been used in medical practice, is increasingly being studied in a research setting. Pupils dilate when dilator muscles constrict under the control of sympathetic nerves; pupils constrict when pupillary sphincters contract under the control of parasympathetic nerves¹⁾. It is known that pupils constrict in response to light stimulation and under near vision. However, because pupillary constriction is controlled by autonomic nerves, pupils also constrict reflexively from pain, cold and hot temperatures, and fear²⁾. In addition, pupils tend to constrict when a person is feeling fatigued or sleepy.

Pupillary size is dynamic and changes rhythmically even under normal conditions. This rhythmic change in pupillary size is known as pupillary unrest³⁾, and the frequency of this change varies widely from a low frequency to several hertz. It is believed that pupillary unrest does not have any particular function and that it is only a result of biological noise. However, Daum and Fry reported the relationship between heart rate and pupillary unrest⁴⁾ and between respiration and pupillary unrest^{5,6)}. Moreover, pupillary unrest is reported to intensify with sleepiness and eyestrain⁷⁾. When pupillary unrest is caused by fatigue, the phenomenon is called hippus⁸⁾. Research is now being conducted to utilize hippus as an indicator of fatigue and drowsiness^{9,10)}.

Observation of pupillary size may also be useful in assessing physiological responses to sports and physical activity. For example, studies evaluating brain function through visual testing¹¹⁻¹³⁾ have shown that pupillary size can be used to evaluate sports-related concussions. This is particularly valuable, because concussions are often difficult to evaluate in sporting venues.

Furthermore, because the pupil is innervated by the autonomic nervous system, pupillary activity can be used to monitor physiological conditions during and after exercise. However, there have been few studies on how exercise intensity affects pupillary activity, and only a few studies have reported on static pupils^{14,15)}. Previous studies have shown that during intense exercise, pupillary activity is predominantly controlled by sympathetic nerves; thus, pupils are expected to dilate during exercise¹⁶⁾. One study showed that resistance training exercises performed during the Valsalva maneuver resulted in an acute reduction

in intraocular pressure^{17,18)}, which could be applicable to the study of glaucoma. However, there is still no conclusive evidence about how a short period of intense exercise affects pupillary size. Therefore, the purpose of this study was to determine the effect of short intense exercise on pupillary size.

2. Materials and Methods

Subjects:

This study enrolled 14 young, healthy male volunteers (age: 19.5 ± 1.0 years) with no history of circulatory or optic nerve disease; however, some subjects did have an error of refraction. The subjects were asked not to consume food, beverages, caffeine, or tobacco and to refrain from using mobile phones for the hour immediately preceding the experiments. Subjects were also asked to avoid excessive sleep deprivation or eyestrain on the day of the experiments. (approval number by the Kitasato University School of Allied Health Sciences Ethics Committee : 2011-010). This study was conducted in accordance with the tenets of the Declaration of Helsinki. The protocol was explained to all subjects before measurement. Written informed consent was then obtained from all the subjects.

Methods:

The subjects were initially placed in a dark room for 10 minutes before performing each type of exercise. Experiment I and II were tested in other day. Pupillary diameter was measured before, during, and after the exercise period using an electronic infrared pupilometer (Irisorder C-10641, Hamamatsu Photonics K.K.) (Fig. 1).



Figure 1. Irisorder, electronic infrared pupilometer

2.1 Experiment I: Maximum-effort pedaling with an ergometer

After being placed in a dark room for 10 minutes, each subject was asked to pedal an ergometer (POWERMAX V-II, Combi) with maximum effort for 30 seconds. To increase the intensity of this exercise, we added 7.5% of a subject's weight to the load. Pupillary diameters were continuously measured with the pupilometer before, during, and until three minutes after the exercise period. Analysis points of maximum pupillary diameters were as follows: (1) before starting the exercise, (2) 0-10 seconds into the exercise period, (3) 11-20 seconds into the exercise period, (4) 21-30 seconds into the exercise period, (5) immediately after the exercise, and (6) 3 minutes after the exercise (Fig. 2).

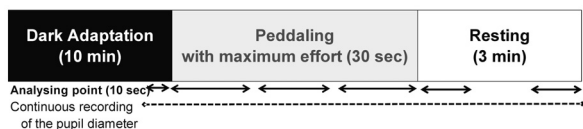


Figure 2. Protocol of experiment I: Recording pupillary diameter with a pupilometer while subject pedals with maximum effort

Statistical analysis:

The maximum pupillary diameters of each 10-second interval were evaluated with repeated measure analysis of variance (ANOVA). The significance level was set at 5% ($P < 0.05$), and a post-hoc test was employed if any significant difference was observed.

2.2 Experiment II: Isometric knee extension

After being placed in a dark room for 10 minutes, each subject was asked to perform isometric knee extension for 10 seconds using a Biodex system. Pupillary diameters were continuously measured with the pupilometer before, during, and until three

minutes after the exercise period. Analysis points of the maximum pupillary diameters were as follows: (1) before the exercise, (2) during isometric knee extension, (3) immediately after the exercise, and (4) three minutes after the exercise (Fig. 3).

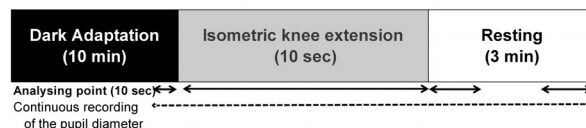


Figure 3. Protocol of experiment II: Recording pupillary diameters with a pupilometer during isometric knee extension

Statistical analysis:

The maximum pupillary diameters at 4 analysis points were evaluated with ANOVA. The significance level was set at 5% ($P < 0.05$), and a post-hoc test was employed if any significant difference was observed.

3. Results

3.1 Changes in pupillary diameter when pedaling with maximum effort

Pupils dilated significantly during the pedaling exercise compared with the size of pupils before starting the exercise. After the exercise period, pupils gradually constricted, such that a significant difference could no longer be detected between the pupillary size before and after the exercise (Table 1, Fig. 4).

3.2 Changes in pupillary diameter during isometric knee extension

Pupils dilated significantly during the isometric knee extension exercise compared with the size of pupils before starting the exercise. Pupils significantly constricted three minutes after the exercise period (Table 2, Fig. 6).

Table 1. Pupillary diameter when pedaling with maximum effort

Pupil Diameter (mm)	
Before	7.26 ± 0.14
0—10 sec	7.69 ± 0.13 **
11—20 sec	7.56 ± 0.14 **
21—30 sec	7.44 ± 0.16 **
Immediate after	7.30 ± 0.14
3min after	7.32 ± 0.13

(Mean ± SE) ** P<0.01

Table 2. Pupillary diameter during isometric knee extension

Pupil Diameter (mm)	
Before	7.24 ± 0.11
Isometric Contraction	7.50 ± 0.13 **
Immediate after	7.25 ± 0.13
3min after	7.13 ± 0.14 **

(Mean ± SE) ** P<0.01

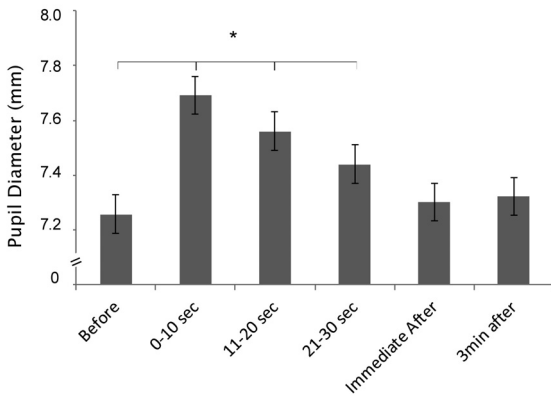


Figure 4. Variation in pupillary diameter during Experiment I. (n=14) *P<0.01 Pupils dilated significantly during exercise compared with the size of pupils before starting exercise. Data are mean and SE values.

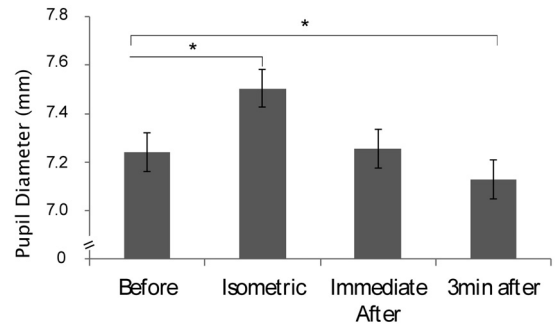


Figure 6. Variation in pupillary diameter during Experiment II (n=14) *P<0.01 Pupils dilated significantly during exercise compared with the size of pupils before starting exercise. Pupils then constricted 3 min after the exercise period. Data are mean and SE values.

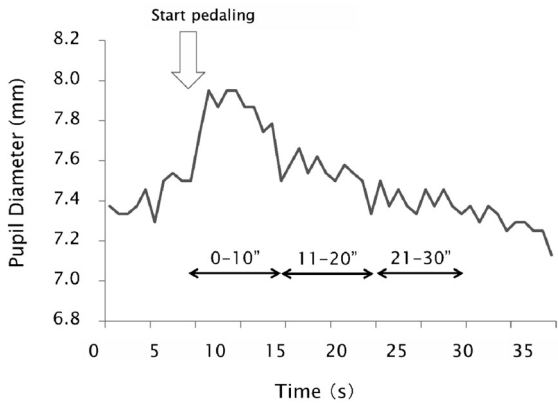


Figure 5. Sample data from Experiment I: Transient mydriasis is notable in a 21-year-old man immediately after starting the exercise.

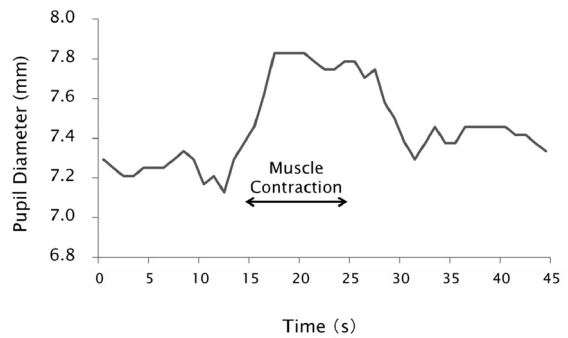


Figure 7. Sample data from Experiment II: Transient mydriasis is notable in a 21-year-old man immediately after starting the exercise.

4. Discussion

We found that pupils dilated during two different types of short intense exercise: maximum-effort pedaling of an ergometer for 30 seconds (Experiment I) and isometric knee extension for 10 seconds (Experiment II). Moreover, pupils significantly constricted 3 minutes after the isometric exercise.

Generally, parasympathetic activity diminishes during the initial stage of exercise and sympathetic activity increases as the exercise intensity increases¹⁹⁻²¹⁾. With sympathetic stimulation, the dilator muscle constricts and the sphincter relaxes, resulting in pupillary dilation. With parasympathetic stimulation, the sphincter contracts and the dilator muscle relaxes, resulting in pupillary constriction. Therefore, we can presume that pupils would dilate in response to sympathetic nerve activity during exercise and that pupils would constrict after exercise due to parasympathetic nerve activity. Ishigashi et al. (1991) did not find noticeable changes in pupillary size in a dark room when an incremental load was added¹⁶⁾. However, it is difficult to observe any changes in the dark due to the ceiling effect because pupillary diameters are already maximized in a dark room. However, Hayashi et al. (2010) also performed exercise load experiments in a dark room and showed that pupillary diameter increased with increases in heart rate and blood pressure as the exercise intensity increased¹⁴⁾.

In our study, experiments were conducted with subjects wearing goggles to prevent interference from an illuminated room. Previous reports only included results from ramp load experiments using an ergometer; therefore, we used two different types of exercise, including pedaling with an ergometer and isometric knee extension.

Experiment I with the ergometer showed that pupillary dilation was most prominent during the first 10 seconds of pedaling. Then, pupils rapidly decreased in diameter 11 to 20 and 21 to 30 seconds into the exercise period. Notably, this was also observed when the speed and power of pedaling decreased. Immediately after the exercise period, pupillary diameters recovered such that there was no significant difference in pupillary size before and after the exercise period. Significant pupillary dilation was also observed during the 10-second isometric knee extension exercise (Experiment II). Similar to Experiment I, pupillary diameters returned to their

initial size after temporarily dilating during the exercise. Thus, we found temporary reflexive mydriasis was induced by two types of short intense exercise. This reaction is most likely due to either the ciliospinal reflex or rapid changes in autonomic nerve activity²²⁾. Therefore, the same mechanism that causes temporary sudden pupillary dilation in response to painful or cold stimulation may also occur during intense exercise.

Because this study was conducted using only healthy young men, further study is needed to evaluate the effect of different factors, such as gender, age, medical history, and environmental conditions, on pupillary size. The influence of various loads on autonomic nerve activity also needs to be evaluated in future studies.

5. Conclusion

We conclude that intense exercise, such as maximum-effort pedaling and isometric knee extension, induces predominantly sympathetic nerve activity, which causes temporary reflexive mydriasis. This mydriasis during intense exercise is most likely due to the ciliospinal reflex.

Measurement of pupillary diameters is minimally invasive and simple. This study demonstrates the feasibility of evaluating changes in autonomic activity during and after exercise by measuring pupillary diameters. Future studies are needed to clarify how pupillary size varies with different types and intensities of exercise in people of different gender, age, and medical history.

6. References

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