Exercise does not increase contrast sensitivity

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The contrast sensitivity of 19 healthy normal subjects was measured before and immediately after 10 minutes of controlled exercise on an exercise bicycle. Contrast sensitivity was measured with an adaptive procedure, which is relatively free of decision criteria effects and the rate of false positive responses was recorded. Ten of these 19 subjects then formed a control group, where contrast sensitivity was measured before and after a 10-minute period of rest.

We found no change in either contrast sensitivity or the false positive response rate after exercise. Similarly, there were no changes after the period of rest in the control group. Hence, previous reports of improved contrast sensitivity resulting from exercise, which have used a less robust psychometric method to measure contrast sensitivity, may have measured a change in the subject's decision criteria rather than a change in contrast sensitivity.

(Key words: contrast sensitivity, physical exercise, psychometric method)

A relationship between sports performance and vision is widely accepted, given that most sports are more difficult or impossible with low vision. Using Arden gratings, elite sports participants have been reported to have better contrast sensitivity than non-participants. This implies either that vision improves as a result of undertaking regular exercise or that the vision was better before becoming an elite sports participant. While this is interesting, of more immediate importance to the athlete is the effect of exercise on visual performance, since changes in vision may influence sporting performance. Fortunately, effects such as transient scotomas and amaurosis reported by apparently normal subjects are relatively rare visual symptoms resulting from exercise.

Other reports of more fundamental changes in vision such as those involving visual fields, visual acuity and contrast sensitivity are of wider interest. Koskela reported an improvement in the mean contrast sensitivity of 11 normal subjects at each spatial frequency studied (1, 6, 19 cpd) after jogging but these changes were subject to individual variation. It was suggested by Koskela that the improvement may have been due to changes in the availability of oxygen or metabolites to the brain, or to changes in mood ('runner's high'). Woods and Thomson obtained similar results using a similar psychometric method (method of limits) for the measurement of contrast sensitivity, though the improvement in contrast sensitivity appeared to vary with the type of exercise (jogging, exercise bicycle or stair climbing). They demonstrated that the improvement in contrast sensitivity was not present when using a more rigorous psychometric method for measuring contrast sensitivity (method of constant stimuli) and suggested that this was because the subject's decision criteria had been controlled. In addition, they were unable to demonstrate a change in mood after exercise (exercise bicycle). Unfortunately, neither of these studies controlled for possible learning effects. Hence, an improvement in contrast sensitivity after exercise could have been due to a learning effect, while a lack of change after exercise could have resulted from a learning effect in combination with an equal reduction in sensitivity after exer-
To examine whether any effect (or lack of effect) of exercise on contrast sensitivity could be due to a learning effect, we measured contrast sensitivity before and after exercise and before and after a period of rest using an adaptive psychometric procedure, which has been demonstrated to give similar results to the method of constant stimuli.

Further, because Woods and Thomson' suggest that subjects may shift their decision criteria, becoming more willing to respond positively to a presentation ('grating seen') after exercise, we measured the rate of false positive responses which would be expected to increase if an improvement in apparent contrast sensitivity was due to a shift in the subject’s decision criteria (reduced specificity) rather than a change in the ‘real’ contrast sensitivity.

**METHODS**

**Subjects**

Twenty-two volunteers aged between 20 and 30 years (mean ±SD: 24 ±3.5 years) participated in this study after informed consent was obtained. All subjects had corrected visual acuities of 6/6 or better and had no evidence of ocular pathology.

Subjects were required to attend two sessions, the first being a practice session to familiarise subjects with the contrast sensitivity measurement procedure. Subjects were encouraged to undertake as many trials as they felt necessary to become confident with the procedure. At the second session contrast sensitivity was measured both before and immediately after exercise. Measurement was made while the subject was seated on an exercise bicycle.

**Contrast sensitivity measurement**

Contrast sensitivity was measured using a custom-built system comprising a Manitron VLR 1593E/80 monitor, an IBM-compatible computer, a Millipede VR1000 pattern generator and custom software. The monitor was masked to give a rectangular field subtending a visual angle of 11.9 by 8.5 degrees. The average background luminance of the monitor surrounding (45.6 by 30.0 degrees) was matched to the average monitor luminance of 30 cd/m². Contrast and luminance calibrations were performed regularly with a Tektronix J16 photometer placed at the testing position. Contrast sensitivity of the right eye was measured with an optimal optical correction for the viewing distance of 1.25 metre and the left eye was occluded. Subjects were seated in a darkened room on an exercise bicycle in front of, and level with, the centre of the monitor. Head movements were restrained by a chin and forehead rest. Subjects were instructed to ensure that a small black target in the centre of the monitor remained clearly in focus.

Adaptive probit estimation (APE) was used to determine the 50 per cent point on the psychometric function. This algorithm has been demonstrated to be an efficient method of contrast sensitivity measurement which is virtually free of the problems associated with changes in the subject’s decision criteria. Subjects were required to indicate detection of vertical sinusoidal gratings of two spatial frequencies (2.0 and 16.0 cpd) using a yes-no procedure. The grating was presented for one second in the form of a temporal square wave. The two spatial frequencies were randomly interleaved, with spatial frequency indicated by a preceding tone. High spatial frequency was indicated by a high-pitched tone and low spatial frequency by a low-pitched tone. This procedure improves reliability by reducing spatial frequency uncertainty. As a measure of shifts in the false positive response rate, 10 blank trials at each spatial frequency were randomly interspersed among the ‘real’ presentations. Approximately 60 presentations were made consisting of 20 APE trials and 10 blank trials for each spatial frequency. More blank presentations would be preferable, but because any effects of the sustained exercise could be expected to be transitory (that is, physiological recovery) it was necessary to keep the duration of the contrast sensitivity measurement to a minimum. The APE algorithm presented contrast levels just above and just below the current estimate of the contrast threshold. At the end of the procedure an estimate of the contrast threshold was determined through probit analysis. Contrast sensitivity was tested immediately prior to and immediately on completion of 10 minutes of exercise.

**Exercise**

Blood pressure and pulse rate were measured with an electronic sphygmomanometer prior to and about five to seven minutes after completion of exercise. Subjects pedalled for 10 minutes on a CatEye ErgoCiser EC 1000 exercise bicycle at a cadence of 80 to 90 rev/min, during which the workload intensity was adjusted to place them in the optimal aerobic training zone for their age. This was calculated by taking 75 per cent of their maximum pulse rate which was determined as 220 minus the subject’s age. The pulse rate was measured with a pulse meter attached to the ear lobe and monitored at 30 second intervals during exercise and post-exercise testing.

**No exercise**

Any measured change in contrast sensitivity after exercise may be due to learning and familiarity effects or the lo-minute interval between pre- and post-exercise measures. Hence, in a further session the contrast sensitivity of 10 of the subjects was measured before and after a lo-minute period of rest.

**Power**

The expected intra-subject variability for the contrast sensitivity measurement, as described by the 95 per cent confidence limits established by test-retest repeatability measurement, were 0.19 log units to 0.18 log units. If we accept typical values of a = 0.05 (likelihood of type 1 errors) and β = 0.20 (likelihood of type 2 errors), a sample size of 22 subjects would allow detection of a difference of 0.05 log units. Koskela reported reductions in contrast sensitivity of between 0.05 and 0.10 log units for the 11 subjects. Complete contrast sensitivity measures were available for 19 subjects only. Conse-
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sequently, at the significance levels above, a difference of 0.053 log units would be detectable. At the more stringent criterion: $\alpha = 0.01; \beta = 0.10$, the sample size of 19 subjects would have allowed us to detect a difference of 0.08 log units.

Analysis

The effects of exercise and rest on contrast sensitivity were assessed using a repeated measures analysis of variance (ANOVA). As false positive response rates were not normally distributed, the Wilcoxon matched pairs signed-rank test was used to assess differences in this measure after exercise and after rest.

RESULTS

With exercise

Contrast sensitivity, shown for pre- and post-exercise in Table 1, did not change after exercise at either spatial frequency (ANOVA, $p = 0.9$). Similarly, as shown in Figure 1, there was no change in the false positive response rate after exercise at either spatial frequency (Wilcoxon: $Z = -0.17, p = 0.9; Z = -0.21, p = 0.8$ for 2 and 16 cpd, respectively). There was no difference in the false positive response rate between spatial frequencies before or after exercise (Wilcoxon: $Z = 0.05, p = 0.4; Z = 0.035, p = 1.0$). The number of subjects ($n = 6$) with a high false positive response rate (defined as false positive rate > 0.4) at some point was greater than we had expected.

No exercise

Contrast sensitivity (Table 2) did not change after a 10-minute period of rest (ANOVA, $p = 0.3$). Contrast sensitivity for these 10 subjects in this no-exercise condition was not different from the with-exercise condition (ANOVA, $p = 0.2$). As shown in Figure 1, there was no change in the false positive response rate after rest at either spatial frequency (Wilcoxon: $Z = -0.34, p = 0.7; Z = -0.53, p = 0.6$) and no difference in the false positive response rate between spatial frequencies before or after rest (Wilcoxon: $Z = -1.35, p = 0.2; Z = -1.36, p = 0.2$). Two subjects had a high

| Table 1. Mean contrast sensitivity (± standard deviation) and median false positive rate (range in parentheses) for 19 subjects measured before and after exercise |

<table>
<thead>
<tr>
<th>Spatial Frequency</th>
<th>Before Exercise</th>
<th>After Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log units</td>
<td></td>
</tr>
<tr>
<td>2 cpd</td>
<td>2.57 ± 0.29</td>
<td>2.63 ± 0.23</td>
</tr>
<tr>
<td>16 cpd</td>
<td>1.74 ± 0.32</td>
<td>1.77 ± 0.36</td>
</tr>
<tr>
<td>False positive rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before exercise</td>
<td>0.1 (0 to 0.4)</td>
<td>0.1 (0 to 0.7)</td>
</tr>
<tr>
<td>After exercise</td>
<td>0.15 (0 to 0.5)</td>
<td>0.1 (0 to 0.7)</td>
</tr>
</tbody>
</table>

| Figure 1. False positive response rates combined for both spatial frequencies. The number of subjects with high false positive response rates (defined as false positive rate > 0.4) was greater than expected among this group of relatively inexperienced subjects. |

| Table 2. Mean contrast sensitivity (± standard deviation) and median false positive rate (range in parentheses) for 10 subjects measured before and after a period of rest |

<table>
<thead>
<tr>
<th>Spatial Frequency</th>
<th>Before Rest</th>
<th>After Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Log units</td>
<td>False positive rate</td>
</tr>
<tr>
<td>2 cpd</td>
<td>2.58 ± 0.15</td>
<td>0.05 (0 to 0.7)</td>
</tr>
<tr>
<td></td>
<td>1.79 ± 0.27</td>
<td>0.1 (0 to 0.7)</td>
</tr>
<tr>
<td>16 cpd</td>
<td>0.15 (0 to 0.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.05 (0 to 0.7)</td>
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</tr>
</tbody>
</table>

|                  | Log units   | False positive rate |
| 2 cpd            | 2.67 ± 0.17 | 0.25 (0 to 0.5) |
|                  | 1.82 ± 0.28 | 0.25 (0 to 0.5)   |
| 16 cpd           | 0.15 (0 to 0.5) |
|                  | 0.25 (0 to 0.5) |
false positive response rate, one of whom also had high false positive response rate before and after exercise.

**DISCUSSION**

The finding of no change in contrast sensitivity after rest (control condition) indicates that learning and familiarity effects had been minimised. Therefore, as there was no change in contrast sensitivity following exercise, the exercise had no effect on contrast sensitivity. This contradicts an earlier report of improved contrast sensitivity after jogging and supports the conclusions of a recent study which found an increase in contrast sensitivity with one psychometric method but not with another.' Koskela measured the contrast sensitivity of 11 subjects using a method of limits and demonstrated an improvement after exercise. Woods and Thomson replicated the earlier results demonstrating an improvement in the contrast sensitivity of 30 and 18 subjects after two different types of exercise using a method of limits. When this was repeated using a psychometric method, which is not influenced by shifts in the subject's decision criteria (two alternative forced choice method of constant stimuli), they found no change in the contrast sensitivity of 18 subjects. Woods and Thomson proposed that the subject's decision criteria may change after exercise, making the subject more willing to respond positively to a grating of low contrast. Koskela noted that there appeared to be two kinds of people, 'stable' and 'unstable' types, in their study group, suggesting that the unstable subjects caused the change in the group average. It may be that elite sports participants are more prepared to indicate that the grating is seen at a lower level of certainty. There are well-known problems associated with shifts in decision criteria. As we found that there was no change in either the contrast sensitivity or the decision criteria after an equivalent period of rest, any effects after exercise can be attributed to exercise.

Reported differences in contrast sensitivity between elite sports participants and non-participants may also be due to differences in decision criteria rather than real differences in contrast sensitivity as the Arden grating test uses a method of limits. It may be that elite sports participants are more prepared to indicate that the grating is seen at a lower level of certainty. There are well-known problems with the Arden grating test, such that a large proportion of the difference between test results can be attributed to differences in the test application."

It is worthwhile remembering that differences in contrast sensitivity may bear no relationship to sporting performance. While it is intuitive that good sporting performance requires good vision, visual clarity is not always necessary. For example, large degrees of defocus do not reduce basketball shooting performance. Reviews suggest that skilled sports participants do not appear to be better on generalised perceptual, cognitive, motor or visual measures, but rather tend to demonstrate better performance on sport-specific measures.

We suspect that many of the reports of improvements in vision after vision training are due to shifts in decision criteria and this view is supported by a recent study of the effects of a range of vision training regimens on a wide variety of visual functions. As noted by Abernethy, the reputed beneficial effects of vision training have yet to be clearly demonstrated. Care must be taken in experimental design and the choice of psychometric methods to avoid the difficulties associated with shifts in decision criteria. Unfortunately, in general there has been a deficit of well-conducted studies in the area of sports vision and many of the precepts of vision training have never been tested properly, leaving sports vision open to criticism. We believe that optometric advice and assistance can benefit sports participants, but we must be circumspect in our claims until proven correct.

Well-controlled and well-analysed studies are vital to the development of sports vision as an optometric discipline.

**REFERENCES**


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