Original Article

Post exercise changes in visual evoked potential measures and contrast sensitivity function

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Visual evoked potential (VEP) latency and amplitude changes and contrast sensitivity (CS) measures were studied in a pre-post exercise paradigm. Results were suggestive of temporal alterations of visual processing with attenuated neuronal activation and CS increase in higher and lower spatial frequencies, after exercise.

Keywords: Visual functions, workload, exercise.

The study of the effects of exercise on visual functions has received relatively little importance. Most researchers have concentrated on measuring aspects such as stricture of the visual field during exercise [1] and changes in pupil size as function of exercise [2]. General measures of visual acuity have been studied more. Static and kinetic acuities [3] were measured before, during and after termination of mild, moderate and severe exercise workloads, static visual acuity improved during and after exercise. Different workload intensities showed no significant differences, whereas kinetic visual acuities decreased in relation to workload intensity. Two reports in the seventies [4,5] mentioned the results of a number of earlier studies which showed that visual acuity improved after certain sporting events. One of these [4] studied the effect of heavy exercise (Harvard Step Test) on visual acuity in a laboratory setting. Visual acuity was measured at threshold levels at which gratings of four different spatial frequencies were observed in exercise and no exercise sessions. All of five subjects showed improved visual acuity in the exercise sessions and it was concluded that heavy exercise load does have a temporary effect in improving visual acuity.

In a more recent study [6] visual acuity was found to deteriorate following a 15 minute bicycle ergometer pedalling under the condition of a mesopic vision environment. Components of visual acuity such as accommodation, refraction and central discernment ability were measured. The visual functions which changed significantly after the exercise were deterioration of visual acuity and extension of accommodative near point distance. The critical flicker frequency with binocular vision was one of the measures which showed deterioration only after maximum load exercise.

Therefore literature reports suggest equivocal effects of exercise, some indicate improved visual acuity while others suggest deterioration. However, it is seen that various measures have been used to define visual acuity and different experimental designs and types of exercise have been used to study exercise effects, leading to varied results from which a generalised conclusion is not presently available.

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The aim of the present study was to study post exercise effects on visual processes, measured by visual evoked potential (VEP) and contrast sensitivity (CS) indices.

Method

Twenty two healthy male jawans with the mean age (SD) of 29.32 yrs (3.08) mean height of 67.73" (1.39) and mean weight of 62.82 (6.64) kg with normal (6/6 or better) visual acuity served as subjects. They were all neurologically and ophthalmologically normal and were not on medication. They were briefed about the procedures and their informed consent obtained. None of the subjects had any prior experience with VEP or CS testing. Subjects were from army units. A total number of 34 subjects were initially screened, however six were discarded for reasons such as poor visual acuity or being medically or physically unfit. Another six were discarded on recording mainly because of lack of motivation and cooperation. After consent was obtained the binocular visual acuity was measured using a Snellen test type chart for distant vision and height and weight measurements were then taken. This was the pre recording phase.

The procedure for the experiment was divided into three main parts, pre exercise recording phase (20 min), exercise phase (6 8 min), and post exercise phase (1-20 min). Three types of parameters were recorded in the pre and post exercise phase, VEP components, CS thresholds and autonomic indices.

VEP Recording: Silver, silver chloride electrodes were attached with paste at Oz and Fpz, Cz was used as ground. Electrode impedance was kept below 5 K Ohms. Signals were amplified using a Nicolet (USA) Pathfinder Plus Computer System through a bandpass of 1-100 Hz. A NIC 1015 visual stimulator provided visual stimuli for recording the VEPs, the stimuli were displayed on an 18" television monitor.

The monitor was centred at 1 m from the nasion with the centre of the screen at the subject's eye level and he was instructed to fixate on the red spot in the centre of the monitor to stabilize fixation and accommodation. He was also cautioned about movements and attentiveness. The observer's head position and eye fixation were continuously monitored. Binocular viewing conditions were used.

The checker board pattern was presented in reversal mode (1.99 Hz) and the stimulus duration was 100 μ sec. Amplifier sensitivity was 100 μv. 100 non rejected stimuli were averaged per trial and analysis time was 250 m sec.

Trials were repeated when there were low quality waveforms and VEPs were repeated twice to ensure replicability. The checker board pattern was viewed from 1 m distance, was size 8 and was presented in a full field. The check visual angle was 3^{0}. Data was stored and analysed off line. Latencies were measured to the peak of the first major positive deflection (P1) whereas N1 and N2 were measured to the peaks of the first and second major negative deflections. VEP component amplitudes were measured relative to the baseline and difference wave form peak amplitudes were also made. The components were picked by eye using a computer display and cursor placement procedure. There were three latency and five amplitude (including difference) values for every condition. The Sign test was used to test for statistical significance.

CS Testing: CS was measured psychophysically with the automated CS function measuring apparatus (Nicolet Optronics, CS-2000) which consists of a cathode ray tube, a control box and a key board.

Vertical stationary, achromatic sinusoidal gratings having a range of 0.5-22.8 c/deg spatial frequencies were generated by the system and displayed on a high resolution cathode ray tube. The mean luminance was calibrated with a built in photocell calibration system to 100 cd/m^2 at the start of each session, maximum contrast of the grating was 0.50. The spatial frequency and contrast of the grating were controlled by microprocessor. The display subtended a visual angle of 5.50° x 4.30° at 3 m.

Subject's binocular contrast thresholds for stationary gratings were measured in a partially darkened room with natural pupils, measurements were done at 3 m viewing distance using all six spatial frequencies, 0.5, 1.0, 3.0, 6.0, 11.4 and 22.8 c/deg. Practice test trials were done until the subject clearly understood the instructions.

Contrast thresholds for each spatial frequency were measured using Von Bekesy's tracking procedure and followed a similar protocol as outlined in a previous study [7]. Single threshold determinants were made for each of the eight spatial frequencies, CS functions were noted during the experimental session so that any anomalous threshold could be probed. The experimenter retested subjects on those frequencies where thresholds deviated more than the estimated normal curve for each subject. The curve was estimated by fitting inverted U-shaped function through the data points by eye.

Polygraph recordings were taken on a Medicare Polyrite 8 channel system. The measures recorded were finger pulse amplitude, EKG, skin resistance, respiration and EMG. Results are not discussed in this paper.

Exercise schedule: The subject underwent exercise on a GIH Monark (Stockholm) cycle ergometer with a gradual increase of workload in a submaximal exercise schedule. Pedalling frequency was 50 rpm paced by a metronome set at 100" and was kept constant. Free pedalling was done for 2 min and the workload was progressively increased in each gradation after 2 min of exercising at each level at the said frequency. The subject was instructed to go on exercising to the point of exhaustion. The workload and time were noted at the end of the schedule.

Procedure

The experimental procedure consisted of a 20 min pre exercise baseline measurement during which the autonomic measures were first recorded for a basal 5 min period. Then the VEP and autonomic measures were recorded simultaneously for another 5 min period. CS was then measured at six spatial frequencies between 0.50 22.8 c/deg. The subject then exercised to the point of exhaustion on the cycle ergometer according to a graded schedule. The exercise was immediately followed by repeated recordings of all the above measures within 0.5 sec - 10 min (autonomic indices) 5 10 min (VEP measures, average time from 6.01 to 9.45 min post exercise) and 10-20 min for CS thresholds (average starting time 10.86, average finishing time 19.86 min post exercise).

Results

VEP measures

a) Latency values: Trends of pre-post exercise changes in latency were observed. These varied according to the component measured. The number of changes shown after exercise are shown in Table 1. The Sign test was done to evaluate any significant statistical differences. The N1 latency indicated a significantly larger number of increases whereas the P1 latency indicated significantly more decreases.

Table 1. Number of changes in VEP latency measures

Change	VEP Component N1	P1	N2
Decrease	09	21	14
Increase	20	08	13
No change	04	05	04
z value	2.04**	2.41*	0.19

** $p < 0.05$, * $p < 0.02$

When changes were tabulated separately for groups of individuals reaching different levels of workloads it was seen that there were a significant number of P1 latency decreases in the maximum workload group ($z=3.0$, $p<0.05$).

There was a group mean increase of N1 latency when pre-post comparisons were made. However P1 and N2 latencies showed a decrease after exercise, these values are shown in Table 2.

Table 2. Mean VEP latency (m sec) in pre and post exercise conditions

Condition		VEP component N1	P1	N2
Pre exercise	M	59.41	93.91	146.43
	SD	5.54	5.16	10.52
Post exercise	M	60.74	91.91	145.16
	SD	7.21	5.69	10.70

b) VEP Amplitude values: The number of different changes outlined in Table 3, were not statistically significant.

Table 3. Number of changes in VEP amplitude measures

Direction	VEP Component N1	P1	N2	D1	D2
Decrease	18	15	18	21	18
Increase	15	19	13	11	13
z value	0.52	0.68	0.89	1.76	0.90

When changes were tabulated separately for different workload groups it was seen that there were significantly more decrease in N1 amplitude in the maximum workload group ($z = 1.90$, $p<0.10$) and N2 amplitude in the minimum workload group ($z = 2.53$, $p<0.05$).

However all five measures of VEP amplitude showed a group mean decrease post exercise, these are shown in Table 4.

Table 4. Mean VEP amplitude (uV) in pre and post exercise conditions

Condition		VEP Component N1	P1	N2	D1	D2
Pre-exercise	M	2.90	6.04	-3.91	8.70	9.36
	SD	1.40	3.02	3.15	3.00	5.40
Post exercise	M	2.53	5.34	-3.03	7.77	8.32
	SD	1.32	2.78	2.93	3.15	5.27

Contrast sensitivity: Data from 21 subjects was analysed in this study. Means and SDs were determined for each subject's CS for each spatial frequency. The number of subjects showing changes are shown in Table 5. To assess the effect of exercise, Sign test was computed and changes were non significant.

Grand means, medians and SDs for grouped data were then computed. Table 6 presents the raw data with the mean log threshold and its SD for each spatial frequency.

The maximum CS for both grouped data was pre, -2.44 and post, -2.42, the inverted "U" shaped relation between CS and spatial frequency was obtained. This trend of changes suggested that maximum number of changes were in the lower and higher spatial frequencies, whereas pre-post exercise comparisons showed relatively fewer changes at the 3 and 6 c/deg frequency range.

Table 5. Number of subjects showing changes in contrast sensitivity

Change	Spatial frequency (c/deg)					
	0.5	1.0	3.0	6.0	11.4	22.8
Decrease	07	08	10	10	10	09
Increase	14	13	11	11	11	12

Table 6. Group mean and SD of log contrast thresholds (n=21) for pre and post exercise conditions

Condition		Spatial frequency (c/deg)					
		0.5	1.0	3.0	6.0	11.4	22.8
Pre exercise	M	-1.37	-1.98	-2.44	-2.34	-2.02	-1.52
	SD	0.17	0.21	0.18	0.18	0.24	0.22
Post exercise	M	-1.43	-2.06	-2.42	-2.35	-2.07	-1.58
	SD	0.20	0.24	0.29	0.30	0.22	0.22

Discussion

VEP: VEP mean latency changes varied according to the component being measured. N1 latency increased whereas P1 and N2 latencies decreased after exercise. The mean VEP amplitude changes in all components showed a decreased trend. Modulations in EEG brain activity during and after exercise have been reported in earlier studies [8,9].

a) VEP latency: The N1 latency increase was seen in the majority of all subjects irrespective of workload. Values of "latency to peak" includes signal transport time of the cortical process and suggests that there appears to be a post exercise delay of processes underlying this temporal component. However, P1 showed a reversed trend of decreased latency after exercise. The N1 and P1 have been proposed to be functionally and anatomically distinct components, which largely reflect the outputs of the parvocellular and magnocellular portions of the visual system respectively. They differ in their spatial frequency and contrast responses. The N1 has been found to be linearly dependent on the spatial displacement of the pattern during a reversal, whereas the P1 is more dependent on the motion "transient" generated by the reversal [10]. These two components have shown different changes in this study. It appears that various facets of "visual processes" are effected by exercise in different ways and this has possibly given rise to the dichotomous findings in this field.

Results of the P1 and N2 latency measures showed more variability. In the minimal workload group P1 latency decrease occurred in 50% of the changes. However, in moderate and high workload groups this increased to 72% and 90%. 50-66% of changes were N2 latency decreases irrespective of the workload. Since these components are of a longer latency, this change may be due to slower cortical processes, and modulation complexities of neural firing by attentional effects observed at both the level of primary cortex in human and in areas beyond the striate cortex [11].

The N1 component generally showed post exercise latency increases and P1, latency decrease. N2 showed equivocal effects. These differences could be the result of the dual effects of both workload and higher cortical processes (such as attentional effects) due to metabolic changes caused by exercise.

b) VEP amplitude: All components showed a mean decrease after exercise. In the minimal and high workload groups the percentage of decreased changes varied from 60-90%. In the moderate group it was from 42-55%. It appears that metabolic changes after either a low or high exercise workload causes homeostatic imbalances which in turn effect processing of visual signals.

Changes in VEP amplitude after exercise are likely to in turn effect visual processes because of a number of reasons (i) there are visual cortical areas which may be additionally involved in the processing of motor modalities. These visual areas are not only interconnected by many direct corticocortical pathways but also are linked to subcortical nuclei which are also known to regulate autonomic responses (ii) the influence of descending signals flowing from cortex to lateral geniculate nucleus (LGN) was shown in a study which found that signals resulting from stimulation in a LGN neuron's receptive field produced inhibitory signals from the cortex to LGN (iii) the corticogeniculate signal is spatially structured in some neurons. The functional role of this pathway might be to allow large areas of cortex to exert an influence on geniculostriate transmission from a small region of the visual field without degrading spatial resolution [11]. (iv) previous findings from this laboratory reported that VEP amplitude reduced when stimuli were centre field as compared to full field [12]. Another study also reported a stricture of the visual field during and after exercise [1]. These observations lead to the assumption that the VEP amplitude decrease results from the attenuation of neural firing caused by homeostatic imbalanced phases of exercise altered metabolism.

These changes are likely to be the influence of descending signals from the cortex to LGN which is known to receive heavy projections from the brainstem and midbrain, which puts its responses under the influence of arousal [11,13]. These changes may also result in visual alterations of spatial structuring resulting in decreased VEP amplitudes.

CS: The trend of changes suggested a marginal increase in CS in all frequencies excepting for 3 c/deg. More changes were seen in the lower and higher frequencies and less were found in the mid ranges of 3 and 6 c/deg. These findings are similar to a study [4] which showed improved visual acuity (using different spatial frequency thresholds) after heavy exercise load.

Other research found that static visual acuity (SVA) measured with a Landolt ring object, improved during and after exercise [3]. A number of reports which dealt with the effect exercise on SVA were cited. In one of these they studied SVA in 30 subjects on 10 km running event and in 8 subjects on bicycle ergometer work. In 22 of the 30 subjects SVA was increased in the running event whereas changes of SVA were variable in the ergometer exercise, it increased in 2, decreased in 2, and remained unchanged in 4 subjects. Another study measured SVA in 22 subjects on a 118 km walking race. SVA decreased in 13 subjects at 68 km whereas it was unchanged at later stages.

After a running event 73% of subjects showed an increase in visual acuity, and it remained unchanged in 27% of the subjects [3]. In 10% subjects, sharpness of vision increased and in another 4% maximal increase occurred after running at 6 and 10 min. Another researcher's [4] results also showed sustained visual acuity increase for as long as 30 min post exercise in all his subjects.

Overall these studies indicate that (i) in any sample of individuals there are interindividual variations (ii) time duration after the start/end of exercise influences results on various parameters. Time course changes was emphasised by one study [3] and another study found workload to be a factor of importance [6].

There appears to be a trend of change showing an overall increase in CS after exercise based on qualitative analysis of data. The results show that in the minimum workload group there is increased CS across all spatial frequencies excepting one. At moderate load the same pattern persists excepting that the 3 and 6 c/deg frequencies show decreased CS. At high load this decrease extends to 11 c/deg.

Secondly, the majority of subjects, 57-66%, show an increase in CS in the lower and higher spatial frequencies whereas only 34-43% show decrease in CS. In the mid ranges of 3 and 6 c/deg the percentages of subjects are nearly equal in both groups varying between 48-52%. In summary there appears to be a pattern of change due to workload and spatial frequency differences.

Conclusion

VEP latency and amplitude changes and CS measures were studied in a pre post exercise paradigm. Results were suggestive of temporal alterations of visual processing with attenuated neuronal activation and a trend of CS increase in the higher and lower spatial frequencies.

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