

Effect of Acute Moderate Exercise on Cognitive Event-Related Potentials N100, P200, N200, and Interpeak Latencies

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ABSTRACT

Background: Effect of acute moderate exercise on cognition has been studied recently, although there are controversial reports in this context. This is the reason we performed this study, to observe the effect of acute moderate exercise on the cognitive functions of persons having a sedentary lifestyle, by measuring the latencies of event-related potentials N100, P200, N200, and the inter-peak latencies N100-P200, P200-N200, and N200-P300. **Materials and Methods:** Sixty right-handed participants (34 males, 26 females) of age group 15 – 30 years, having a sedentary lifestyle, were recruited for the study. A baseline recording of event-related potentials was conducted and then they were subjected to acute moderate exercise (60 – 80% of the maximum load of effort during exercise, where 100%=200 - Age), again the recording was carried out using the paired student's 't' test, to compare the present values with the initial values. **Results:** After performing the exercise there was a significant decrease in the latency of wave N1 and P2 of females for both frequent and rare stimuli. A significant decrease in the latency was seen in wave N2 with rare stimulus in both females and males. While, for frequent stimulus a significant decrease was seen only in females. Also the N2-P3 interpeak latency significantly decreased in males, while there was no significant decrease in females. **Conclusion:** There was a definite role of exercise in enhancing the cognitive functions as evidenced by its effect on the latencies of event-related potentials N100, P200, N200, and interpeak latencies.

Key words: *Event-related potential, exercise, interpeak latencies*

INTRODUCTION

The effect of the physical activity on the brain and cognition has grown in interest in recent years, with an increasing number of reports indicating that chronic participation and single, acute bouts of exercise, benefit

a host of cognitive processes.^[1] Coe and colleagues administered a three-day physical activity recall questionnaire to sixth grade children and observed their academic performance in four core classes (i.e., mathematics, science, English, world studies) and Terra Nova standardized test scores. They found an increased performance in the core academic classes for those children who reported vigorous physical activity outside of the school relative, to those who reported no physical activity.^[2] Several other studies have appeared in literature as well, indicating positive relations between physical activity and the aspects of academic performance.^[3-5] Although, several studies have also observed no relation between physical activity and academic performance.^[6]

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Cognitive control is a term used to describe a subset of goal-directed, self-regulatory operations involved in the selection, scheduling, and coordination of computational processes underlying perception, memory, and action. Core cognitive processes collectively termed 'cognitive control' or 'executive control' include inhibition, working memory, and cognitive flexibility.^[7] Of these core processes, inhibition has been the most studied in the acute exercise literature and relates to the ability to act on the basis of choice rather than impulse.^[8-10]

Event-related potentials (ERPs) reflect invariant changes in the ongoing electroencephalographic (EEG) activity evoked by the stimulus. The ERP components are usually identified by their peak amplitudes and peak latencies. The most prominent ERP components observed in the studies of selective attention, using the auditory oddball paradigm are, N100, P200, N200, and P300, with peak latencies at about 100, 150, 200, and 300 ms after the stimulus onset, respectively. The long-latency potentials of the auditory evoked potentials (AEP) comprise of the N1 (N100) and P2 (P200) peaks, the so-called vertex potentials. The vertex potentials do not represent the first volley of sensory information into the primary auditory cortex, which occurs on the order of tens of milliseconds rather than hundreds. In addition, these vertex potentials represent several components with different brain generators, some of which are not purely sensory, but are modulated by subjective mental operations. For example, attention to the tones can lead to an increase in the amplitudes of N1 and P2, and hence, there is some endogenous aspect to the vertex potentials. The N1-P2 deflection has also been considered as an indicator for the cortical arousal response.^[11] Thus, the N1 and P2 are probably the best considered event-related potentials (ERPs) encompassing both exogenous and endogenous potentials.^[12] The N200 (N2) component is usually assumed to reflect the classification or categorization of deviant stimuli.^[11] This reflects processes of transient arousal triggered by unattended discrimination processes, which in turn trigger a target reaction.^[13] Typically evoked between 180 to 325 ms following the presentation of a specific visual or auditory stimulus, the N2 is a negativity resulting from a deviation in the form or context of a prevailing stimulus. N2 is typically evoked before the motor response, suggesting its link to the cognitive processes of stimulus identification and distinction.^[14] Sumi *et al.* showed that by using the evaluation of the P300 interpeak latency (IPL), we can assess the disturbed steps in the cognitive process in schizophrenic patients.^[15] Very few studies have been found in literature to access the role of acute exercise on cognition using event-related potentials (N1, P2, and N2) and inter-peak latencies of ERP, that is the reason for our having designed this study, to see if there is any

effect of an acute bout of exercise on the ERP of people having sedentary lifestyles.

MATERIALS AND METHODS

Sixty right-handed participants (34 males, 26 females) of age group 15–30 years, having a sedentary lifestyle, were recruited from undergraduate and postgraduate students and staff members of a medical college. All the participants reported no adverse health conditions, such as, previous history of stroke, diabetes, depression, hypertension, osteoarthritis, chronic obstructive lung disease, visual or auditory impairment, or smoking habits. Basic anthropometric measurements such as age, sex, height, and weight were recorded and the body mass index (BMI) was calculated [Table 1].

Before taking part in the experiment, all the participants signed written consent forms and were fully informed about the protocol. The participants visited the laboratory at the same time of the day, between 9 to 11 a.m. The basal recording of the event-related potential (ERP) was recorded using Recorders and Medicare Systems-Electromyography (RMS-EMG), EP Mark-II (Chandigarh) in a sound proof room, and then the subjects were asked to do moderate exercise for five minutes on an Electronic bicycle ergometer (MAGCYCLE). The severity of the exercise was moderate (60–80% of maximum load of effort during exercise, where 100%=200-Age). Immediately after doing the exercise, the ERP was recorded again.

ERP recordings

An Ag-AgCl electrode was placed at Cz actively, according to the international 10–20 system,^[16] referenced to earlobe electrodes, and with a forehead electrode as a ground electrode. Impedances were maintained below 5 k Ω and were measured from each lead at the beginning and end of each session. The P3 potentials were recorded with a band-pass of 0.1–100 Hz. Recordings were made for 300 seconds, excluding the rejection errors. P300 potentials were obtained from an auditory oddball paradigm. The target tones were presented with a probability of 20%, whereas, the non-target tones were presented with a probability of 80% binaurally over headphones, at a sound level intensity of 80 dB. The tone bursts were presented with an inter-stimulus interval of one second, randomly. At

Table 1: The demographic pattern of the study group

Variable	Total	Female	Male
n	60	26	34
Age (years)	23.13 \pm 4.66	21.38 \pm 3.52	24.3 \pm 4.99
Height (cm)	164 \pm 7.96	159.15 \pm 4.42	167.21 \pm 7.71
Weight (kg)	58.8 \pm 10.05	53.85 \pm 7.3	61.88 \pm 9.58
BMI	21.78 \pm 2.68	21.25 \pm 2.64	22.08 \pm 2.65

the end of each session, each participant's count was compared with the actual number of target tones given, to assess the accuracy of the task performance. All participants performed the tasks with an error rate <5% in all trials.

The principal peaks and their identification were made according to the standard recommendations for long latency auditory event-related potentials of The International Federation of Clinical Neurophysiology using the principal component analysis technique.^[16] Waveforms from each electrode and stimulus condition were analyzed with the P300 component defined as the largest positive going peak occurring for all electrode sites after the N100-P200-N200 complex, within the latency window, between 250 and 500 ms. Interpeak latencies were measured between the peaks of the consecutive waves.

Data thus collected was subjected to statistical analysis using the paired student's 't' test, comparing the before and after exercise values.

RESULTS

Table 2 shows that on doing an acute bout of moderate exercise there was a significant ($P<0.01$) decrease in the latency of wave N1 of all females, for both frequent and rare stimuli, while there was no significant change

in males. Also there was a significant decrease in the latency of wave P2 in females, for both frequent ($P<0.001$) and rare ($P<0.05$) stimuli. However, there was no significant change seen in males. A significant decrease in latency was seen in wave N2, with rare stimulus in both females ($P<0.01$) and males ($P<0.001$), while for frequent stimulus, a significant ($P<0.05$) decrease was seen only in females.

Table 3 shows that in total there was a significant decrease in N2-P3 interpeak latency for both target ($P<0.001$) and non-target ($P<0.05$) stimuli. N2-P3 interpeak latency significantly decreased in males, while there was no significant decrease in females. Also there was a significant ($P<0.05$) decrease in P2-N2 interpeak latency for the target stimuli in total, although there was no significant decrease when males and females were compared separately.

DISCUSSION

There is evidence that aerobic exercise produces its effect on event-related potentials by increasing arousal. Exercise helps contribute to decreased peak latency.^[17] Yagi *et al.* examined the auditory and visual P3 and reaction times in young volunteers before and after exercise on a cycle ergometer.^[18] Bulut *et al.* reported that acute and regular exercise shortens the latency of sensory evoked potentials.^[19] Two basic mechanisms have been

Table 2: Mean±S.D. of latencies (ms) of different ERP waves before and after doing exercise

	Before exercise			After exercise		
	N1	P2	N2	N1	P2	N2
Females						
Fcz-A1/A2	80.27±20.14	135.92±21.34	216.66±37.97	72.28±10.15**	129.23±14.42**	202.65±12.35*
Rcz-A1/A2	85.95±20.20	148.55±23.74	214.27±14.46	71.37±17.07***	135.84±36.81*	195.68±28.11**
Males						
Fcz-A1/A2	73.79±11.66	133.86±12.31	203.15±19.45	74.37±15.57	134.89±23.12	200.62±20.51
Rcz-A1/A2	74.04±13.62	140.74±15.02	198.49±19.47	76.86±17.55	134.62±23.37	184.24±25.10***
Total						
Fcz-A1/A2	76.60±16.07	134.75±16.70	209±29.46	73.47±13.43	132.44±19.88	201.5±17.34*
Rcz-A1/A2	79.20±17.66	144.13±19.50	205.33±19.042	74.48±17.42	135.15±29.67*	189.20±26.83***

* $P<0.05$, ** $P<0.01$, *** $P<0.001$ compared to the before exercise values

Table 3: Mean±S.D. of interpeak latencies (ms) between different ERP waves before and after doing exercise

	Before exercise			After exercise		
	N1-P2	P2-N2	N2-P3	N1-P2	P2-N2	N2-P3
Females						
Fcz-A1/A2	80.74±28.74	55.65±14.62	92.49±34.48	73.42±14.86	56.95±10.97	90.91±31.59
Rcz-A1/A2	65.72±18.53	62.60±19.42	75.51±30.83	59.84±24.91	64.47±25.93	65.31±23.85
Males						
Fcz-A1/A2	60.07±15.68	69.28±18.52	94.19±28.62	60.52±19.32	65.73±21.55	79.52±36.41*
Rcz-A1/A2	66.71±18.81	57.75±22.46	83.58±24.24	57.76±22.17	49.62±14.62	65.67±24.79***
Total						
Fcz-A1/A2	58.16±15.26	74.25±23.97	93.45±31.02	58.97±16.22	69.06±19.18	84.46±34.60*
Rcz-A1/A2	64.93±19.03	61.20±21.06	80.08±27.34	60.67±23.89	54.05±20.22*	65.51±24.18***

* $P<0.05$, ** $P<0.01$, *** $P<0.001$ compared to the before exercise values

suggested to explain the effect of aerobic fitness on cognitive processes: the cerebral circulation hypothesis and the neurotrophic-stimulation hypothesis, which predicts a beneficial effect of neuromuscular activity on higher brain centers; both mechanisms may contribute simultaneously.^[20]

Event-related potentials offer the requisite temporal precision to gain insight into covert cognitive operations that occur between stimulus engagement and response selection, which may be more sensitive to these processes than overt behavioral measures of task performance. ERPs refer to patterns of neuroelectric activation that occur in response to, or in preparation for, a stimulus or response. Previous studies have examined the P3 component of the stimulus-locked ERP, to understand the alterations in stimulus engagement.^[21]

In our study, an acute bout of moderate exercise led to a significant decrease in the latency of wave N1 and P2 of females for both frequent and rare stimuli. Significant decrease in latency was seen in wave N2 with rare stimulus in both females and males, while for frequent stimulus, a significant decrease was seen only in females. In a study by Ozkaya *et al.*, the latencies of the P2 and N2 components at the Fz and Cz sites, decreased significantly in the strength training (ST) group compared to the endurance training (ET) group, and after training, the latencies of the N1, N2, and P2 components shortened significantly in the ST group compared to the control group. Also the latencies of the N2 and P2 components shortened significantly in the ET group compared to the control group.^[22] In contrast Pontifex *et al.* observed longer N2 and P3 latencies during exercise (cycling at 60% of maximal HR) relative to rest.^[23] Also Stroth *et al.*, in their study, suggested that physical fitness, but not an acute bout of aerobic exercise, enhanced cognitive processing by increasing attention allocation to stimulus encoding, during task preparation.^[24]

In our study, we found that the N2-P3 interpeak latency significantly decreased in males, while there was no significant decrease in females, suggesting that males had a specific effect on information processing between the generation of the P2 and P3 waves. No study was found in the literature regarding exercise and interpeak latencies of event-related potentials.

CONCLUSION

We conclude that there is a definite role of exercise in enhancing the cognitive functions as evidenced by its effect on event-related potentials. Sedentary females are benefited more than males from a short duration of moderate exercise. Males feel its effect on the later

parts of information processing, as suggested by the interpeak latencies. Extensive research is needed in this field to assess the role of exercise at a molecular level.

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