ASSESSEMENT OF COGNITIVE FUNCTIONS RELATED TO THE LEVEL OF PHYSICAL EXERTION

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Abstract

The chronic effects of physical activity on cognitive functions are scarcely documented. The aim of this experiment was to give inligth on the influence of single bouts of exercise at different intensities on the amplitude and latency of P300 component of cognitive potentials in the offense team of American football players. The subject sample consisted of 11 male athletes – members of the American football team "Dukes" Novi Sad, all engaged in the offense team. The control group was formed of 10 age matched students of the University of Novi Sad who were not engaged in any organized physical activity. In the present study the participants were engaged in single bouts of exercise on a cycle ergometer at different intensities. In American football players the amplitude of P300 wave after exercise intensity achieved at 75% HRmax (Fz 15.34±3.99 mV; Cz 19.00±6.26 mV) was statistically higher ($p<0.05$) than the amlitude at rest (Fz 11.08±4.65 mV; Cz 13.00±5.16 mV) and after exercise at 60% HRmax (Fz 11.87±4.39 mV; Cz 13.43±3.13 mV). There was a significant decrease in amplitude after exercise at 90% HRmax (Fz 11.96±4.48 mV; Cz 13.82±7.10 mV) to the levels of baseline values obtained at rest. In the control group the amplitude of P300 wave after exercise intensity achieved at 60% (Fz 11.02±4.99 mV; Cz 13.98±2.31 mV) and 75% HRmax (Fz 11.58±3.97 mV; Cz 14.64±1.94 mV) were statisticaly higher ($p<0.05$) than the amplitude of P300 at rest (Fz 7.99±2.95 mV; Cz 11.56±1.81 mV) and after 90% of maximal puls (Fz 8.76±3.05 mV; Cz 12.63±3.31 mV). There were no differences ($p>0.05$) between the amplitudes after 60% and 75% of HRmax, as well as between the values obtained at rest and after 90% of HRmax. Short duration exercise corresponding to 75% HRmax facilitated cognitive processing in the CNS in athletes, showing that strenuous exertion on the field improves cognitive capabilities in American football players.

Keywords: P300, American Football, Cognitive Abilities.

Introduction

Attention may be specifically altered by mental fatigue or physical activity in athletes where mental sources dealing with incoming information are of key essence. Such a sport is American football, a game about gaining territory and scoring a touchdown or a field goal. There are three teams within a team: the offense, the defense and a special team. A team`s offense is responsible for taking the ball down the field towards it`s opponents end zone, doing this against the various tackling methods of a defense team preventing them from scoring . Members of the offense team (quarterback – QB, offensive linemen, wide receivers – WR, tight ends – TE, running backs: tailbacks – TB, halfbacks – HB and fullbacks – FB) besides having specialized positions and specific sets of skills must make prompt and precise decisions under strenuous exertion in order to advance in the field. Evaluation of their cognitive functions after different levels of single bouts of exercise might give us more accurate information on their decision making under physical stress on the field.

It is generally been held that an event related potential (ERP) is the result of a set of discrete stimulus-evoked brain events. It is a summary measure of the brain`s electrical activity derived by averaging the post-stimulus electroencephalogram (EEG) over a large number of trials (Penny 2002). P300 is generally considered a cognitive neuroelectric phenomenon because its elicitation depends much more upon the subjective meaning or informational value of the stimulus than on its physical

characteristics. In the most common two-tone auditory oddball task the subject listens to random series of high- and low-pitch tone pips. One pitch is presented commonly and the other rarely in the series. Subjects are instructed to respond to the rare target tone, but not to the common non-target tone. Analysis of brain electrical activity following rare target tones contains a late positive potential wave with a modal latency of about 300 ms in young healthy adults, termed the P300 (Yagi 1999). P300 amplitude is related to the amount of attentional resources devoted to a given task and context updating of working memory. P300 latency reflects the stimulus classification speed or stimulus evaluation time (Higashiura 2006).

The aim of this experiment was to give inligth on the influence of single bouts of exercise at different intensities on the amplitude and latency of P300 component of cognitive potentials in the offense team of american football players.

Methods

Subjects

The subject sample consisted of 11 male athletes – members of the American football team "Dukes" Novi Sad, all engaged in the offense team. The control group was formed of 10 age matched students of the University of Novi Sad who were not engaged in any organized physical activity (more than three times a week, more than one hour a day) the last six months before the start of the investigation. All subjects were in self-reported good health, free from medications affecting brain activity and had medical histories free from hearing and cardiovascular problems. Their physical fitness level was tested through Wingate anaerobic test (WAnT), for the actions of the offense team on the field are mainly short lasting, high-intensity anaerobic actions.

Auditory oddball task

In the standard two tone auditory oddball task tone pips (90dB) of 1 kHz (80%, common) and 2kHz (20%, rare) were presented binaurally at random intervals and in random order over headphones. Subjects were instructed to ignore the common low pitch tones and press a button with the dominant hand each time the rare high pitch tone occurred.

Brain activity recording

Measurements were carried out on an EMNG equipment Keypoint, Medtronic from Denmark. Brain electrical activity was recorded from an array of two midline electrodes (Fz and Cz) of the International 10-20 system referenced to linked ears. Electrode impedances were kept below 5 kΩ. Data were amplified with a gain of 30.000, bandpassed 1-100Hz and sampled for 1000ms epoch on each trial. Trials were administered until data from 60 target trials and approximately 200 non-target trials were collected. Only data from target trials were analyzed further.

Processing, which consisted of P300 identification and measurement was performed blind to experimental conditions. ERP waveforms were 15 Hz low pass filtered. The P300 peak was identified individually at each electrode site as the highest positivity within a 220-450 ms latency window, and the latency and amplitude of the P300 peak were measured. Alongside these parameters, false reactions, percentage of hits after target pitches and response time were also registered.

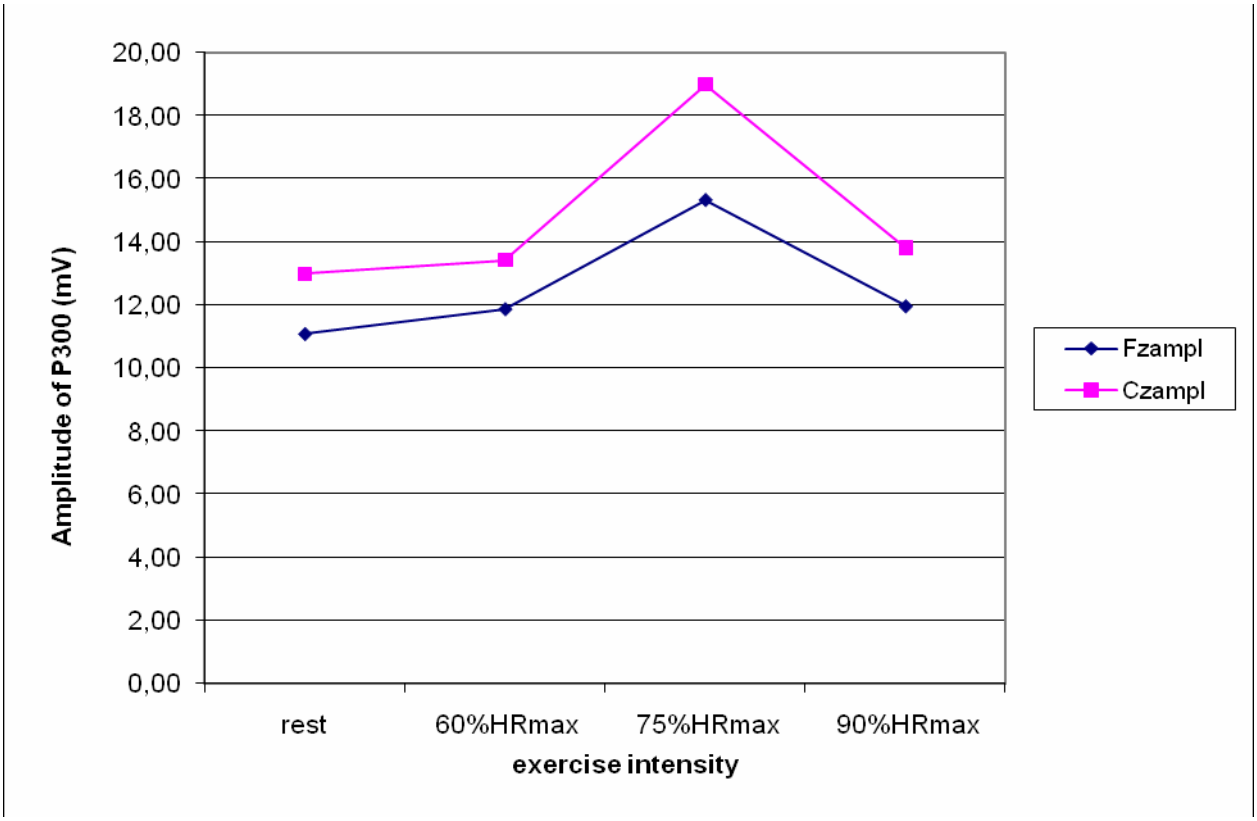
Protocol

After registering cognitive event related potentials at rest participants underwent a controlled exercise on a cycle ergometer (Weba Expert). Each exercise lasted for 10 minutes with succesive increase of intensity up to 60%, 75% and 90% of maximal heart rate (HRmax) and holding this level of intensity for six minutes. Pmax was set according to the age maximum of the participants. Pedaling cadence was set at 60 per minute. Immediately after finishing each bout of exercise, event related potentials were registered again. In american football players the reached intensities were as follows – at 60% HRmax (120 bpm) 85.91±17.86W; 75% HRmax (150 bpm) 143.64±25.99W; 90% HRmax (180 bpm) 197.73±38.95W. Immediately after each bout of exercise ERP was registered. Between two successive bouts a rest lasting for 20 minutes was given for active recovery of the paricipants.

Results

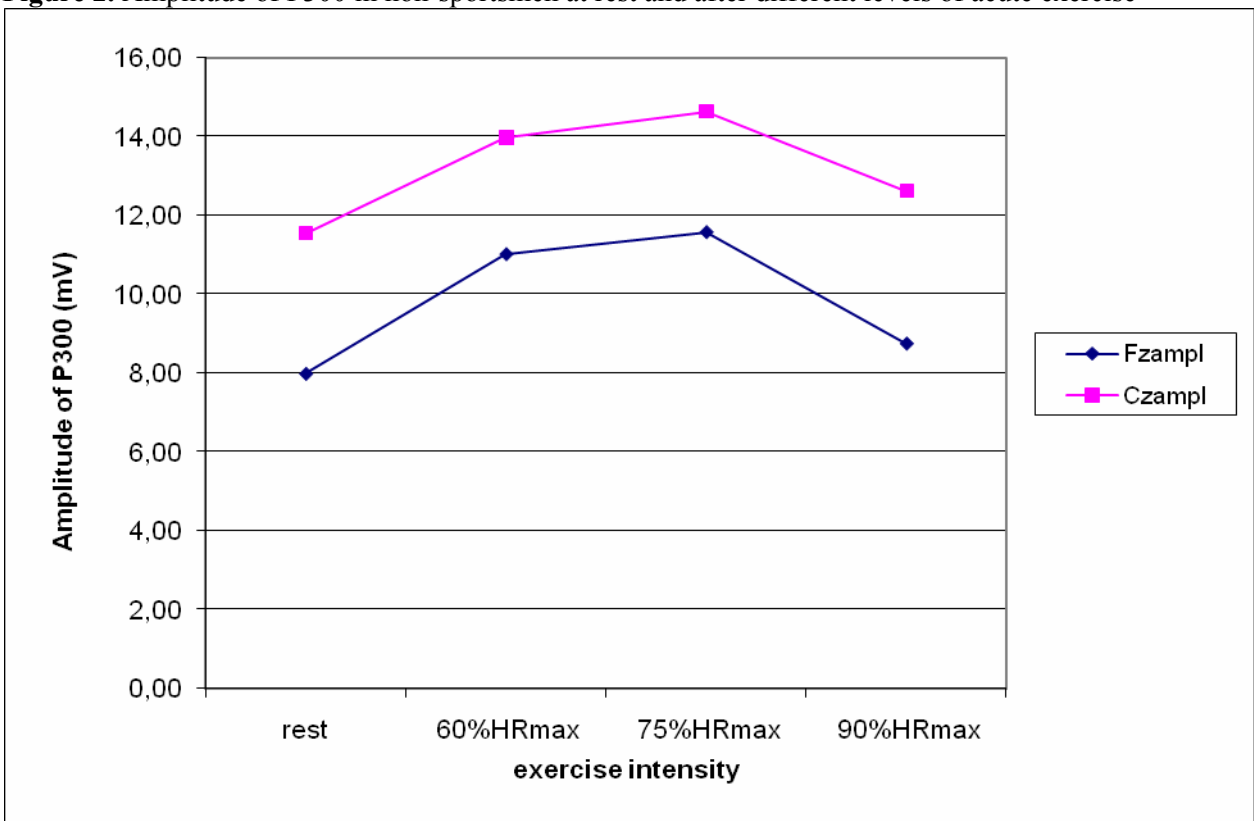
In the present study the participants were engaged in single bouts of exercise on a cycle ergometer. In American football players the amplitude of P300 wave after exercise intensity achieved at 75% HRmax (Fz 15.34±3.99 mV; Cz 19.00±6.26 mV) was statistically higher ($p<0.05$) than the amlitude at rest (Fz 11.08±4.65 mV; Cz 13.00±5.16 mV) and after exercise at 60% HRmax (Fz 11.87±4.39 mV; Cz 13.43±3.13 mV). There was a significant decrease in amplitude after exercise at 90% HRmax (Fz 11.96±4.48 mV; Cz 13.82±7.10 mV) to the levels of baseline values obtained at rest (figure 1). There were no differences ($p>0.05$) between the amplitudes at rest, after 60% and 90% HRmax. There were no statistically significant differences ($p>0.05$) among the latencies of P300 registered at rest (Fz 329.82±17.14 ms; Cz 329.82±17.14 ms) and after 60% of HRmax (Fz 320.55±21.82 ms; Cz 322.00±21.47 ms), 75% (Fz 325.60±12.62 ms; Cz 325.80±12.41 ms) and 90% of HRmax (Fz 325.64±11.60 ms; Cz 325.55±11.31 ms).

Figure 1. Amplitude of P300 in American football players at rest and after different levels of acute exercise



In the control group the amplitude of P300 wave after exercise intensity achieved at 60% (Fz 11.02±4.99 mV; Cz 13.98±2.31 mV) and 75% Pmax (Fz 11.58±3.97 mV; Cz 14.64±1.94 mV) were statisticaly higher ($p<0.05$) than the amplitude of P300 at rest (Fz 7.99±2.95 mV; Cz 11.56±1.81 mV) and after 90% of maximal puls (Fz 8.76±3.05 mV; Cz 12.63±3.31 mV) (figure 2). There were no differences ($p>0.05$) between the amplitudes after 60% and 75% of Pmax, as well as between the values obtained at rest and after 90% of Pmax. There were no statistically significant differences ($p>0.05$) among the latencies of P300 registered at rest (Fz 321.67±19.89 ms; Cz 321.67±19.87 ms) and after 60% Pmax (Fz 314.00±26.16 ms; Cz 314.22±25.73 ms), 75% Pmax (315.20±13.93 ms; Cz 313.70±13.68 ms) and 90% Pmax (Fz 315.11±21.25 ms; Cz 315.89±21.85 ms).

Figure 2. Amplitude of P300 in non-sportsmen at rest and after different levels of acute exercise



Discussion

Results of some laboratory research tried to connect cognitive capabilities to the level of physical effort. Levitt and Gutin measured reaction time after running on treadmill with velocities equivalent to 115, 145 and 175 heart beats per minute. Reaction time improved after heart rate increased to 115 beats per minute, returned to baseline values when heart rate reached 145 bpm and dropped even below at heart rate 175 bpm. Samela and Ndoye presented the results of complex reaction time in an inverted-U shape relationship with levels of physical exertion. After initial shortening of reaction time at heart rate of 115 bpm, increase of RT emerged again at 145 bpm. This phenomenon was explained on the basis of a classical assumption that physical arousal associated with exercise leads to a narrowing of attentional focus. Similar relationship was presented by Brisswalter et al. who recorded reaction time performance at different imposed pedal rates performed at same power output. Best results were obtained at medium cadence (50 rpm) and worst at high cadence (80 rpm). Brisswalter and Alcerin investigated the effects of exercise on a cycle ergometer where resistance was determined for each stage as a percentage of Pmax, respectively 20, 40, 60 and 80%. They revealed a significant decrease of cognitive performance during strenuous exercise. For 60 to 80% Pmax lactate concentration was higher than 4 mmol/l indicating anaerobic metabolism as a source of paying the energy costs where lactate accumulation could lead to increased reaction time (Brisswalter 1997).

Recent publications use more objective parameters of ERPs as a method to evaluate cognitive functions after different intensities of exercise. Higashiura investigated the interactive effects of exercise intensity and duration on cognitive processing in the central nervous system. His findings suggested that low intensity exercise corresponding to 50% HRmax might not affect cognitive processing, such as attentional allocation, in the CNS. Short duration, high intensity exercise corresponding to 80% HRmax on the other hand facilitated cognitive processing in the CNS (Higashiura 2006). Kamijo in his paper showed that P300 amplitude after medium intensity exercise was significantly larger than in the control condition and after low and high intensity exercise. He argues this observation in the light of earlier papers witnessing increased alpha activity in the EEG that reflects a state of decreased cortical activation indicative of relaxation and decreased anxiety (Kamijo 2006). Increased alpha activity after cardio training is reported in other works as well, arguing neuronal synchronization as a basis for their findings

(Hillman 2002). Polich sees the decrease in beta power a state of synchronisation in neural activity. He describes a correlation between the individual variability of alpha spectrum power and P300 linking changes in EEG activity in rest directly to influence ERP (Polich 1997).

Like Higashiura, Kamijo chose exercise intensity according to the Borg scale rate of perceived exertion (Higashiura 2006, Kamijo 2006). In our experiment exercise grading was assessed according to the participant`s maximal pulse which might lead to a more objective evaluation of the level a physical stress. Implementing such methodological approach our finding did not differ much from the previously cited observations. In athletes though a statistically significant increase in P300 amplitude was observed only after 75% HRmax. This might be in accordance with the findings that values obtained at rest and after exercise level of 60% HRmax did not differ, but were higher than in non-athletes. Exercise levels where 60% HRmax was reached were not different between the two groups. In non-athletes this intensity might be enough to arouse cognitive functions, but for athletes it represents a much weaker trigger. On the other hand 75% HRmax was reached on a much higher exercise intensity in athletes than in the control group. This level exertion is presented to the football players on the field where they have to make prompt and accurate decisions.

Although the neurobiological supports are still debated, the P300 can be considered as a manifestation of central nervous system involved with the processing of new information when attention is engaged to update memory representations. In this context, it is widely accepted that P300 amplitude is proportional to the amount of attentional resources in terms of processing capacity that is employed in a given task and P300 latency is considered as a metric of stimulus classification speed (Polich 1995, Grego 2004, Yagi 1999, Kamijo 2006). Attentional resources and cognitive functions could be improved because of increased cerebral blood flow due to increased physical activity presented in single bouts of exercise. The increase in cerebral blood flow leads to changes in the electrophysiological activity of the central nervous system (Polich 1997). At the same time increased oxygenation of the brain neurons might also be argued as a potential factor leading to increases in P300 amplitude.

Generally positive relationship of exercise on ERP and neurophysiological measures of mental processing speed has been reported (Tomparovski). In our study we demonstrated larger values of P300 in athletes, but statistical difference was established only at exercise intensities of 75%HR max. Polich et al. investigated the long term effects of physical activity on mental processes and demonstrated that young adult low-exercise subjects show smaller P300 amplitudes than high exercise subjects. They concluded that exceptional amounts of physical exercise can alter the P300 ERP component from simple auditory and visual stimuli, but these effects are variable across subjects and most evident only with very high amounts of weekly aerobic exercise (Polich 1997).

In our study the effects of single bouts of exercise at different intensities seem to be positive on the amplitude of P300 component of ERP. Short duration exercise corresponding to 75% HRmax facilitated cognitive processing in the CNS in athletes, showing that strenuous exertion on the field improves cognitive capabilities in American football players. High-intensity exercise corresponding to 90% HRmax decreases cognitive functions. Effects of long term physical exercise seem to positively correlate with P300 amplitude, demonstrated through higher values in athletes.

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