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# Biofeedback Training for Peak Performance in Sport - Case Study

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**Abstract**

The use of peripheral biofeedback and neurofeedback is growing rapidly in sport psychology. The aim is to lower competition stress, anxiety, and muscle tension.

We present a case report concerned to biofeedback training in an athlete in preparation to Olympic Game competition. It is the first case in our region to prepare athlete with biofeedback modalities. Obtained results are very encouraging.

## Introduction

There is a strong relationship between mental and physical performance in sport. In this context, the development of a wide range of mental powers, such as focus and concentration, elevates sport performance. Focus means selective attention due to brain energy and concentration is duration of this complete attention in time [1]. In addition to psychological support, many biofeedback modalities are applied to obtain self regulation of bodily functions. The objective of biofeedback is to increase the voluntary control over the physiological processes that are otherwise outside awareness, using the information about them in the form of an external signal. Various biofeedback approaches are increasingly used worldwide as non-pharmacological and cost-benefit effective research and therapeutic tools. A significant increase in research has documented the efficiency of biofeedback for children and adolescents that manifest behavioral, emotional and cognitive problem [2,3]. In addition, biofeedback showed very good results for peak performance (in sport, music, ballet, for singers, as well as for executives in business) [4-8].

Biofeedback modalities can be divided into peripheral (based on electromyography, electrodermal response, heart rate, temperature, blood volume pulse) or central (based on electroencephalography, i.e.

neurofeedback). Treatment by EDR biofeedback is generally based on training patients in strategies for lowering arousal and maintaining a healthful sympathetic/ parasympathetic tone, measured by electrodermal activity (conductance or resistance) [9-11].

Neurofeedback (NF) i.e. EEG biofeedback refers to a specific operant-conditioning paradigm where an individual learns how to influence the electrical activity (frequency, amplitude or synchronization) of his brain. The brain's electrical activity is simply relayed to the computer, so that no electrical current is put into the brain. It involves teaching skills through the rewarding experience of inducing EEG changes reflected in a perceivable signal (light or sound). It means that we are now literally able to recondition and retrain the brain. Neurofeedback has been shown to be particularly useful in reference to pathologies characterized by dysfunctional regulation of cortical arousal, such as epilepsy and attention deficit hyperactivity disorder [2, 9, 12].

In addition to different kinds of psychophysiological disorders, we also applied biofeedback in healthy students. The obtained results using Peak achievement training in high school adolescents for improving concentration and attention were very good [4]. A combination of EEG and EMG biofeedback was used for peak performance in musicians [5]. Other research has also documented the potential of neurofeedback in enhancing optimal performance in high level musical performers [6] and in dance performance [7].

As we mentioned, psychological and physiological preparation for sport competition is in the focus of interest, especially for Olympic sports. The Olympic training centers in Colorado Springs and San Diego have full-time staffs of clinical psychologists for helping athletes to endure training regiments and very stressful international competition. There is agreement among sport participants that manifestation of stress and tension before and during competition are major threats to the success. Logically, the prevention and treatment of stress symptoms are high priority. Generally, sport psychologists commonly use a variety of stress- reducing techniques (e.g. relaxation, visualization, goal setting etc) or cognitive-behavioral strategies and hypnosis.

Contrary to some sport teams (football, baseball, basketball etc) where large number of athletes is involved, individual athletes often seek clinical assistance from professionals who use biofeedback.

Emotional arousal is primarily topic in sport psychology that is commonly related to biofeedback [8, 13]. Consequently, arousal reduction is essential to successful performance. On Figure 1 schematic representation of the dependence of arousal (A) and attention (At) on input agents is displayed. It is clear that attention and arousal are related to higher frequencies of brain activity. The best performance and attention, on the other side, are obtained during middle mental arousal state. Thus, more systematic assessment of athletes via applied psychophysiology and biofeedback has merit, and control become more prominent. The training protocols must be adapted for obtaining middle arousal allowing the best level of attention and achievement.

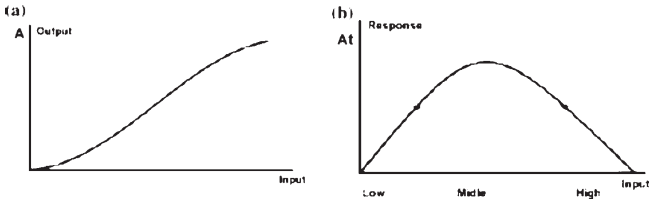


*Figure 1: Schematic representation of the dependence of arousal (A) and attention (At) on input agents.*

"Flow state" is considered the ideal state of mind associated with achievement or optimal performance. The fundamentals of flow are absence of fear, awareness of objectives, clarity of goals, effortless motion, and concentration on the task and central control [14]. The factors known to facilitate the occurrence of flow state include mental and physical preparation, confidence, clear mind, optimal motivation and optimum arousal level [15]. It was shown in some studies that heart rate biofeedback training plus relaxation over six week period resulted in a decrease of sympathetic output in athletes [16-18].

Peak achievement training (PAT) is one particular EEG biofeedback system which monitors activity from 0-40 Hz with an "inhibit all" protocol displayed as a concentration line on a graph [12]. Fluctuations in the line are intriguing to the user because they are directly proportional to quiet versus active mind states (Figure 2).

The threshold for obtaining concentration in PAT is around 10 Hz (alpha band) and the duration of concentration time is measured in seconds. The percentage of total time concentration during one session can be also calculated. The aim of the client is to obtain longer time of concentration (the line being stable and over 10 Hz).

In this article we will present a case study of biofeedback training for peak performance in sport. As we

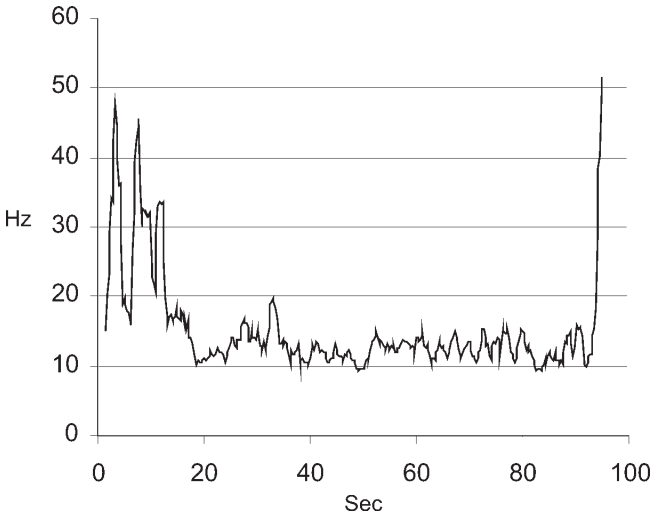


*Figure 2: Display of one session for concentration training with peak achievement training (PAT).*

know, it is the first application of biofeedback in the preparation of athlete for competition and we found it very encouraging.

## Subject and Methods

A twenty aged male sport student asked our help for stress management needed for better results. The athlete obtained pretty good results in training of skiing, and the coach proposed to him to succeed the tests for Olympic Games. One of the reasons for previous unsuccessfulness was emotional tension and anxiety during the competition. On the other side, the athlete was an excellent student, without any problems during lectures and examinations in the high school.

He was very motivated to qualify for competition at Olympic Games and agreed to follow all proposed psychological support as well as biofeedback training sessions.

Before training, we applied psychometric test (MMPI), as well as qEEG recording.

The applied biofeedback modalities comprised: Relax plus and Inner Tunner Professional, Ultramind, UK; Biograph ProComp, Thought Technology LTD, Canada and Peak Achievement Trainer (PAT), USA.

In the literature concerned to biofeedback modalities used in sports there are not much information about specific protocols and selected parameters to use with different sports. So, we started with EDR biofeedback (for obtaining control of the autonomic nervous system), proceeding with pulls-related biofeedback games (Biofeedback games, Novosibirsk, Russia), two weeks, twice a week, 45 minute duration, to obtain relaxation. In the following we applied EEG SMR-training, in the next two weeks, also two time/weekly, 50-60 minute duration, and finally we used PAT-training, concentrated to the brain work, for one week, two time weekly, 10-15 minute duration. Total time of biofeedback training for this athlete was two months continuously.

## Results

The intelligence evaluated by Wechsler Intelligence Test resulted in IQ = 115 (in both manipulative and verbal part). The applied MMPI (Minnesota Multiphase Personality Inventory) showed a normal personality profile (Figure 3).

The psychophysiological assessment comprised qEEG (MITSAR Co. LTD, Russia) and basic peripheral biofeedback measuring galvanic skin activity.

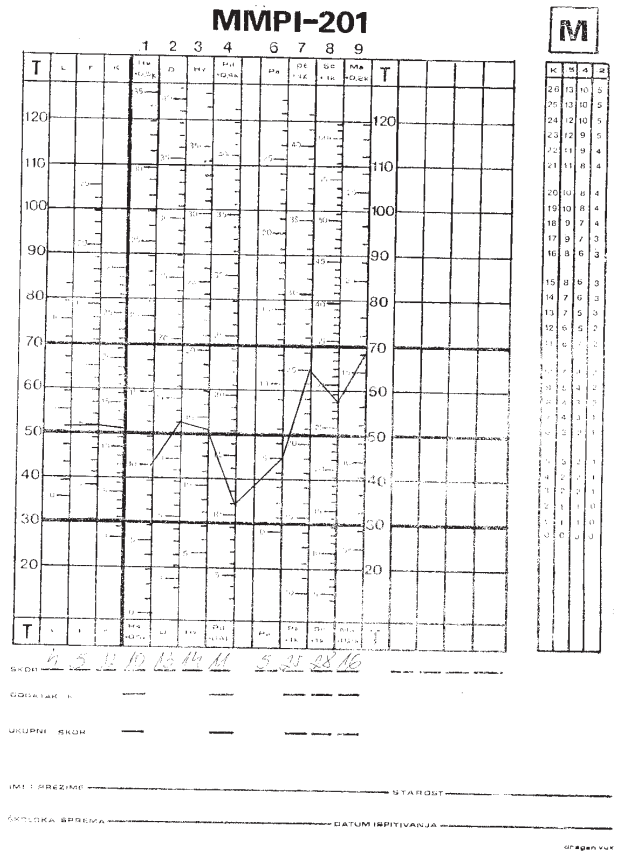


*Figure 3: Personality profile obtained with MMPI (Minnesota Multiphase Personality Inventory).*

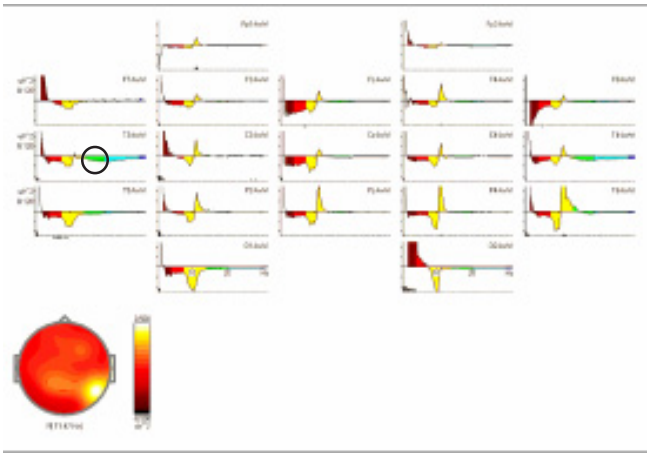

*Figure 4: EEG spectra in EC condition.*

Generally, qEEG spectra in both eyes open (EO) and eyes closed (EC) condition did not showed significant abnormalities compared with the data-base. The alpha power was high and width, but in temporoparietal region some beta activity in EC condition appeared, related to higher anxiety level (Figure 4 and 5). For evaluating obtained results we use data-base originated from the Institute of the Human Brain of Russian Academy of Sciences, St. Petersburg. Each obtained result is compared with "normal" distribution of the related band for the appropriate age and sex.

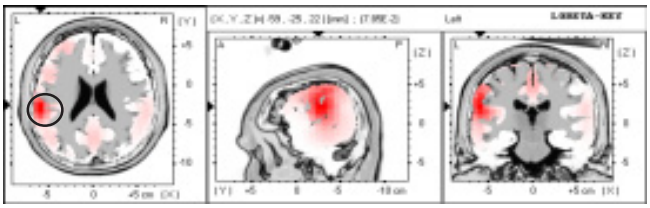

*Figure 5: Low Resolution Electromagnetic Tomography (LORETA) recording obtained in the same condition (EC).*

Low Resolution Electromagnetic Tomography (LORETA) showed temporal source of beta activity, especially at the left side.

ERP's by visual and auditory stimulations showed very good outcome (no omissions and commissions, results were better then the expected ones for the age). ERP's comprised 20 min recording with visual continuous performance test (VCPT) and 20 minutes with auditory continuous performance test (ACPT), included in MITZAR system we used. The ERP's results are also compared with data-base.

Four biofeedback games, developed by the Institute for Medical & Biological Cybernetic, Novosibirsk, were applied: Magic blocks, Canal, Virra and Rally. The goal of all games is to obtain relaxation and to maintain self-control. Through the game the person can discover improve his behavior under stress conditions, and has the possibility to acquire physical sensations of comfort and relaxation. For example, the goal of Magic blocks game is to build as large stack of blocks as possible, preventing them from falling down. In the game VIRA the client is asked to lower heart rate. Special biosensor usage allows a player to maintain self-control. Figure 6 and Figure 7 show the results obtained for heart rate as well as for Magic blocks, respectively.

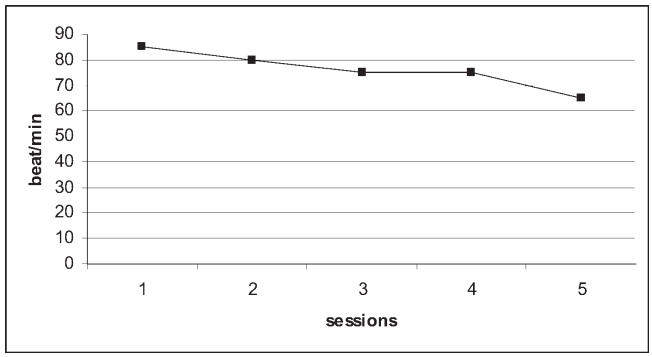


*Figure 6: Changes of heart rate during sessions (lower heart rate is better).*

As can be seen, through the training sessions athlete succeeded to lower heart rate, and to obtain more scores on Magic block which is related to better relaxation level and control of sympathetic activation.

Neurofeedback we used comprised sensory-motor rhythm (SMR) training protocol. It means suppressing

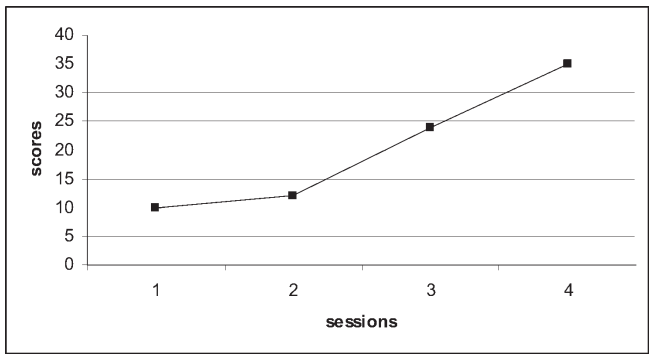


*Figure 7: Scores obtained for relaxation during Magic blocks (higher scores are better).*

theta brain waves (4-8 Hz) and rising high alpha brain waves (13-15 Hz). For our previous experience this kind of training helps in psychomotor stability and concentration. The application of neurofeedback training is relatively easy because we own very good instrumentation obtained from Thought technology Canada. It is the same type of instrumentation which was used to train football world winner in 2006. On the screen (Figure 8) we can visualize row EEG, as well as power of EEG spectra and follow the changes of the bars representing different brain waves activities. In addition we can choose the threshold needed for best performance. After two weeks of training, t-test for theta was t= 2.738 (p= 0.017982); and for high alpha t= 0.168 (p=0.87).

Generally, after two weeks of neurofeedback training, organized two times weekly, and for 50-60 minute duration, the athlete learnt how to shift brain waves according to the aim.

*Figure 8: Display of neurofeedback screen showing row EEG signal as well as spectra power.*

In the last week of biofeedback training we applied peak achievement training (PAT) (Fig. 7). This technique is supposed to activate the executive attention network – the part of the brain that has been recently identified as area which is most important for performing tasks and for new learning. We applied two times per week training, duration 15-20 minutes per day. The aim of training is to obtain longer duration of concentration time. The difference of the duration of concentration between the first and last session on PAT is significant ($t$ = 3.44, p = 0.0017; % time total t = 3.00, p< 0005).

The difference in the obtained results during ski competition before and after biofeedback training is shown on Table 1.

**Table 1: Results obtained from Federation Internationale de Ski.**

| Slalom | Giant slalom | Super giant slalom | Super combination | Rank | Year |
|---|---|---|---|---|---|
| 39.78 | 62.77 | 111.01 | 173.71 | 1804 | 2009 |
| 34.68 | 53.42 | 87.38 | 139.95 | 1106 | 2010 |

It is clear that all results are better than before biofeedback training. It is confirmed with good outcome on the Olympic game in Vancouver this year.

## Discussion

Sport psychologist describe biofeedback as an important tool in: (1) helping an athlete learn to control activation level (2) helping him to manage emotions and mood swings and (3) ultimately assuring physiological readiness of the body for optimum performance [18].

The most common biofeedback modalities that sport psychologists used include HR, respiration, temperature training, EMG, EDR and EEG. Unfortunately there is not much definitive information about specific protocols and selected parameters to use with different sports.

The psychological preparation of athletes for competition could be described as “taking the brain to the weight room”. That is, the athletes are being mentally conditioned to withstand the rigors of fatigue, time pressure, undue expectations, and crowd pressure to give them the possibility of meeting or exceeding their performance goals. Beside psychological support, biofeedback technology and skills training should be an integral part of a training regiment. Competition stress, anxiety, and muscle tension are common antecedents of performance. Through biofeedback, the athlete can objectively assess and control these variables in the long run.

Another area where neurofeedback may hold potential for improving athletic performance is in facilitating greater physical balance. Namely, improvements in balance might enhance performance, skiing, ice skating, hockey, skateboarding, snowboarding, ballet, and possibly also in tennis, martial arts, basketball, baseball, and football.

In the presented case, psychological support together with peripheral biofeedback and neurofeedbak showed very successful outcome. Our client achieved stabilization of emotional arousal which has been the main brake of the success. He obtained improved results, won

in qualifications and he has been selected for competition at Olympic Games.

By this, we have confirmed the usefulness of biofeedback in sport psychology with potential for improving concentration and attention, lowering anxiety and disruptive mental chatter. To our knowledge, this is the first time in this Europe region that biofeedback is used for sports.

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