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ORIGINAL

Application of the EEG Biofeedback method in attention deficits therapy in young sportspeople - A pilot study

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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abstract

Background While working with contestants, sports psychology has been successfully applying the biofeedback (neurofeedback) method since 1970s, noticing its potential in the field of attention concentration, decrease in destructive tension hindering achievement of the expected results in various sports disciplines. The researchers aimed at demonstrating to what extent the EEG Biofeedback method may prove useful in correcting attention concentration deficits in young sportspeople). The presented research project was of a pilot character, and the studies undertaken may be extended and modified.

Material/Methods The research project included young sportspeople (16–17 years old) who were students of the Academic Secondary School of Sports Championship at the School of Economics and Innovation in Lublin. Students (N = 20) were assessed by the school psychologist and teachers as to the noticed difficulties in attention concentration, and they were diagnosed with the application of two methods: EEG Biofeedback and Brickenkamp's Attention Test d2 R. in the Polish adaptation by E. Dajek. On the basis of analysis of the obtained results 10 students were selected, who undertook EEG Biofeedback trainings (20 one-hour sessions, twice a week, in the period between March and June 2016).

Results Both the attention measurement and the EEG Biofeedback training record assessment demonstrated favorable changes in each of the participants in the project (an increase in the ZK indicator, a change in the brain waves proportion Theta/Beta/Beta2).

Conclusions The subsequent examination with the use of an attention test as well as analysis of the EEG Biofeedback training record confirmed the effectiveness of the applied method as a method of correcting deficits/ attention concentration difficulties in young sportspeople.

Key words EEG Biofeedback, sport, attention concentration properties

article details

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INTRODUCTION

Electroencephalography, as a method of imaging the work of brain has had many applications in medical diagnostics and planning clinical examinations [1, 2]. First attempts at applying imaging of brain waves activity in connection with feedback were undertaken by the Japanese psychologist Joe Kamiya, although M. Barry Sterman is universally regarded as the father of the EEG Biofeedback method. In the 1960s he conducted research at California University [3, p. 198–199].

EEG Biofeedback is defined as self-regulatory method of normalizing EEG waves, allowing conscious modification of psycho-physiological status through changing the pattern of brain waves. Due to the application of operative conditioning, the EEG Biofeedback method is regarded as an instrumental psychotherapy method [4]. Certain ranges can be strengthened or inhibited by means of training. The method takes advantage of biological feedback, allowing controlling and modifying the functions that in everyday functioning remain independent of our will. The training takes place with the application of two computer systems with a special EEG Biofeedback module. The apparatuses enable us to trace the recording of the patient's brain waves and imaging them graphically – as a video game. The host, using appropriate parameters, stimulates desirable and inhibits undesirable bands of brain waves. Depending on whether the trainee achieves the set parameters – the game has a successful course or not. The training is aimed at improving bioelectrical function of the brain, depending on the disorder. Thanks to the so-called feedback, the trainee can learn to regulate their brain waves on their own, strengthening or weakening them. The trainee purposefully influences the function of his or her own brain.

The most popular, and, simultaneously, the earliest implemented applications of the method is, first of all, to help with coping with stress [5, 6, 7, 8, 9, 10, 11, 12]. Special significance is also acquired by the application of biofeedback with reference to the persons with posttraumatic stress disorder – PTSD [13]. Nowadays the EEG Biofeedback method is vastly applied in working with attention-deficient children, including those with motor hyperexcitability syndrome with attention deficit (ADHD – attention deficit hyperactivity disorder) [14, 15, 16, 17].

Throughout a few decades of applying that method, literature has been presenting cautious attempts at applying them in new areas, as, for instance, in pedagogy [15, 18, 19] or psychology of work [20]; its restrictions have also been analyzed [21, 22, 23]. More and more frequently EEG biofeedback becomes not only a method of correcting deficits and disorders, but also an attractive form of improving the brain work [23].

EEG BIOFEEDBACK IN SPORT

Zaichkowsky [24, p. 309–312] applied neurofeedback in sport as one of the first. Justifications for the applications of neurofeedback in sport are based on a principle that changes in the mental and emotional condition are accompanied by an observable physiological change that can be monitored. Analogically, a change of thoughts and emotions will appropriately affect physiology. Therefore, biofeedback is an excellent tool for self-regulation and increasing the effectiveness of sports training among sportspeople representing different

disciplines. Both controlling fear and stress, undesirable tension as well as optimization of excitation in the way providing possibly the highest expected achievements seem to be crucial from the perspective of sports training [25, 26]. The hitherto conducted studies including the application of biofeedback training protocols in groups of sportspeople representing different disciplines, such as gymnastics, skiing, skating, hockey or snowboarding, demonstrated surprisingly promising results [27]. Here, it is worth emphasizing that the EEG Biofeedback method is perceived not only as a method that allows correcting deficits or reducing unfavorable tensions, but also as a method that allows improving sports training through developing self-regulation skills in a contestant thus allowing him or her to obtain the most optimal, desirable states indispensable for the increase of achievements [28, 29].

As researchers emphasize [30, 31], we should expect that sports psychologists would more and more willingly attempt to use such a non-invasive method as biofeedback, considering the constantly appearing reports on promising effects of applying that tool in the work with both individual contestants and teams. A correctly applied EEG Biofeedback method allows contestants to increase their strengths and correct their weaknesses. The hitherto study results in this field allow for designing training courses for contestants' coaches to enable them to use that tool [32] and support the training with other methods in preparing for competitions [33, 9]. In view of the above, the main aim of the undertaken studies was to assess the effectiveness of the EEG Biofeedback method in correcting attention deficits in young sportspeople.

MATERIAL AND METHODS

The study comprised a group of 20 sportspeople (16–17 years old), students of the Academic Secondary School of Sports Championship at the School of Economics and Innovation in Lublin. The presented research project was of a pilot character, and the studies undertaken may be extended and modified.

The practical purpose of the studies was to find the answer to the question to what extent the EEG Biofeedback method can prove applicable in correcting attention concentration deficits in young sportspeople. Students (N = 20) were assessed as to attention concentration deficits. The assessing persons were the psychologist working with them and teachers of selected subjects. For that purpose a questionnaire taking into consideration the selected areas of functioning, where attention deficit may manifest itself was used. A significant dimension of that assessment was also the fact that the students themselves assessed their difficulties. The test was repeated after the trainings had been completed[1]. Then the students were diagnosed with the use of two methods: EEG Biofeedback and Attention Examining Test d2 by R. Brickenkamp in the Polish adaptation by E. Dajek [34]. On the basis of the analysis of the obtained results, 10 students were selected, who started and carried out training during three months with the application of the EEG Biofeedback method (20 hours of training, twice a week between March and June 2016). The program of trainings was established so as to avoid overload and discouragement as well as to provide the best possible effect. Training protocols were established for sportspeople in accordance with the basic principle of the EEG Biofeedback therapy, determining the direction of changes – inhibiting the excess and

[1] Due to the main problem of this article, which is the assessment of the EEG Biofeedback method effectiveness, the analysis of results of the pedagogical questionnaire was disregarded.

strengthening the deficit of waves. In EEG Biofeedback trainings, ways of operative (instrumental) and classic conditioning were used. The trainee learnt to repeat ways of behavior bringing about positive results or preventing behavior bringing about negative results. In this way specific patterns of brain waves are created. Repeating favorable behavior patterns was possible thanks to obtaining visual and sound rewards, proving the feedback effectiveness. The positive image of a video game strengthened by sound constitutes a reward for good performance of the task, and thus it is positive reinforcement. After a series of 10 trainings, the students underwent Attention Test d2 again.

ATTENTION TEST D2

Attention Test d2 is a non-verbal technique, supplying a few attention indicators concerning the perception speed, the number of errors and the general perception ability (corrected speed indicator taking into consideration the number of errors) and concentration. Test d2 is based on the definition of attention, according to which attention is a kind of selection and concentration is the person's ability to work incessantly, to analyze significant internal and external stimuli fast and appropriately, selectively, without paying attention to insignificant stimuli. As a result of the test four indicators are calculated:

(a) WZ – assessing the subject's work speed (the overall number of letters worked out);
%B – the percentage of errors made (the percentage of errors made in the overall number of letters worked out), being the indicator of work accuracy;
WZ-B – indicator of the general perception ability, which is the difference between the number of all letters analyzed (WZ) and the number of all errors (B);
ZK – which is obtained by summing the number of correctly drawn letters decreased by the number of errors made; that indicator tells us about the subject's ability to concentrate.
Indicators WZ, %B and ZK reflect the following features of attention: efficiency, accuracy and aptitude. The ZK indicator, which is the basis for assessing subjects' results, was assumed to be the most significant.

EEG BIOFEEDBACK DIAGNOSIS

Problems with concentration at the level of EEG record are the most noticeable in the left brain hemisphere; therefore, in our research we focused on the analysis of data from point C3 (according to the International System 10–20 recommended by the International Federation of Electroencephalography and Clinical Neurophysiology). To assess concentration ability in this point at the level of a EEG record, first of all, significant is the course of three brain waves defined as: Theta (4–8 Hz), Beta (15–20 Hz) and Beta 2 (20–28 Hz). Beside the amplitudes achieved in particular waves, to assess the brain work we applied the indicators based on the mutual relationship of brain waves: Theta/Beta and Beta/Beta 2. Normal values, norms of these indicators for adults are the following: Theta/Beta – value between 1.0 and 2.0, where 2.0 is the upper normal value; Beta/Beta 2 – value above 1.0.

Due to the specificity of numerical values achieved in Q-EEG results in the dimension of particular ranges of waves as well as within mutual relationships of particular waves (Theta/Beta, Beta /Beta 2), it is impossible to show the significance of changes in the recording on the basis of strict numerical

results. Additionally, assessing the improvement in EEB recording, we had to take into consideration changes in both parameters, where due to different normal values, results are not comparable and the assessment has to be of a holistic nature. Therefore, we decided to appoint 10 competent judges (neurotherapists, experienced in conducting therapy with the use of ELMIKO equipment) to assess the differences observed between particular initial and final results. The judges had the ready specification of initial and final results, and their task was to assess the observed difference in the scale 1–10, where 1 meant lack of noticeable improvement in waves proportion (separately for Theta/Beta and Beta/Beta2 as well as the overall assessment of the change in EEG recording) and 10 meant a very significant improvement in waves proportion. Then arithmetic mean was drawn from the obtained results, which was presented as "change assessment". To correct the recording, there was no need to correct two indicators if one of them was normal at the beginning.

RESULTS

The subjects underwent Attention Test d2 twice, i.e. at the beginning of the procedure and after the completion of the series of 20 EEG Biofeedback trainings. As optimal from the perspective of the examined group, the indicator of attention assessment, from among a few persons examined with the use of d2 method, the ZK indicator was assumed – concentration ability and its values were compared before the commencement of EEG Biofeedback trainings and after they had been completed. The obtained results are presented in Table 1.

Table 1. Results of Attention Assessment Test d2

Subjects	Test I		Test II		Difference	
	ZK1–AC1	ZK–AC rank %	ZK2–AC2	ZK–AC rank %	ZK2–ZK1 AC2–AC1	Difference rank %
Subject 1	214	86	238	98	24	12
Subject 2	127	3	186	60-61	49	57
Subject 3	152	17	202	75	50	58
Subject 4	131	3	188	63	57	60
Subject 5	202	75	234	96	32	21
Subject 6	154	19-20	190	65	36	46
Subject 7	222	95	239	98	17	3
Subject 8	132	3-4	158	24-25	26	22
Subject 9	150	16-17	186	60-61	36	44
Subject 10	149	16	186	60	37	44

Before the project was commenced, the participants underwent diagnosis of the bioelectric brain function (Q-EEG recording) with specification of activities of particular brain waves, which constitutes the first stage of training with the use of the EEG Biofeedback method. We assessed the proportion of the waves which were the most significant from the point of view of the project assumptions, i.e. Theta, Beta and Beta2. Another assessment was performed at the end of the series of 20 EEG Biofeedback trainings. The appointed judges assessed the observed difference in the scale 1–10, where 1 meant a lack of noticeable improvement in EEG recording (separately for Theta/Beta and Beta/Beta2, as well as the overall assessment of the change in EEG recording) and

10 meant a very significant improvement in EEG recording. Then from the obtained assessments arithmetic mean was calculated, which was presented as "assessment of change". The results are shown in Table 2.

Table 2. Results of brain wave diagnosis (Q-EEG recording) before the beginning and after the end of EEG Biofeedback trainings

Subjects	TH/B START	TH/B END	Difference TH/B	Change assessment TH/B	B/B2 START	B/B2 END	Difference B/B2	Change assessment B/B2	Overall change assessment
Subject 1	2.60	2.35	-0.25	7.2	0.91	0.97	0.06	2.4	6.2
Subject 2	2.14	1.84	-0.3	6.1	0.80	1.25	0.45	8.9	8.5
Subject 3	3.78	1.99	-1.79	9.9	0.94	1.11	0.16	4.3	9.6
Subject 4	1.48	1.38	-0.1	2.3	0.72	0.99	0.27	6.8	6.2
Subject 5	2.43	2.04	-0.39	7.1	0.82	0.96	0.15	4.8	6.0
Subject 6	2.25	1.58	-0.67	7.9	1.02	1.01	0.01	1.0	7.8
Subject 7	1.91	1.87	-0.04	1.2	0.64	0.71	0.07	2.1	2.0
Subject 8	1.99	1.62	-0.37	3.5	0.83	0.79	0.04	1.0	3.4
Subject 9	1.84	1.6	-0.24	3.0	0.7	0.89	0.29	3.3	3.2
Subject 10	1.28	1.21	-0.07	1.1	0.77	1.14	0.37	9.8	9.2

DISCUSSION

As Thompson reports [22, p. 286], in literature there are still few studies undertaking the analysis of the effect of EEG Biofeedback trainings upon selected cognitive functions, such as memory, attention or creative thinking. Referring to similar, contemporary studies on cognitive functions, also including attention, allows confirmation of the justifiability of the applied procedures [35]. Assuming after the researchers [1] that the brain waves which are the most significant from the perspective of attention concentration and high effectiveness of action are the waves Theta, Beta and Beta2, the relationship between these waves in subjects were analyzed. Before the beginning and after the end of trainings the proportion of Theta/Beta and B/B2 waves was calculated in each of the subjects (Table 2). The final result improved in each of the subjects – the results in the Theta/Beta proportion decreased, whereas in Beta/Beta2 proportion they increased. The lowest observed change in Theta/Beta proportion is -0.7, the highest is 1.79. The lowest correction of Beta/Beta2 proportion at the end of training is 0.01, whereas the highest is 0.45. The assessment of change performed by competent judges, referred to as "overall change assessment" assumes values from 2.0 to 9.6.

Attention test performed twice – before and after EEG Biofeedback trainings (Table 1) allowed observing differences in the value of the ZK indicator – the ability to concentrate (CA). The difference between the ZK2 (CA2) indicator value after the completion of trainings and ZK1 (CA1) before their commencement assumes the values between 17 and 50. Percentage rank differences of both indicators were also calculated. The lowest value of that difference is 3; the highest one is 60.

The correctly conducted EEG Biofeedback training made it possible to lower the proportion of Theta/Beta waves and to increase the advantageous Beta/Beta2 proportion in all subjects. In the dimension of the concentration ability,

increased results were observed in all subjects. Besides, favorable changes were confirmed in quantitative measurements (lowering the proportion of Theta/Beta waves, increasing the advantageous Beta/Beta2 proportion as well as the increase in the concentration ability indicator ZK-CA). During EEG biofeedback trainings a significant regularity was observed, which was connected with cooperation of coaches with the subjects. Due to the fact that the participants of the project were young sportspeople, it was especially significant for the researchers to be able to form in them the ability to take advantage of feedback on which the EEG Biofeedback method is based. Therefore, the trainings constituted the process of learning the skill of self-regulation. Coaches (therapists of the EEG Biofeedback method) were trained and prepared to work with sportspeople. Their task was to give feedback, depending on the need, explaining doubts, and reinforcing motivation for training in the period when it decreases. The coaches also drew the sportspeople's attention to the possibility of observing the results of EEG Biofeedback trainings in school situations and during sports trainings. The obtained declarations indicating subjective conviction about training effectiveness reinforced the sportspeople's motivation and consolidated the skills.

CONCLUSIONS

The aim of the present study was to check to what extent trainings with the use of the EEG Biofeedback method may prove effective in the field of improving attention concentration in young sportspeople. On the basis of the accomplished research project, the following conclusions can be formulated:

1. Both the performed initial attention measurement (before the trainings) and the diagnosis of Theta, Beta1, Beta2 brain waves proportion confirmed their effectiveness as methods allowing to select persons with difficulties in attention concentration.
2. The developed training procedure – 20 EEG Biofeedback trainings (twice a week) became optimal to obtain the expected results.
3. The attention test repeated after completion of EEG Biofeedback trainings confirmed an increase in the ZK (CA) indicator in all persons involved in the training.
4. In all trained persons the analyzed parameters of the proportion of Theta, Beta and Beta2 brain waves improved (decreasing the unfavorable Theta/Beta brain waves proportion and increasing the favorable Beta/Beta2 proportion).
5. The conditioning mechanism applied in EEG Biofeedback training allowed for an increase in the sense of prime mover and satisfaction in young sportspeople, which can be regarded as an additional value of the carried out trainings. We could also consider extending the studies by that aspect of forming the sense of prime mover and self-regulation competence in young sportspeople.
6. The experience of conducting EEG Biofeedback trainings allowed us to notice that the knowledge of possibilities brought about by the EEG Biofeedback method as well as of special benefits in the sort still has not been propagated enough in the circles connected with education and sports training. Also the expectations of sportspeople themselves should be adequately specified for the highest possible effectiveness of training and comfort of conducting it.

Due to the fact that the conducted studies were of an innovative character (no analogical studies in literature), it is difficult to find direct reference to other studies in this field. Similar studies with the use of EEG biofeedback trainings confirm the effectiveness of that method in training certain cognitive functions. It seems interesting to extend the studies concerning the possibility of applying EEG biofeedback trainings in modifying other dimensions, such as mental tension (fear, stress) or the response speed of contestants representing various sports disciplines.

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