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Original Research

The Role of Practice in Arousal Regulation: Improving the Performance of Skilled Shooters

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ABSTRACT

Improving athletic performance through biofeedback training has been observed in some studies. Findings related to the relationship between arousal and performances are limited and more research is needed to reach a definitive conclusion. This study aimed to investigate the effects of arousal regulation practice on the performance of skilled shooters. Twelve skilled shooters air rifle 10 (m) volunteers participated in the study. After the pre-test shooting, the 10 shooters who scored the entry point were divided into two groups of five, experimental and control, as the only subjects available. The shooters of the experimental group participated in three sessions of arousal regulation training and then in five sessions of shooting practice with an emphasis on reducing the level of arousal to the baseline. But the subjects in the control group practiced in these five sessions in the same way as usual. Then both groups participated in the post-test and shooting transfer test. The arousal training program was developed with the help of a biofeedback specialist. Shooting tests were performed by the conditions of the official shooting competitions. The results of repeated measures analysis of the variance test showed that the score of shooters in the experimental group in the post-test and shooting transfer test increased significantly $p \leq 0.05$. In addition, the arousal level of the last half-second of the last shots of the experimental group was significantly lower than the level of arousal of the last half-second of their first shots in a total of five shooting practice sessions $p \leq 0.05$. The results of the study, confirming the ability to learn to regulate arousal, showed that due to biofeedback training, control over physiological responses is increased and the sympathetic system is turned off and the parasympathetic system is activated. As a result, athletic performance is improved through self-regulation of arousal. The findings of this study can be explained by the theory of Reversal.

Keywords: Biofeedback, Self-regulation, Activation, Shooting

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INTRODUCTION

Arousal is a physiological and psychological activity that varies in a continuum from deep sleep to intense excitement [1]. People with high arousal are mentally and physically active and their heart rate, respiration, and sweating increase. Sports psychologists measure the level of arousal using a variety of instruments, including changes in heart rate, respiration, skin conductance, and biochemical-based techniques [1]. Skin conductance level (SCL) is the golden key to measuring arousal [2], which is known as an indicator of arousal of the sympathetic nervous system [3]. When the activity of the sympathetic nervous system increases, due to the activation of the sweat glands and moisturizing of the skin, the skin's resistance decreases, and its conductivity level increases [4]. But when the activity of the sympathetic nervous system decreases, the resistance of the skin to the transmission of electric current increases, and as a result, the arousal decreases [5]. One of the most important topics of interest to sports psychologists is to determine the positive or negative relationship between arousal and sports performance [1].

Over the past decades, various theories such as Inverted U Hypothesis, Drive Theory, Reversals, Catastrophe Model, Zone of optimal functioning, and more recently the motivation trait model by Movahedi et al [6] have determined the relationship between motivation level and performance. Meanwhile, some studies on the approach of differentiation of arousal and activation have attributed physiological responses to arousal and function to activation [7-8]. This approach is the result of the distinction between arousal and activation proposed by Pribram & McGuiness. They consider activation as the result of subtracting the baseline level of arousal from the level of arousal during execution and consider it an indicator for change in arousal [9]. Recently, some researchers have found evidence of a relationship between activation and performance [7, 8, 10, 11]. Few studies have emphasized the role of skill complexity [12], and individual differences in performance improvement [9]. Under laboratory conditions, a positive effect of activation on athletic performance has been observed [13] and by calculating the level of arousal, possible performance prediction [14], and performance improvement due to biofeedback of the galvanic response of the skin has been observed [15-18]. Recently, support for the effectiveness of biofeedback training to help athletes and improve athletic performance has increased [19]. Researchers believe that biofeedback training is a good technique for athletes to gain self-regulatory control, and through the feedback information that athletes gain from their bodies and minds after biofeedback training, psychological skills are changed into automatic reflexes [20]. Recent findings have shown that biofeedback improves the cognitive and emotional self-awareness of athletes. Hence, some sports psychologists are excited to quantify biofeedback [21]. While definitive information on training guidelines for the use of biofeedback is limited [22], the choice of the type of biofeedback to meet the demands in real competition is emphasized [20]. But the lack of use of skilled participants, lack of research in real sports conditions, short-term interventions, subject-based assessments, and lack of control group are among the problems leading to definitive conclusions about the effectiveness of biological feedback on athletic performance [23].

Despite the existence of various theories to explain the relationship between arousal and activation with performance, there is not enough empirical evidence to prove the effect of arousal or activation on improving athletic performance in real conditions. Shooting is one of the sports that have always been of interest to researchers due to a large number of medals in the Olympic Games. While the range of body motion in shooting sports has provided the conditions for conducting studies in the field of biofeedback, the scope of research on the impact of biofeedback in shooting sports is limited. While some studies believe that biofeedback of heart rate variability improves shooters' performance [24-26], limited studies that differentiate between arousal and activation have found no link between arousal and performance [7-11], and only one study has shown that activation is related to the performance of shooters [13]. As can be seen, the content of the above research lacks training and learning program for arousal regulation and is based on the theories of inverted UV, driver, catastrophe models, optimal performance zones, and arousal characteristic models, which are more related to the relationship between the level of arousal and Activation rates are described. Therefore, it seems that regardless of the level and direction of arousal, it is important to examine whether athletes can regulate their arousal and the effect of their interpretation of arousal level on their performance. In the sport of shooting, the feedback from the shots is limited to information about aiming and observing weapon oscillations relative to the target. But during the race, sometimes changes in physiological symptoms such as increased heart rate, shortness of breath, and impaired vision can prevent good shots. According to Khazan [5], the shooter's attempt to control the above symptoms makes the sympathetic system more active and the situation becomes more critical. In such cases, it is suggested that awareness of the arousal level helps to control it during the activity [1]. Therefore, it seems that increasing shooters' awareness of arousal is created through arousal control practice. Therefore, the present study seeks to find the possibility of learning arousal regulation through a personalized program, containing training and arousal regulation training in skilled shooters and study the effects of this exercise on their athletic performance. The results of this study will show the effects of training and practicing biofeedback of skin conductance and arousal regulation on the performance of skilled shooters.

MATERIAL AND METHODS

This quasi-experimental study was conducted in the form of a program including pre-test, educational and training intervention, post-test, and transfer test shooting. Figure 1 shows the process of the research.

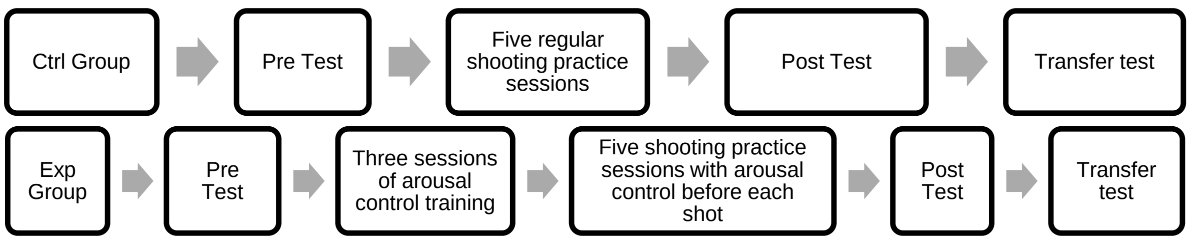

Figure 1. Stages of research in the experimental group and the control group

Research Sample

In the air rifle 10 (m), the central ring of the target has 10 points, which if the shot is in the center of the target, its score increases to 10.9 points. Each shooter has 60 shots that can score a maximum of 645 points. Therefore, the criterion for entering the study was to obtain a record of 600 in the initial shooting test by the official competition conditions. Of the shooters in national competitions and the 10-meter air rifle shooting league, only a record 50 shooters were above 600. After distributing invitation cards among shooters participating in three national freestyle competitions, 12 of them announced their application to participate in the research. The executive program of the research, how to obtain biological information about the body, how to perform shooting tests, along with the conditions for canceling the research was explained to them as well. None of the volunteers had a history of disease affecting the results and history of biofeedback training. After obtaining the initial record, 10 shooters obtained the minimum score and entered the study as the only available samples. After matching the scores in the three categories, the participants were randomly divided into two groups of five, experimental and control groups, including six women and four men with a shooting history of 4.80 ± 1.17, competition history of 3.50 ± 1.13, and an average age of 25.82 ± 1.3. The results recorded in the initial record of the shooters were accepted as their pre-test scores.

Ethical considerations

Since the subjects in the experimental group experienced the installation of a biofeedback device, the steps of electrode connection, data collection, and information about training protocols were described to all of them. Subjects had the right to state their status at the earliest opportunity if they did not wish to participate in the study. All stages of the research were performed by the ethics guidelines of the Islamic Azad University of Tehran, and license No. 121.1399.IR.IAU.TMU.REC was obtained from the relevant authority.

Research Procedure

After the pre-test, the shooters in the control group performed only five regular shooting sessions in two weeks without receiving any augmented feedback. They only saw the score for each shot. But the experimental group shooters first received three sessions of skin conductance biofeedback control training and then five sessions of shooting training with arousal level information for all shots. In these sessions, first, how the biofeedback device and software windows work and then how to install skin and temperature conductors in sitting, standing, and shooting positions were taught. Since the shooting was not possible despite the installation of the receivers by the subjects, based on the findings of Van Dooren and Janssen (2012), the receivers were installed on the foreheads of the subjects. According to his findings, there is high proximity in Eccrine sweat gland densities in the forehead with the fingers and palms, and in addition to the fingers, organs such as the soles of the feet and forehead are the next positions of the body in response to skin conductance [27]. Therefore, in biofeedback training sessions, the receivers were mounted on the foreheads of the shooters through a fabric headband.

To be sure about the content of the arousal training program, the opinions of an official instructor of the Biofeedback Federation of Europe, who is also a member of the Iranian Neuropsychological Association, were used. In the training sessions, first, the skin and temperature conductance device and receptors were connected to the subjects in a sitting position and the training window was opened in Biography Infiniti software. They were then asked to take a deep breath in a sitting position for 10 minutes and think about nothing. After evaluating the biological information and the accuracy of the device, the mean arousal for the first two minutes was recorded as the basal level of arousal. The high amplitude range was then set equal to the mean baseline arousal, and subjects were asked to observe their arousal level through the screen for 20 minutes and keep it equal to or below the baseline average. If their arousal level was above baseline, non-verbal music would play through the computer and a red light would be on the screen at the same time, and as soon as the arousal level was within the specified range, the music stopped and the light went out.

This exercise was performed three times in each session for 20 minutes each time, and at the end of each session, a report of the shooter's ability to manage the level of arousal was presented to them. After ensuring that the subjects in the experimental group were able to observe and understand how their arousal level changes, five 60-shot shooting training sessions were conducted with biofeedback. The content of this program was a combination of the usual training of shooters as well as the content of three sessions of biofeedback training. The preparation steps in the five shooting training sessions with biofeedback were similar to the pre-test conditions, and the first biofeedback training sessions. In these five sessions, shooters were allowed to fire when their level of arousal was within the designated individual range of the session. Otherwise, the shooter was not allowed to shoot and had to observe his level of arousal on the screen and set it according to the content of the training sessions and his level of arousal in the range set for that session. Shooters were generally allowed to fire when music was not playing and the red screen light was off. This operation was considered for 60 shots performed in five shooting training sessions with receiving biofeedback from the experimental group. The steps of implementing the research plan were performed for each shooter separately. Also, shooters were allowed to rest and prepare at the beginning of each session. The shots fired during training sessions and shooting tests were calculated by current and international law and recorded as the result of the shooters. Since there was no biofeedback in the three shooting tests, they only observed the result of their shooting. There was no biofeedback in the shooting tests, and the subjects only observed the result of the shots in the scatt system. According to the research plan, after training and shooting training sessions with the observation of skin conductance and arousal control, the post-test was performed a day later. Then, the transfer test was performed one week after the post-test using real shots on electronic targets approved by the World Federation (SIUS-ASCOR). After the transfer test, an in-depth qualitative interview was conducted with the experimental group. In this interview, the subjects talked about the effective components and the positive or negative dimensions of the feedback provided. Then, the issues raised by them were separated by the researchers and used to explain the findings. The degree of arousal at different times depends on factors such as ambient temperature and the activity of the individual. Therefore, similar to [7, 8] studies, the level of arousal during the shooting training sessions was deducted from the baseline level of arousal in the same session. The residual value was then calculated as the rate of change in arousal level, which was a kind of activation rate.

In general, the steps of firing a shot include raising a weapon on the body, aiming, holding the breath, triggering and firing the shot, and preparing for the next shot, which usually takes a minute. The most important part of this process is the shooting situation at the last moment of each shot, which determines the fate of that shot. Therefore, to obtain the magnitude of the change in the firing arousal level, first the arousal level information recorded in the biofeedback device is extracted from the biography software report section and synchronized with the firing information extracted from the scatt software with an error of 125 thousandths of a second. Then, the average arousal of the last half-second leading to 1500 shots was calculated in 25 shooting training sessions of the experimental group. Then, the mean arousal of the base level of each session was subtracted from the arousal of the last half-second of the shots in the same session. so the remaining number was used as the measure of change arousal of level shots during the last half-second.

Measuring tools

The set of facilities and tools used in this study included a shooting range, shooting equipment, a shooting analysis device, and a biofeedback device. To create similar conditions in all stages of the research, training sessions and shooting tests were conducted by the rules of the International Shooting Sport Federation. Therefore, the sessions were held in halls where shooters practiced regularly. In the pre-test, post-test, shooting sessions, as well as shooting practice sessions, with the receipt of biofeedback, the USB model scatt shooting analysis, and practice device were used. This device has been used in several studies [7, 13, 28, 29]. Also, the ProCamp-2 Thought Technology was used for training, practice, and receiving biofeedback. This device has been used in various studies such as [21, 22, 25, 30, 31].

Statistical Analysis

Descriptive statistics were used to express frequencies, central tendencies, scattering indices, and data correlation, and parametric statistical tests were used because of the shooting information ratio scale. The Shapiro-Wilk test was used to determine the normality of the distribution of pre-test shooting scores as a dependent variable, Levin test was used to check the variance of errors, and Mauchly's Statistics was used to determine the variance of the dependent variable values between groups. Also, to determine the points of difference between the results of the shooters in the three shooting tests as a factor within the group and also between the two groups of subjects as an intergroup factor and their confrontation with each other, the analysis of variance test with repeated measures was used. Paired t-test was used to determine the difference between the mean activation of the first and last shots of the shooters in the experimental group. The statistical results obtained in SPSS software version 24 at a significance level of $\alpha \leq 0.05$ were used to explain the research findings.

RESULTS

The mean of the pre-test shooting record of all subjects was 612.99 ± 5.84 points and their minimum and maximum records were 606.10 and 622.20 points. Due to the equal number of subjects in the experimental and control groups, their normal distribution was obtained by the Shapiro-Wilk test (sig = 0.285; $p < 0.05$). Levin test also showed that the variances of errors in all three shooting tests were equal (sig = 0.419; sig = 0.375; sig = 0.912; $p < 0.05$). Equivalent to Mauchly's Statistics in Table 1, the homogeneity of the distance between the shooters' results was proved ($W = 0.979$; sig = 0.929; $p < 0.05$). Therefore, to determine the differences in the results, the analysis of variance with one-way repeated measures was used. Analysis of variance for the type of shooting test as tests of within-subjects effects showed that the passage of time is an effective factor in the results of shooting tests and the results of shooters in the pre-test, post-test, and transfer test are significantly different (sig= 0.000; $p < 0.05$; $F_{(2,16)} = 14.83$).

The result of this test was significant for measuring the effect of time between the factor of three shooting tests and the factor of two experimental and control groups in obtaining the results of the shooting test (sig = 0.001; $p < 0.05$; $F_{(2,16)} = 11.416$). In this way, it is proved that in a linear model, the components of shooting tests and groups of subjects are effective factors in obtaining the results of shooters. The mean scores of the three shooters' shooting tests were 612.99 ± 5.84, 617.68 ± 6.44, and 618.41 ± 6.82, respectively. Table 2 shows a significant difference between the mean scores of post-test and transfer test with pre-test shooting (sig = 0.003; $p < 0.05$) and (sig = 0.001; $p < 0.05$). As can be seen in Figure 2, the average score of the control group shooters in the post-test is equal to 613.62 ± 3.36 and in the transfer, a test is equal to 613.24 ± 4.46, which shows an increase of 0.88 and 0.5 points respectively. But in the experimental group, the subjects were able to gain 621.74 ± 6.39 and 623.58 ± 24.2 points in the post-test and transfer test, an increase of 8.5 and 10.5 points compared to the pre-test. Table 3 shows that there is no significant difference between the shooting results of the control group. But in the shooters of the experimental group, the post-test and transfer test scores are significantly different from the pre-test (sig = 0.001; $p < 0.05$) and (sig = 0.000; $p < 0.05$). In this way, the subjects in the experimental group were able to significantly increase their performance after a training course on observing the skin conductance level and shooting along with arousal level management, but in the control group, which did not provide any additional feedback, no significant change was observed except for the location of the shots.

RESULTS

The results of statistical analysis showed that the peak torque of the ankle in the sagittal (P = 0.005) and horizontal (P = 0.003) plates in landing from three different heights are significantly different (Table 1). Similarly, maximum ankle angle in sagittal plates (P = 0.017) and minimum (P = 0.044), peak angular velocity of the ankle in frontal plates (P = 0.000), linear ankle velocity in sagittal plates (P = 0.000) and horizontal (P = 0.025), The linear velocity peak of the foot in the sagittal (P = 0.039), frontal (P = 0.000) and horizontal (P = 0.029) planes in landing from three different height are significantly different (Table 2). Finally, the linear acceleration peak of the ankle in the horizontal plates (P = 0.003), the linear acceleration peak of the foot in the sagittal plates (P = 0.008), the frontal (P = 0.003) and horizontal (P = 0.018), the linear peak acceleration of the shank (crus) in the horizontal plates (P = 0.033), peak angular acceleration of ankle in sagittal plates (P = 0.004), peak angular acceleration of foot in sagittal plates (P = 0.015), frontal (P = 0.003) and peak angular acceleration of shank in sagittal plates (P = 0.016) was significantly different between three landings from different height (Table 3). Due to the large volume of statistical data, kinematic and kinetic parameters that did not show significant differences due to landing from different heights were not reported.

Table (1). Homogeneity distance test the results of three shooting tests in all subjects

Mauchly's Test of Sphericity[a]							
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	0.979	0.147	2	0.929	0.98	1	0.5
Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.							

Table (2). Pair comparisons of the averages of the three shooting tests on the two groups' control and experimental

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Pre-test	Post-test	-4.690*	1.144	0.003	-7.329	-2.051
	Transfer test	-5.420*	1.009	0.001	-7.747	-3.093
Post-test	Pre-test	4.690*	1.144	0.003	2.051	7.329
	Transfer test	-0.73	1.083	0.519	-3.226	1.766
Transfer test	Pre-test	5.420*	1.009	0.001	3.093	7.747
	Post-test	0.73	1.083	0.519	-1.766	3.226
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).						

Table (3). Results of paired sample test The rate of activation of the last half-second in the first and last shots of the experimental group

Groups	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Exp Group	Pre-test	Post-test	-8.500*	1.618	0.001	-12.232	-4.768
		Transfer test	-10.340*	1.427	0.000	-13.631	-7.049
	Post-test	Pre-test	8.500*	1.618	0.001	4.768	12.232
		Transfer test	-1.84	1.531	0.264	-5.371	1.691
	Transfer test	Pre-test	10.340*	1.427	0.000	7.049	13.631
		Post-test	1.84	1.531	0.264	-1.691	5.371
Ctrl Goup	Pre-test	Post-test	-0.88	1.618	0.601	-4.612	2.852
		Transfer test	-0.5	1.427	0.735	-3.791	2.791
	Post-test	Pre-test	0.88	1.618	0.601	-2.852	4.612
		Transfer test	0.38	1.531	0.810	-3.151	3.911
	Transfer test	Pre-test	0.5	1.427	0.735	-2.791	3.791
		Post-test	-0.38	1.531	0.810	-3.911	3.151
*. The mean difference is significant at the .05 level.							
b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).							

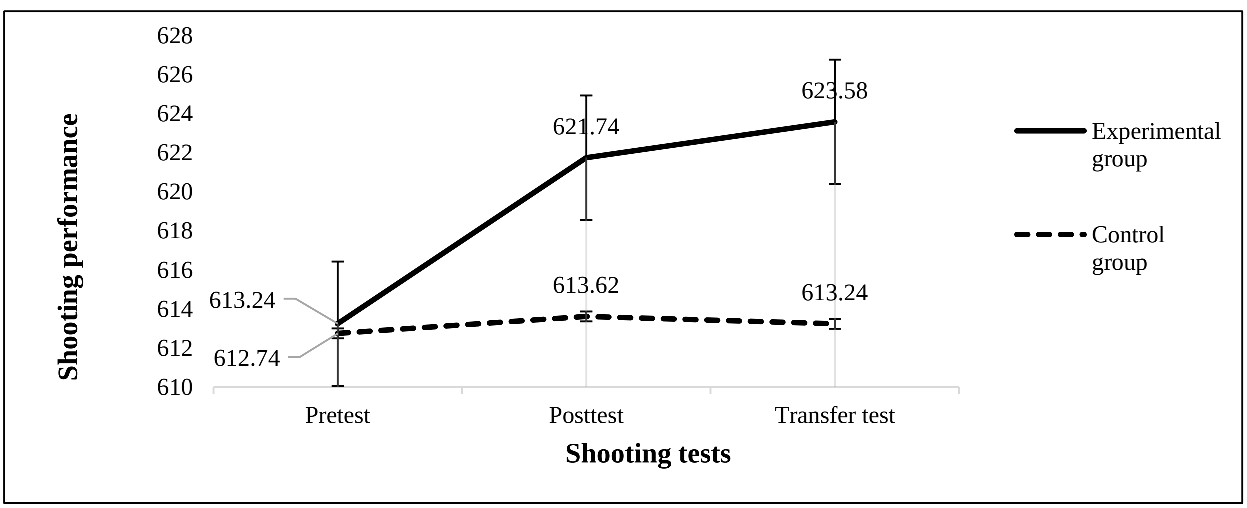

Figure 2. Shooters' performance in three shooting tests

To determine the effects of the skin conductance feedback training program on changes in the arousal level of the training shots of the experimental group shooters, the changes in the arousal level of the last half-second of their first and last shots were compared. As can be seen in Figure 3, the difference between the mean last half-second of arousal of the first and the last shots compared to the mean base level of arousal, which is a kind of activation rate, has been decreasing. The values in Table 1, which is the result of paired t-test to determine the difference between the mean activation of the last half-second of the first and last shots show a decrease in the activation rate of the first to fifth sessions of the experimental group, respectively, equal to 2.36, 2.19, 4.10, 2.15, 2.92 and in all sessions were equal to 2.74 micro Siemens (μS). The results of this test showed that the difference between the mean activation of the first and last shots of the experimental group in all sessions except the first session and also the average of all sessions was significant (p = 0.00). Overall, the level of arousal in the final half-second shots of the experimental group was significantly lower than the level of arousal in the final half-second of their first shots, meaning that the rate of activation of the final shots was significantly lower than that of the first shots in the experimental group.

Figure 3. Average activation of the last half second of the first and last shots in five shooting training sessions of the experimental group

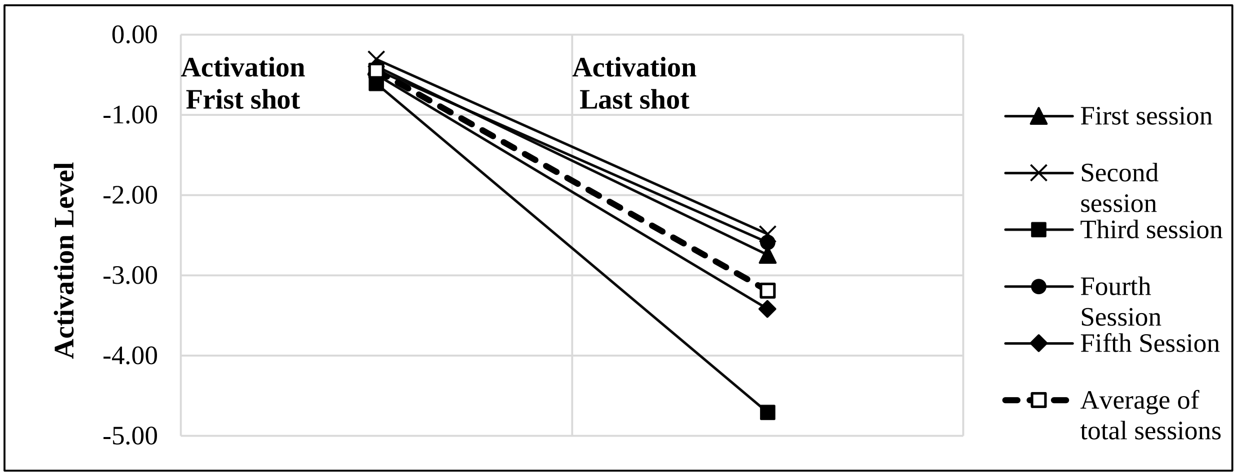

Figure (4). Results of paired sample test The rate of activation of the last half-second in the first and last shots of the experimental group

Variable	Pair	Mean	Std. Deviation	t	Sig
Activation the first session	First Shots Last Shots	-0.39 -2.75	0.78 2.37	2.04	0.111
Activation the second session	first Shots Last Shots	-0.30 -2.49	0.44 2.00	2.99	0.040*
Activation the third session	first Shots Last Shots	-0.61 -4.71	0.49 3.42	2.93	0.043*
Activation the fourth session	first Shots Last Shots	-0.44 -2.59	0.47 1.81	3.31	0.030*
Activation the fifth session	first Shots Last Shots	-0.50 -3.42	0.60 2.21	3.62	0.022*
Activation is the average of total sessions	first Shots Last Shots	-0.45 -3.19	0.53 2.37	6.37	0.000*

*. The mean difference is significant at the .05 level.

DISCUSSION

This study aimed to observe the effects of biofeedback practice on the regulation of arousal and performance of skilled shooters. According to the research design, the shooters of the control group performed their usual shooting practice sessions after the shooting test. But the experimental group experienced a program containing training and practice in adjusting the level of arousal associated with the shooting. The performance chart of the groups in Figure 2 shows that the difference between the pre-test scores of the shooters of the two groups is small and the performance of the control group shooters in the post-test and transfer test is no different from the pre-test. But the shooters of the experimental group recorded significant progress equal to 8.5 and 10.5 points in the post-test and transfer test compared to the pre-test. Since the subjects in the study were highly skilled in performing shooting techniques and were asked not to change their technical pattern, therefore, the improvement of experimental group performance in pre-test and post-test compared to pre-test can be attributed to the biofeedback. In this program, the possibility of adjusting the level of arousal was taught with a reducing approach, and after that, shooting was practiced in conditions where the level of arousal before each shot was equal to or less than the basic level of arousal. Considering the significant increase in the post-test record and the transfer test of the experimental group, it is inferred that adjusting the level of arousal within the specified range not only did not prevent the correct execution of the shots but also improved their performance. Assuming the acceptance of Perry's idea (2011) that the strategies learned in training programs will transfer into actual performance, there is likely to be a similarity between the content of the training program and what the shooters needed, and the practice of adjusting the level of arousal has been transferred to the requirements of the shooting task in real conditions. Improved performance from arousal regulation training is consistent with the results of studies that have observed improved performance due to biofeedback [15-18].

Other research evidence has shown that by receiving feedback information from body and mind, athletes' psychological skills are converted into automatic reflexes, and biofeedback training is a good technique for achieving self-regulation in athletes [20]. Skin conductance level is a good measure of neural responses as the function of sweat glands. The activity of the sweat glands is closely related to the activity of the sympathetic nervous system. Increased activity of the sympathetic nervous system causes the activity of sweat glands and moisturizes the skin. A change in skin resistance indicates a change in arousal. Studies have shown that the level of skin conduction indicates the activity of the peripheral sympathetic nervous system [4, 9], and efforts to control arousal make the sympathetic nervous system more active. In such cases, it is suggested that awareness of the level of arousal controls it during the activity [1]. Zaichkowsky (1982) argues that providing physiological responses during execution accelerates the process of function regulation through greater control over the autonomic nervous system (cited in [15]). Especially when biofeedback is provided at the same time with the performance, athletes' self-regulation skills are developed [14, 23]. Also, Wilson and Cummings (2004) believe that biofeedback links athletes' attitudes to physical activity, and they learn to alter the body's physiological responses and improve their mental state (cited in [15]). Therefore, it may be inferred that the presentation of information about the level of arousal has led to the objectification of physiological information in the form of auditory and visual feedback, thus creating the conditions for control and mastery over the autonomic nervous system and self-regulation. In addition, since the content of the training program included a change in the level of arousal with a reductionist approach, the decrease in the activity of the sympathetic system may have provided a calm and comfortable position for the shooters.

The reason for this claim was a significant decrease in the activation rate of the experimental group shooters during training sessions. As can be seen in Figure 3, a total of five sessions of arousal training had a decreasing trend in the level of arousal of the shooters in the experimental group, and the activation of the last half-second of the last shots was significantly less than that of the first shots. This means that the skin resistance of the shooters in the final shots was higher than the initial shots. Since skin resistance is inversely related to the activity of the sympathetic system and the skin's conductance to cognitive and emotional stimuli such as stressful thoughts and feelings is highly sensitive and responsive [5], conditions are likely to be provided for shooters' sympathetic system to shut down, and in a way, their arousal has diminished. In this study, the decrease in the arousal of shooters in the experimental group is manifested in the form of a decrease in their activation rate and indicates that activation is inversely related to the performance of skilled shooters. This finding is consistent with the results of studies in which activation can be used as a variable in determining performance [7-10, 13]. Similar to some findings [4, 15, 32], the above results indicate that the galvanic response of the skin is a good criterion for predicting athletic performance.

Also, due to the fact that the activity of sweat glands depends on genetic components and the number of sweat glands and other influential factors and people show different responses to arousal changes [33], so the similarity of the physiological response of the subjects in the experimental group in each of the shooting practice sessions reinforces the hypothesis that their cognitive interpretation of the level of arousal and receiving information about the level of arousal was considered positive and improved their performance. So far, various theories such as the U-inverted hypothesis (emphasis on the optimal level of arousal), Hull and Spence driver theory (attention to skill level), Fazcy & Hardy theory (effect of cognitive and physical anxiety), Henin theory of individual optimal functioning area (the effectiveness of individual differences) and the theory of the Reversal or Apter and Kear have explained the relationship between arousal and performance [34]. Since the shooters of the experimental group in the qualitative interview obtained after the transfer test considered the feedback provided as encouraging, motivating, reinforcing, and reducing error, the findings of the present study from the theory of reversal based on the effectiveness of Individuals' interpretations and evaluations of motivation provide more support for performance that neither causes excitement due to increase nor dullness due to decrease in arousal. There are not many studies that have practiced biofeedback to regulate the level of arousal and its effect on improving athletic performance. Researchers' lack of attention to arousal regulation training and the focus of most studies on determining the relationship between arousal rate and performance, has led to the lack of answers to existing theories and models to the questions that can be asked in determining the relationship between performance and arousal. The findings of the present study can encourage researchers to try this invisible part of the effect of biological feedback in explaining the relationship between arousal and performance.

CONCLUSION

Although this study was limited in the subjects, however, the results showed that if the biofeedback is commensurate with the needs of the athletes and the requirements of the task and the athletes' interpretation of the information received is in line with the skill requirement, accepting the effectiveness of biofeedback on performance in real sports conditions will be possible. The results of the study, confirming the ability to learn to regulate arousal, showed that due to biofeedback training, control over physiological responses is increased and the sympathetic system is turned off and the parasympathetic system is activated. As a result, athletic performance is improved through self-regulation of arousal. Also, assuming that the subjects are skilled, it is possible to learn the regulation of arousal in real sports conditions, and if the content of the feedback provided is consistent with the skill requirement, the benefits of biofeedback training can be transferred to the actual performance of the exercise. The findings of this study support the theory of reversal while confirming the role of evaluation and interpretation of individuals in the effect of arousal on performance.

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نقش تمرین تنظیم انگیختگی: بهبود عملکرد تیراندازان ماهر

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چکیده

بهبود عملکرد ورزشی از طریق آموزش بازخورد زیستی در برخی پژوهش‌ها مشاهده شده است. یافته‌های مربوط به رابطه انگیختگی با عملکرد محدود است و برای نتیجه‌گیری قطعی به پژوهش‌های بیشتری نیاز است. پژوهش حاضر با هدف مشاهده آثار آموزش و تمرین تنظیم انگیختگی و نتایج آن بر عملکرد تیراندازان ماهر انجام شد. ۱۲ تیرانداز ماهر تفنگ بادی ۱۰ متر داوطلب شرکت در پژوهش بودند. بعد از پیش‌آزمون تیراندازی، ۱۰ تیراندازی که امتیاز ورود به پژوهش را کسب کردند به عنوان تنها آزمودنی‌های دردسترس به دو گروه پنج نفری آزمایش و کنترل تقسیم شدند. سپس تیراندازان گروه تجربی، در سه جلسه آموزش تنظیم انگیختگی و پنج جلسه تمرین تیراندازی با تأکید بر کاهش سطح انگیختگی تا حد انگیختگی سطح پایه شرکت کردند. اما گروه کنترل، پنج جلسه تمرین تیراندازی را معادل روال همیشگی اجرا نمود. سپس هر دو گروه در پس‌آزمون و آزمون انتقال تیراندازی شرکت کردند. در تدوین محتوای برنامه آموزش و تمرین انگیختگی از نظرات یک مدرس بایوفیدبک استفاده شد. آزمون‌های تیراندازی مطابق با شرایط مسابقات رسمی تیراندازی انجام شد. نتایج آزمون تحلیل واریانس با اندازه‌گیری مکرر نشان داد که امتیاز تیراندازان گروه تجربی در پس‌آزمون و آزمون انتقال به‌طور معناداری افزایش یافته است $\alpha \leq 0.05$. همچنین، سطح انگیختگی نیم ثانیه پایانی شلیک‌های آخر تیراندازان گروه تجربی به‌طور معناداری کمتر از سطح انگیختگی نیم ثانیه پایانی شلیک‌های اول ایشان در مجموع پنج جلسه تمرین تیراندازی بوده است $\alpha \leq 0.05$. نتایج پژوهش ضمن تأیید قابلیت یادگیری تنظیم انگیختگی، نشان داد که بر اثر آموزش تنظیم انگیختگی، کنترل بر پاسخ های فیزیولوژیکی افزایش یافته و سیستم سمپاتیک خاموش و سیستم پاراسمپاتیک فعّال می‌شود. در نتیجه عملکرد ورزشی از طریق خود تنظیمی ناشی از تنظیم انگیختگی بهبود می‌یابد. یافته‌های حاصل از این پژوهش با نظریه بازگشت قابل تبیین است.

واژگان کلیدی: بازخورد زیستی، خود تنظیمی، فعّالسازی، تیراندازی