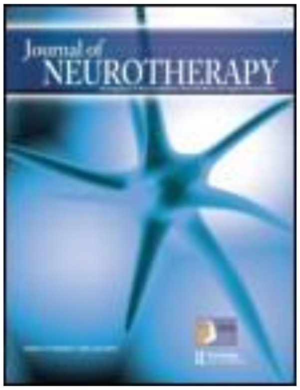

Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience

The Effects of Neurofeedback on the Improvement of Rifle Shooters' Performance

Reza Rostami [a b] , Heidar Sadeghi [c] , Kobra Allah Karami [a] , Masoud Nosrat Abadi [b] & Payman Salamati [d]

[a] Exercise Physiology Research Center, Baqiyatallah University of Medical Science , Tehran , Iran

[b] University of Tehran , Tehran , Iran

[c] University of Tarbiat Moallem , Tehran , Iran

[d] Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences , Tehran , Iran

Published online: 21 Nov 2012.

To cite this article: Reza Rostami , Heidar Sadeghi , Kobra Allah Karami , Masoud Nosrat Abadi & Payman Salamati (2012) The Effects of Neurofeedback on the Improvement of Rifle Shooters' Performance, Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience, 16:4, 264-269, DOI: 10.1080/10874208.2012.730388

To link to this article: http://dx.doi.org/10.1080/10874208.2012.730388

Journal of Neurotherapy, 16:264–269, 2012

ISSN: 1087-4208 print/1530-017X online
DOI: 10.1080/10874208.2012.730388

THE EFFECTS OF NEUROFEEDBACK ON THE IMPROVEMENT OF RIFLE SHOOTERS' PERFORMANCE

Reza Rostami[1,2], Heidar Sadeghi[3], Kobra Allah Karami[1], Masoud Nosrat Abadi[2], Payman Salamati[4]

[1]Exercise Physiology Research Center, Baqiyatallah University of Medical Science, Tehran, Iran
[2]University of Tehran, Tehran, Iran
[3]University of Tarbiat Moallem, Tehran, Iran
[4]Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran

The aim of our study was to compare rifle shooters' performance between two groups of expert shooters, one trained with a neurofeedback method and the other not trained. The study design employed a pretest–posttest design with an untreated control group (nonrandomized). The sample included 24 national and provincial shooters. Shooting performance was studied based on 6 indicators via a device called "Scott," and paired and independent *t* tests were performed with corrections for multiple comparisons. A significant improvement was found for the neurofeedback group for the mean of shot results before and after the training ($p = .001$), but no other improvements were found (all $ps > .05$). In the control group, no differences were found on any of the study indicators (all $ps > .05$). There was a significant difference between mean discrepancies of shot results between the two groups ($p = .01$), whereas there were no such differences in any of other the indicators (all $ps > .05$). Neurofeedback can be suggested as a method to improve rifle shooters' performances.

INTRODUCTION

One of the main concerns of sport psychology is finding new methods to increase athletes' performances. In recent decades, different tools have been utilized to achieve this goal. Zaichowsky was one of the first researchers who recommended the application of stress management for sportsmen and women in this field (Zaichowsky & Sime, 1982). EEG biofeedback is one of the methods, which increases awareness of mind–body lineage, enhances control over the physiology, and improves access to self-regulation strategies (Edmonds & Tenenbaum, 2012). Electrodes are applied to the head, whereby brain activity can be measured and fed back. Up until now, most of the studies have focused on the clinical applications such as attention deficit hyperactivity disorder (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009), epilepsy (Tan et al., 2009), and insomnia (Cortoos, De Valck, Arns, Breteler, & Cluydts, 2010; Hoedlmoser et al., 2008), and only a few studies have investigated the application of neurofeedback in sport medicine (Arns, Kleinnijenhuis, Fallahpour, & Breteler, 2008; Hatfield, Haufler, & Spalding, 2006; Hillman, Appareis, Janelle, & Hatfield, 2000; Thompson, 2008; Thompson, Steffert, Ros, Leach, & Gruzelier, 2008).

The central nervous system has critical effects on some kinds of sports including rifle shooting. Thus, improving shooters' performances has been one of the main objectives of sport researchers and coaches. Nonetheless, there are only a few studies that have investigated the effectiveness of neurofeedback in

Received 19 February 2012; accepted 27 August 2012.
Address correspondence to Payman Salamati, MD, Sina Trauma and Surgery Research Center, Tehran University of Medical Sciences, Tehran, Iran. E-mail: psalamati@tums.ac.ir

improving shooting skills. In this study, we compared the performance indicators of two groups of expert rifle shooters—one group trained using neurofeedback and the other group, which did not receive training.

METHODS

This study employed a pretest–posttest design with a control group. Twenty-four national and provincial shooters were selected (nonrandom) with the cooperation of the National Sport Shooting Federation of Iran. Inclusion criteria were no history of general anesthesia, neurologic illnesses, mental disorders, or drug/ medication usage. All shooters were right-handed, and they had signed the informed consent. Pretest and posttest measures, which measured rifle shooters' performance, were identical for both groups, and they were assessed under the International Sport Shooting Federation rules. In the women's division, this consisted of 40 shots in 75 min, and in the men's division 60 shots in 105 min. The target was set at a distance of 10 m. Shooting performance was studied based on six indicators to analyze performances via a dedicated device called "Scott." This device is made for shooting analysis and consists of two major sections: software (Version 5.28) and hardware. The latter includes an optical receiver that is placed under the rifle, an electronic target that can be installed between 4 and 12 m away from the shooter, a control unit, and related cables. The indicators were as follows (Ball, Best, & Wrigley, 2003):

1. Shot results: The results were between 0 and 10.9. Scott could record the results in decimal. Mean results were considered in decimal for each shooter.
2. Steadiness in 10.a0: Percentage of time the shooter kept the aim point in an area the size of the 10 scoring zone. This was used to indicate the steadiness of aiming.
3. Steadiness in 10.0: Percentage of time the shooter kept the aim point in the 10 scoring zone. This was used to indicate the accuracy of aiming.
4. Trace length: The distance the shooter covered from aiming point to shoot (in mm).
5. Distance between the average aiming point and the breech: The distance between the center of target and the shot mark (in mm).
6. Aiming time: How long did it take to aim for each shot? (in seconds).

All of the individuals participated on a weekly basis according to their normal schedule. Twelve participants were in the intervention group (neurofeedback) and 12 were in the control group (no intervention). Neurofeedback consisted of fifteen 60-min sessions (30 min for each protocol) over the course of 5 weeks with three sessions per week. In the intervention group, an SMR neurofeedback protocol (reward SMR [13–15 Hz] and inhibit high beta [20–30 Hz]) was used. Electrode placement was in accordance with the International 10–20 system with electrodes placed at C3 with the reference at C4 and the ground at A2. The second portion of each session consisted of an alpha-theta neurofeedback protocol (training crossover between alpha [8–12 Hz] and theta [4–8 Hz] with high beta [20–30 Hz] inhibition) at PZ with the reference at A1 and the ground at A2. At the beginning of each session a 2-min baseline was recorded and thresholds were adjusted 0.5 to 1 microvolt higher or lower than the band power in each of the bands that were to be rewarded or inhibited. The participants were rewarded whenever they successfully maintained the band power above the baseline level for 80% of the training duration (at least for 0.5 s) and inhibited the designated bands for 20% of the training duration (at least for 0.5 s). Threshold levels were adjusted when participants received rewards 90% (at least for 0.5 s) of the training time. All threshold levels were adjusted manually. In the alpha-theta protocol, reward threshold was set at 60% instead of 80%. Participants were seated on a comfortable chair in a quiet room. A pair of electrodes was placed on the individual's head and two were placed on their earlobes. Next, based on the participant's baseline EEG, audio-visual feedback (in the form of computer games, images, or sounds) was presented. Thought Technology Procomp P2 & Procomp P8 neurofeedback equipment (made in Canada) was used in this study. The training was performed at the Atieh Comprehensive Psych and Nerve Center in Tehran, Iran. When neurofeedback training was complete, posttests were conducted on all of the participants in both groups. The study was approved by the Iranian Registry of Clinical Trials and our institutional ethics committee.

The data were analyzed using paired *t* tests for the comparison of pretest and posttest performance indicators in each group and independent *t* tests for the comparison of mean discrepancies of indicators between the two groups. An adjusted *p* value of .02 was used to correct for multiple comparisons (six independent *t* tests for variables).

RESULTS

There were 12 participants in each group. The mean and standard deviation of the age of the participants was 30 ± 6.7 years for the neurofeedback group and 30.92 ± 5.52 years for the control group. Five (41.7%) of the participants in each group were male. The means and standard deviations of the experience intervals were 7.5 ± 6.13 years for intervention group and 6.58 ± 4.87 years for the control group. The two groups were not statistically different on age and years of experience ($p = .766$ and $p = .718$).

We compared pretest and posttest performance indicators in the intervention group (Table 1). A significant difference was found between mean shot results before and after neurofeedback ($p = .001$), but there were no differences for other indicators (all $ps > .05$). We compared the same indicators in the control group (Table 2) and found no significant differences in any of the study indicators (all $ps > .05$). We compared the difference of mean discrepancies of indicators between two groups (Table 3). There was a significant difference between mean discrepancies of shot results among the two groups ($p = .01$), whereas there were no differences in any of the other indicators between the two groups (all $ps > .05$).

TABLE 1. Pretest and Posttest Results Based on Performance Indicators in Neurofeedback Group

Indicator	Test	M	SD	Paired *t* test	*p*
Shot result	Pretest	9.48	0.26	−4.506	.001
	Posttest	9.73	0.13		
Steadiness in 10.a0	Pretest	33.33	10.25	−0.457	0.657
	Posttest	34.92	7.96		
Steadiness in 10.0	Pretest	57.08	12.68	0.466	0.650
	Posttest	54.67	18.47		
Trace length	Pretest	97.31	48.61	−0.622	0.547
	Posttest	100.31	42.49		
Distance between average aiming point and breach	Pretest	7.98	2.59	1.012	0.333
	Posttest	7.39	2.11		
Aiming time	Pretest	6.87	2.31	0.425	0.679
	Posttest	6.59	1.96		

TABLE 2. Pretest and Posttest Results Based on Performance Indicators in Control Group

Indicator	Test	M	SD	Paired *t* test	*p*
Shot result	Pretest	9.53	0.33	0.796	.443
	Posttest	9.45	0.22		
Steadiness in 10.a0	Pretest	36.42	21.49	0.124	0.903
	Posttest	36.08	15.94		
Steadiness in 10.0	Pretest	54.75	21.14	−0.357	0.728
	Posttest	55.50	18.77		
Trace length	Pretest	79.48	49.65	−1.097	0.296
	Posttest	90.53	55.75		
Distance between average aiming point and breach	Pretest	6.26	3.30	−1.034	0.323
	Posttest	6.89	3.65		
Aiming time	Pretest	7.30	2.63	0.634	0.539
	Posttest	6.88	1.96		

DISCUSSION

The primary aim of this study was to investigate if neurofeedback training can improve the shooting abilities of expert rifle shooters, as assessed by performance indicators. The results demonstrated that after 15 sessions of neurofeedback training significant improvements were obtained in the shot results. Based on the Table 1, comparing the indicators between pretest and posttest results in the neurofeedback group, there was a statistically significant

TABLE 3. Discrepancy Results Based on Performance Indicators in Both Groups

Indicator	Group	M	SD	Independent *t* test	*p*
Shot result	Neurofeedback	0.25	0.19	2.827	.01
	Control	−0.08	0.35		
Steadiness in 10.a0	Neurofeedback	1.58	12.01	0.533	0.599
	Control	−0.75	9.26		
Steadiness in 10.0	Neurofeedback	−2.42	17.97	−0.551	0.587
	Control	0.67	7.29		
Trace length	Neurofeedbacck	0.75	14.37	−1.106	0.281
	Control	12.74	34.72		
Distance between average aiming point and breach	Neurofeedback	−0.59	2.03	−1.446	0.162
	Control	0.63	2.12		
Aiming time	Neurofeedback	−0.21	1.70	0.292	0.773
	Control	−0.45	2.31		

finding only for shot results ($p = .001$). However, there were no statistically significant results in other performance indicators. This implies that neurofeedback training results in improved performance in shot results as compared to pretraining. Furthermore, the control group did not seem to demonstrate any improvements on this measure. In addition, as seen in the Table 3, we compared the difference of mean discrepancies of indicators between the two groups and the participants in neurofeedback group improved in their shot results ($p = .01$). Shot result is the main indicator used in shooting because this indicator, regardless of any other indicators, is considered in the final results and ranking of shooters.

Babiloni et al. (2008) studied the relationship among the frontal cerebral rhythms and fine motor control and balance in golfers. They studied 12 expert golfers and showed that sensorimotor EEG rhythms could predict the golfers' performance (Babiloni et al., 2008). Of interest, some members in the Italian soccer team had used biofeedback and neurofeedback techniques before winning the 2006 World Cup soccer championship (Wilson, Peper, & Moss, 2010). Landers et al. (1991) investigated the influence of neurofeedback on archery performance. The participants were 24 archers who had been enrolled in three groups: correct feedback, incorrect feedback, and no feedback. The results showed that archery performance was improved only in the first group.

Haufler, Spalding, Santa Maria, and Hatfield (2000) studied EEG cortical activity patterns during the aiming period in 15 expert marksmen and 21 novice volunteers. The results were remarkably different in each frequency band in the groups (Haufler et al., 2000). Because they studied performance as a single factor in other kinds of sports, the results could not be completely generalized to our research due to the fact that we had studied several indicators in different fields of shooting.

There are a few studies conducted on shooters in this field. Hatfield, Landers, and Ray (1984) studied the time preceding rifle shooting. They revealed that there was a hemispheric shift and decrease activity in the left hemisphere prior to shooting (Hatfield et al., 1984). Domingues et al. (2008) studied shooting precision using the motor learning of pistol shooting. They investigated 23 subjects aged 18 to 20 years old. They showed a significant improvement in shooting results among the participants (Domingues et al., 2008). However, they didn't have a control group. Doppelmayr, Finkenzeller, and Sauseng (2008) investigated 18 rifle shooters. Eight subjects were experts, and 10 of them were novice. The researchers recorded participants' EEG while they were shooting. The results showed significantly stronger theta activity among the experts (Doppelmayr et al., 2008).

One of the limitations of the current study was that participants were nonrandomly distributed in the two groups. The second limitation was the use of a nontreated control group, rather than a placebo control group, thus it cannot be ruled out that the outcomes were due to nonspecific effects.

In conclusion, based on the findings from this study and prior studies, neurofeedback has been shown to improve rifle shooters' performance, most specifically on the measure of shot result. This study further demonstrates the interaction between improvements in brain functioning with progress in individual functioning related to shooting performance.

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