The effect of a Biofeedback Training Course and Transcranial Direct Current Stimulation (tDCS) on Balance, Proprioception ,and Performance of Athletes 18 to 30 Years Old

Ali Asghar Jamebozorgi [a], Heydar Sadeghi [b*], Abbas Rahimi [c], Seyyed Morteza Kazemi [d], Hassan Matinhomaei [a]

a Department of Sports Physiology and Biomechanics, Central Tehran Branch, Islamic Azad University, Tehran, Iran; **b** Department Biomechanics of Sport and Injuries, Faculty of Physical Education and Sport sciences, Kharazmi University, Tehran, Iran; **c** Department of Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran; **d** The Bone Joint and Related Tissues Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Corresponding Author:** Biomechanics Faculty, Kharazmi University, Tehran, Iran. ***E-mail: sadeghih@yahoo.com

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Abstract

Introduction: Balance is one of the basic required components for daily life activities, which is as one of the functional independent indicators. Proprioception plays a key role in maintaining balance and optimally doing exercise skills and preventing injury. In this research, the effect of biofeedback and TDCS was compared along with the promotion of balance, proprioception, and performance. **Method**: In the present experimental study, 36 athletes were randomly divided into three groups of biofeedback (12), TDCS (12), and control (12). Balance assessment was performed by force-plate, proprioception was done with digital photography, and the functional balance was determined by star testing before and after the intervention. Anova and T-stent pair tests were used at a significance level of 0.05 to analyze information. **Results**: The results show a significant difference in the absolute error rate of the reconstruction of the target angle following the biofeedback intervention at angles of 30° (*P*=0.01), 45° (*P*=0.03), and 90° *P*=0.002) as well as improving the balance in the biofeedback group after intervene in the anterior, external, external, posterior, posterior, and TDCS groups in the anterior, posterior, posterior, internal, and internal posterior directions. **Conclusion**: The findings showed that the use of biofeedback and TDCS along with proprioception exercises could be recommended to athletes to improve their proprioception and functional balance.

Keywords: Electromyographic Biofeedback, Transcranial Direct Current Stimulation, proprioception, Balance, Functional Balance

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Introduction

Maintaining balance statically and dynamically is essential in many sports activities such as jogging, catching, and throwing balls, and most of the daily activities of individuals. The proprioception also plays an important role in optimally performing sports skills and preventing injury and maintaining balance (1). Many factors such as information obtained from the sensory systems of the body, vision and vestibular system, and motor responses caused by coordination, motion range, and muscle strength, affect balance (2). Proprioception is responsible for the perception of motion, the status of connected parts of the body without the use of vision. Proprioception information of length, muscle tone, and joint position is required along with information, stereotypes, and vision to maintain balance, control posture, stability in a particular situation, or during dynamic movement. The effect of proprioception in the absence of other systems related to balance in individuals in different age groups has been investigated and it has been specified that all age groups depend on proprioception to maintain balance (3, 4). Weakness and disorder in proprioception significantly increase the risk of injury during exercise and daily activities (5). According to Gambeta and Gray (2000), balance is the most important part of an athlete's ability, so that it plays a decisive role in sedentary sports such as shooting and in active sports such as gymnastics and wrestling (6). Studies show that inefficient neuromuscular control in the lower limbs during exercise is one of the main causes of anterior cruciate ligament injuries. An athlete with a sports injury distances him/herself from the sport for a while. The longer this time, the more difficult it is for the athlete to return to sports and may adversely affect his or her athletic performance (7).

Different methods such as strengthening exercises, proprioception-strengthening exercises, stretching exercises and a combination of them are usually used to prevent injury and improve the athlete's balance that helps to strengthen muscles and improve the performance of athletes (8). In recent years, attention has been paid to the perception of mechanisms of neuromuscular dysfunction and dynamic stability and the use of new technologies such as neurofeedback, biofeedback, and TDCS have been considered as safe and painless methods to improve brain function and self-control and improve the proprioception, and balance. Biofeedback is a technique used to facilitate normal motor patterns before and after injury (10, 9). According to conducted types of research, the use of biofeedback therapy is possible and effective in improving functional balance and postural control (12, 11). Another new intervention is the use of Transcranial Direct Current Stimulation (TDCS), which is a non-invasive method of stimulating the brain, and uses low-intensity electric current directly to the target areas of the brain through electrodes placed on the surface of the skull. The use of TDCS with increasing intensity and duration increases motor function, and an MRI study has shown the effect of this method on the motor adaptation of areas of the brain associated with the lower extremities (13). So far, no study has been conducted on the effects of TDCS on balance indicators and people's proprioception without brain problems. Because balance is a determining and important factor in the athletic success of athletes and the functional activity of individuals, and the role of proprioception information is very important in the movement and posture system. The purpose of this research is to investigate the effect of TDCS-induced central nervous system stimulation and compare it to biofeedback exercises that affect the peripheral nervous system to find out the effects of these two techniques on improving balance, proprioception, and performance in athletes.

Method and Materials

Thirty-six people were randomly assigned to participate in three groups and participated as subjects who were among the students aged 18 to 30 participating in sports Olympiads at Shahid Beheshti University of Medical Sciences. The inclusion criteria were the lack of neuromuscular disease, difference in limb length, drug and alcohol addiction, and any balance disorders, as well as the lack of cognitive, visual, and auditory disorders, and the lack of neurological or seizure disorders. The participants was excluded from the study if they did not wish to continue the cooperation, surgery or musculoskeletal injury during the study and also the absence of more than 3 sessions in training. The conditions and process of conducting the test, intervention and research objectives were explained to participants in the study after obtaining the criteria for entry and consent, and the demographic information including age, sex, height, weight, etc. were recorded. The convenient samples were randomly assigned to three groups of 12 people including biofeedback, TDCS, and control group without being notified. Evaluation tests were then performed on the subjects. The target angle reconstruction method was used in the standing position in all three groups to assess the detailed proprioception. In this method, a system consisting of skin marking and digital photography was used. The camera was aligned at all stages of the study at a distance of 185 cm from the individual and 65cm from the ground, so that the lens is completely along the knee joint, on the tripod and perpendicular to the knee plate. The person was then placed in a standing position (complete extension of the knee joint) and was asked to contact the ground to some extent at the beginning of the non-dominant leg test (a ball test was used to determine the dominant leg) to easily maintain the balance. The subject was also asked to keep his/her head straight (to prevent stimulation of the vestibular system) and not to lean his/her body back or forward. Then, while the test person's eyes were closed, he/she was asked to bend his/her knee joint. When the knee reached an angle of 30, 45, and 90 degrees of flexion, which had already been drawn on the wall, the order was stopped and the person was asked to maintain that angle for 5 seconds and to remember this position. After ten seconds of rest, the person was asked to reconstruct the angle and announce it. The angle reconstruction test was repeated three times, with a 10-second break between each repetition to measure more accurately. The photo was taken after the person was informed of the reconstructed condition, which was done with a system consisting of digital photography and analysis with Digimizer software version 5.3.4. The difference in test and reconstruction angle was considered and recorded as an absolute error (14). The star rotation test was used to evaluate the balance performance. In this test, the person had to maintain his/her balance on one (dominant) leg without engaging the level of reliance and disturbing the balance. While performing the acquisition operation with the other foot by obtaining the maximum distance in eight directions, he/she was tested and its data were recorded (15). ForcePlate was also used to evaluate balance indicators. For this purpose, participants were evaluated to assess the static balance in standing positions on two legs with open eyes, standing on two legs with closed eyes, standing on one leg with open eyes, and standing on one leg with closed eyes. The order of these modes was different for each subject and was randomly selected. The scope and velocity of the cop pressure center were examined in the anterior-posterior and internal-external directions. The subject jumped on the force-plate, in which peak vertical

Table 1. Investigating the similarity of demographic characteristics in the three control groups, biofeedback and TDCS

	Control group	Biofeedback group	TDCS group	*P*-Value
Weight (kg)	66/5± 6/03	65/7±4/6	65/5±5/41	ANOVA (0.898)
Height (cm)	174±56	173/7±8/68	171/6±4/42	ANOVA (0.665)
Body Mass Index ٢) kg/m(	22±0/92	21/7±2/42	22/2±1/1	ANOVA (0.083)
Age (years old)	20/9±1/88	22/9±2/57	22/5±1/83	Kruskal-Wallis (0.083)

Table 2. Distribution of mean statistics and p-value values for comparison of deep variables at three angles of 45, 30, and 90° before and after intervention in control groups, biofeedback, and TDCS in healthy individuals by degree

		Before intervention	After the intervention	Difference	P-Value
Proprioception 30°	Control	5/96 ± 2/18	6/78 ± 4/79	↑1/82 ± 5/34	0/433
	Biofeedback	9/2 ± 6/61	2/36 ± 0/93	↓ 8/43 ± 6/85	0/003*
	TDCS	6/72 ± 2/2	6/48 ± 5/67	↑ 0/75 ± 4/96	0/53
	P-Value	0/06	0/01	**0/001**	0/01*
Proprioception 45°	Control	8/14 ± 5/94	6 ± 3/52	↓ 2/1 ± 7/6	0/182
	Biofeedback	11/9 ± 8/17	2/17 ± 0/92	↓ 9/7 ± 8/1	0/003*
	TDCS	8/2 ± 5/29	7/55 ± 4/23	↓ 0/65 ± 5/65	0/814
	P-Value	0/388	0/001	**0/015**	0/0001*
Proprioception 90°	Control	10/3 ± 5	8/9 ± 7/14	↓ 1/43 ± 10	0/32
	Biofeedback	7/68 ± 2/89	2/29 ± 0/82	↓ 5/39 ± 2/89	0/002*
	TDCS	11/4 ± 6/76	5/1 ± 3/88	↓ 6/32 ± 4/42	0/002*
	P-Value	0/244	0/006	0/19	0/006*

ground reaction (pvgr) was measured to assess the dynamic balance. The subject was first asked to jump the maximum distance that he/she could on both feet and the tester measured this distance. Then, half of this distance was determined, from which the person jumped on the force plate with both feet (16). All tests were performed by a trained examiner (non-researcher). The interventions were performed by TDCS, biofeedback and fake biofeedback devices in the laboratory in a quiet and uniform environment for all three groups. Each group was treated for 4 weeks and three half-hour sessions each week, except that the biofeedback control group received electromyography in the recorded form (the individual received visual feedback via computer and muscle contraction did not alter signal signals). Electromyographic biofeedback means measuring electrical signals with muscle activity, preparing, and displaying these signals as visual feedback to individuals to control muscle activity, and thus, the signals were presented to the intervention group. The study used a 5-channel ProComp5 biofeedback device made by Canada's Thought Technology Company, model SA7525. The electrode was mounted on the medialis obliques Vastus muscle (VMO) diagonally at an angle of 55° above the muscle bulk and 4cm above the edge of the patella and at a distance of 3cm from the inside of the upper edge of the patella and at a distance of 20mm from each other. The reference electrode was also placed on the tibial protrusion, at which point the maximum isometric contraction of the individual was recorded in the knee extension position. In this way, the person contracted four times for four seconds and rested for ten seconds in a row, and at the end, the average of these contractions was calculated by the software. During the intervention, 20% of the average contraction was reduced to prevent muscle fatigue and was considered a threshold point, and the person received feedback when the instantaneous muscle contraction was greater than the threshold value. The TDCS was performed with an amplitude of 2mAh and a time of 20 minutes according to the International Membrane Stimulation System by the Active Tek device, a super-thermal electrical excitation device manufactured by Active Tek. Exercises were performed in three knee extension, squat, and one-legged stretches, each for 10 minutes. After the intervention, the studied variables were re-evaluated. The results of the study were analyzed using SPSS software version 22. Descriptive statistics were reported in the form of scatter indices (mean and standard deviation). Anova test was used to compare the three groups at each time of the study (and, if not normal, Kruskal Wallis test). To compare between before and after the intervention in each of the studied groups, pairwise t-test (and, if not normal, Wilcoxon test) were used and p values less than 0.05 were considered as significant levels.

Results

The results showed that the participants in the study did not have a significant difference in terms of average age, weight, height and BMI in the three groups. Also, at the beginning of the present study and before the application of training protocols, there was no difference in the values of deep sense and balance between groups (*P*>0.05) (Table 1).

The present results showed that the absolute error rate of reconstruction of the target angle at an angle of 30° between the three groups after the intervention was significantly different (*P*=0.01). It was found that in the biofeedback group, the angle of reconstruction of the target angle at 30° with an average of 61.8 10 8.10 before biofeedback intervention was changed to 93.3 36 2.36 after the intervention and the absolute error has decreased significantly (*P*=0.003). It was also found that the error of reconstruction of the target angle at a 45° angle was significantly reduced after the intervention in the biofeedback group and biofeedback has significantly improved the sense of depth at 45° compared to the other two groups (*P*=0.03). In addition, the reconstruction of the target angle at a 90° angle was determined in the absolute error rate. Both biofeedback and TDCS compared to the control group (*P*=0.002) caused a significant change in the improvement of the sense of depth (Table 2). Comparison between displacement in the eight directions of functional balance test showed that there was a significant difference between before and after the intervention in the biofeedback group in the anterior directions (*P*=0.023), external anterior (*P*=0.012), external (*P*=0.005), posterior-external (*P*=0.006). There was a significant difference between before and after the intervention in the TDCS group, in the anterior directions (*P*=0.05), posterior (*P*=0.006), internal posterior (*P*=0.023), internal (*P*=0.23), but there was no significant difference in the control group between before and after the intervention. Comparing the mean range of c.o.p displacement in the anterior-posterior, internal, and external directions, as well as the c.o.p displacement velocity in the anterior-posterior and internal-external directions, was not significant in all four cases. However, in the TDCS group, the amplitude of c.o.p displacement in the two-legged and open-eyed states (*P*=0.04) as well as the c.o.p displacement velocity in the posterior anterior direction on one leg with the open eye were significant.

Discussion

In the present study, it has been tries to investigate the effect of electromyographic biofeedback and TDCS on balance, proprioception, and performance of athletes. This study showed that the absolute error rate in knee joint reconstruction decreased after biofeedback intervention (at angles of 30, 45, 90°) and TDCS intervention (at 90°) compared to the control group. This was more noticeable in the biofeedback group, both at different angles and in the amount. This means that it has been more effective in improving the proprioception of the knee than the TDCS and the control group in intra-group biofeedback.

The results of the present study regarding the effect of biofeedback on improving the proprioception were consistent with researchers such as Chomaghchi (17) in 2016, Tassiasilveria (18) in 2016 and Ilaria (18) in 2017 on patients such as cerebral palsy, cruciate ligament rupture and Parkinson. The accuracy of the reconstruction of the angle tested in assessing the sensation of the knee joint depends on the amount of information sent from the skin, muscle, and joint receptors, that is, the proprioception. The positive results of the present study also show that visual feedback along with proprioception exercises increase the information sent from the knee receptors and improve the accuracy of proprioception even in healthy people. This is because the received visual feedback leads to the learning of precise movements by correcting the observed errors during the exercises and is consistent with the analysis of fhynny-Taek oH (2018) (19). Using visual biofeedback as well as proprioception training in patients with knee arthroscopy, the study suggested that information received through visual feedback could serve as a sensory alternative to compensate for the proprioception in damaged organs in patients (19).

Proprioception is the process by which the central nervous system receives information from the environment about the state and movement of different parts of the body on a conscious and unconscious level. Proprioception, along with the visual and vestibular sensory systems, provides the central nervous system with the information it needs to plan and design various movements. Proprioception is contracting as a sense of force or heaviness related to understanding the magnitude of muscle strength, which is usually assessed under different conditions by comparing the individual's ability to regenerate the torque produced by the muscle group (20).

The results showed that according to the functional balance was significantly higher than before the intervention in the biofeedback intervention group in the anterior, lateral, external, external, posterior, posterior, which was also true in TDCS intervention group, in the anterior, posterior, posterior, posterior, and posterior interventions while this significant difference was not found in the control group.

During the star test, both contraction of the hamstring and quadriceps muscles are necessary to maintain balance.

Ambegaonkar et al. (2014) stated that there is a significant relationship between flexor and extensor muscle strength and getting a better score in star testing in the anterior and posterior-external directions (21). Dae et al. (2018) also emphasized the improvement of Rectus femoris and biceps femoris muscle activity following the use of TDCS (22).

The quadriceps, hamstrings, abductor, and femoral adductor muscles are active as muscle stabilizers when controlling body movements to perform active access (15).

Understanding the intensity of muscular force is defined as the awareness of the produced force during muscle contraction that is continuously used by producing a constant force during the contraction of the sense of force. The possible mechanism for judging the sense of force is one related to the conscious sense of muscle strength based on the lateral discharges of motor messages to the sensory cortex. Some call this the sense of effort, and the other is the perception of voluntary force of the muscles based on environmental information about the muscle, skin, and joint receptors, called the sense of force. The sense of force or tension is an important component in the quality of motor function and can be accurately reconstructed by humans. People with sensory impairments have difficulty estimating muscle strength and weight. These results show the input information directly in providing a sense of force and calibrating the mechanism involved in the sense of effort. In most studies, the effect of TDCS on cerebral cortex application has been demonstrated on skill learning. The cerebellum is part of the motor skills learning network. In addition to the cerebellum, the network includes the primary motor area, the premotor area, and the peritoneal and basal ganglia. However, the cerebellum plays a special role in the early stages of learning due to the connection of the posterior-external hemisphere of the cerebellum with the prefrontal region (23). Biofeedback also increases the information sent from the knee receptors and in enhancing the proprioception along with visual feedback leads to the learning of precise movements by correcting the observed errors during the exercises. In the present study, it seems that the association of biofeedback and TDCS with proprioception has been able to play an important role in regulating movements using muscle control and improving functional balance in various directions in addition to increasing accuracy in sending sensory information by affecting the nervous-central and environmental systems as well as strengthening the muscles around the knee according to the training positions.

There was no significant difference between the groups in terms of balance indicators. There was a significant difference only in the intragroup TDCS study, the C.O.P. forward-backward amplitude in the two-legged standing position with the eyes open, and the C.O.P. However, it was not significant in the other cases, and this was consistent with the study of Dumant et al. in 2015 (24). Since the samples studied in this study are all athletes and healthy and had a good and normal performance in sports activities and controlling their posture, it could be a reason why the study studies present in the ten sessions failed to have significant changes in the equilibrium indicators in this statistical community. A similar study is recommended for people with balance problems and more challenging situations.

Conclusion

The use of biofeedback modality along with proprioception exercises reduced the rate of reconstruction error at angles of 30, 45, and 90° and TDCS at an angle of 90°, which also improved functional balance when using biofeedback in frontal, external, external and posterior external posterior and TDCS in anterior, external posterior, internal and internal posterior. Therefore, the use of biofeedback or TDCS with proprioception exercises is recommended to enhance proprioception and functional balance.

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