

## **COMPARATIVE EFFICACY OF BIOFEEDBACK INTERVENTIONS IN PREDICTING IMPROVEMENTS IN BILATERAL SOCCER SHOOTING PERFORMANCE**

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### **Abstract**

The beneficial impact of the differential biofeedback intervention technique on modification in autonomic competence, as well as the ultimate impact on bilateral shooting ability, were studied on young and competitive male soccer players. A total of 45 young high-performing soccer players in the age range of 18 to 24 years were recruited. At first, the players were subjected to baseline evaluation of psychomotor (i.e., reaction time – RT), physiological (viz. resting heart-rate; VO<sub>2</sub>Max, electrical muscle potentiality, etc.), and psychobiological indices (such as skin conductance components – latency, amplitude and recovery time). Thereafter, they were equally categorized into: Control Group, Experimental Group I [who received skin conductance (Sc) biofeedback training], and Experimental Group II [who received electromyography (EMG) biofeedback intervention training]. Participants of the experimental groups were subjected to their respective interventions (Sc & EMG biofeedback intervention training), which were imparted for 24 sessions (15 mins/day; 2 days/week for 12 weeks). After six weeks of intervention, mid-term evaluation of all of the aforementioned parameters (assessed during baseline evaluation) was performed. Thereafter, intervention sessions continued following the identical protocol for six weeks. At the end of the 12<sup>th</sup> week, a post-intervention assessment on all of the psychological, psychomotor and psychobiological variables was carried out on all of the participants to verify the effect of training on dependent measures. Post-intervention analyses revealed improvements in physiological, psychobiological and performance parameters, which could be rationally attributed to the differential biofeedback therapeutic interventions introduced to the experimental groups. The outcome suggested that both interventions facilitated improvement in bilateral shooting ability, while in-depth analyses clarified that a higher extent of autonomic recovery emerged as the most significant factor facilitating shooting ability in the experimental groups.

*Keywords:* Autonomic recovery, biofeedback, shooting ability

## **Introduction**

Soccer is universally accepted as the most popular spectator team sport. Kicking the ball is one of the chief inherent aspect of the game. It is perhaps perceived as a means of catharsis, or channelizing repressed frustration and aggression, which gradually might have unconsciously placed the game of soccer into an ultimate height of grandeur (Saha, Mukhopadhyay Pritha, & Chattopadhyay, & Saha Srilekha, 2005; Saha, Saha Srilekha, Mazlan, & Arriffin, 2013a; Saha et al., 2014a). A kick is the main offensive action during the game, and the team with more kicks on target recorded has a better chance to score, and consequently win a game. For this reason, improvement of the instep kick technique is one of the most important aims of training programs for young players (Weineck, 1997).

The successful kicking technique is the most significant aspect of soccer performance (Lee, 2003). Therefore, understanding of the biomechanics feature related to shooting, or kicking, a soccer ball is of utmost importance, particularly for instep soccer kicking (Katis et al., 2013). In kicking a ball, the multi-articular movements involved are characterised primarily by a proximal-to-distal motion of the segments of the lower limb of the leg in action (Kellis, Katis, & Gissis, 2007). Thus, particularly when bilateral shooting performance is taken into consideration, players need to engage in alternative instep kicking performance. When bilateral shooting activity is performed within a short time span, and from a shorter distance, the task requires a fast reaction ability. Players are supposed to kick a ball using an instep towards a wall in such a way that the ball bounces back to the player, in order to perform the bilateral shooting task. In these actions, controlled movement involving angular velocity is initiated in the thigh, and hence, estimation of net moments exerted in the hip-joint is a fundamental issue (Nunome, Asai, Ikegami, & Sakurai, 2002). Thereafter, the motion-dependent moments act upon the shank, and finally, the regulated shooting takes place by the foot (Kellis, Katis, & Vrabas, 2006).

The perceptual-motor component inherent within shooting, especially when kicking the ball consecutively using both of the feet, demands the ability of quick positioning, change of directions and alert actions (Oxyzoglou, Kanioglou, & Ore, 2009; Milanovic, Sporis, Trajkovic, James, & Samija, 2013; Sekulic, Spasic, Markova, Cavar, & Sattler, 2013). Apart from the multifaceted influence of cortical and autonomic regulations, morphological-anthropometric indices (i.e., the muscle-fibre length and size related structural factors) are also recognised as key components of excellence in shooting ability (Sekulic et al., 2013).

Apart from these structural factors, the issue of cathartic influence, such as the innate tendency of a player to channelize unresolved tension and aggression, has attracted little attention (Saha et al., 2005; Saha et al., 2012). Furthermore, apart from the incorporation of kinematic and biomechanics, and nutritional interventions, any attempts of improvement in kicking performance should also include psychobiological, viz. autonomic skin conductance activity and efficacy of psychotherapeutic self-regulation techniques used by soccer players (Lazarus, 2000; Eubank & Collins, 2000; Saha et al., 2013a; 2014a). Kellis et al. (2007) emphasized on the kinematic issues, and

more significantly, hinted upon the role of electromyography intervention in enhancing maximal isometric effort to ensure optimal shooting performance.

With such a background, the present study purports:

- To observe the effect of Sc Biofeedback training in improving bilateral shooting performance in soccer players
- To investigate the impact of electromyography biofeedback intervention on the shooting ability of soccer players
- To compare the efficacy of Sc biofeedback intervention over the EMG biofeedback intervention in improving the shooting ability in soccer players

## Methods

### *Participants:*

### *Sample Size Calculation:*

[1] -- Saturday, March 29, 2014 -- 03:06:21

**F tests** - ANOVA: Repeated measures, within-between interaction

**Analysis:** A priori: Compute required sample size

<b>Input:</b>	Effect size $f$	=	0.27
	$\alpha$ err prob	=	0.05
	Power (1- $\beta$ err prob)	=	0.95
	Number of groups	=	3
	Number of measurements	=	3
	Corr among rep measures	=	0.5
	Nonsphericity correction $\epsilon$	=	1
<b>Output:</b>	Noncentrality parameter $\lambda$	=	19.6830000
	Critical F	=	2.4803223
	Numerator df	=	4.0000000
	Denominator df	=	84.0000000
	Total sample size	=	45
	Actual power	=	0.9503179

Forty-five high performing young-adult competitive male soccer players in the age range of 18 to 24 years were recruited for this study. They were selected as consistently high performing soccer players by their respective coaches. The sample size was calculated using G power 3.1.9. The power of the study is set at 95%, with a 95% confident interval, and an effect size F of 0.27.

### **Inclusion criteria of the study:**

- 1) Soccer players having a higher-order with ball agility, and who were observed to have faster and consistent simple muscular reaction time (SRT; i.e., faster than 0.32 sec. SRT) were selected as participants. Based on the data obtained on reaction ability from young adult male and female ball game and soccer players living in and around Kota Bharu, over the period from March 2010 to February 2014, SRT scores faster than 0.32 sec would be considered fairly fast reaction times (RTs).

- 2) There was no previous exposure to any kind of biofeedback training program.
- 3) Participants who were able to adapt to the training of intervention technique within the stipulated time (i.e., within 4 sessions).

## **Materials**

- 1) Electronic Reaction Movement Timer Apparatus (Lafayette Reaction & Movement timer, USA, 2008)
- 2) Skin Conductance Apparatus (ProComp5 Infinity, USA 2014) along with electrodes
- 3) Electromyography Apparatus (Mega ME 6000, USA 2008) along with the surface EMG Ag-AgCl- Electrodes

## **Procedure**

After preliminary selection and obtaining a signed ethical consent from all of the participant players, they were subjected for baseline assessment. For this assessment, all of the 45 participants were evaluated in the laboratory of the Exercise & Sport Science Program of Universiti Sains Malaysia. The factors considered were psychomotor variables (i.e., reaction time), physiological parameters (i.e., resting heart-rate and  $\text{Vo}_2\text{Max}$ ) and psychobiological indices (i.e., phasic skin conductance components, such as latency; amplitude and recovery time). For the soccer specific evaluations, ball agility test and shooting ability tests, players were assessed in the University's soccer stadium. The reaction ability of the participants was evaluated with the help of a Lafayette Reaction & Movement timer, which consisted of two touch key-pads attached with the main processor unit. Participants were required to react to specified auditory or visual stimulus signals, either by depressing or by releasing the key of the initiator touch-pad (which denotes reaction time - RT), using the index finger of their dominant hand (Figure 1). They were also required to move the hand and the upper body (while the lower body remains stationary) towards the other touch key-pad to press the key and denote the movement time (MT). The processor unit assesses the initiation of the RT and accomplishment of the task with the MT response in the second touch key-pad. This protocol of evaluation of RT-MT was substantiated by employing assessment of anticipation and whole-body reaction ability, which could ensure that evaluation of RT-MT reveals the perceived sense of competence evident in the players. While they attempted to react to the stimulus signals, they intended to perform up to the best of their reaction potential (Saha et al., 2012).



**Figure 1:** Participant using the initiator touch-pad.

The outcome of any unprecedented performance have been observed to be associated with subjective feelings of apprehensions. Often, these apprehensions pertain to the issue of either success, or failure, and hence, we intended to analyze these feelings of competitive performance related to apprehensiveness (Saha et al., 2012). Autonomic indices of emotionality (which are aptly revealed through phasic skin Sc component indices), along with the evaluation of startling response (SF) and autonomic response latency, amplitude and recovery time, are known as capable of identifying the autonomic adaptation associated with the feelings of apprehension (Beauchaine, 2001; Dawson, Schell, & Filion, 2000). Skin conductance activity assesses autonomic indices of emotionality. Skin conductance judges emotionality in two basic ways: tonic and phasic. Tonic Sc indicates the usual level of emotionality, and phasic Sc clarifies the nature of change in emotionality with respect to different types of stimulation. In this study, phasic Sc data were decomposed as latency, amplitude and recovery time. Orienting latency is the time lapse between the onset of stimulation and the corresponding autonomic change to occur. Orienting Amplitude indicates the startling response to sudden change in emotionality, whereas orienting recovery time is the time required to recover from the heightened emotionality. Sc was evaluated using the tonic sweat gland activity, which refers to the evaluation of basal Sc, and the habituation paradigm response-specific or event-related responses were measured by employing phasic modalities (latency, amplitude and recovery from stress; Dawson, Schell, & Filion, 2007; Saha et al., 2012). The Sc composite biofeedback intervention technique is tailored to train to cope with the immense autonomic pressure, and to ensure modification into the phasic Sc modalities. Thus, incorporating rigorous methodological control, and with the application of several psychomotor and psychobiological indices, the data pertaining to reaction ability and psychobiological evaluations were extracted.

It is worthy to note that, regarding bilateral shooting performance activity, players were subjected to kick a soccer ball to a wall from a distance of 12 feet (Figure 2). As the ball bounced back, they were supposed repeat the kicking activity continuously using the opposite foot, for a 15 second duration (assessment was conducted in an indoor set-up meant for FUTSAL). The number of times the ball is kicked bilaterally using both feet was considered as their “Bilateral Shooting Performance Score”.



**Figure 2:** Participants engaged in activity for assessment of Bilateral Shooting Performance Score.

Thereafter, following the research randomizer program, they were equally and randomly categorised into three groups. The first two were Control Group (Gr. 1) participants, who didn't receive any intervention; and Experimental Group I (Gr. II) participants, who received skin conductance (Sc) biofeedback training. In this intervention, Sc surface electrodes were attached to the fingers of the subjects, and they observed their basal Sc levels and Sc changes, owing to simpler attentional and cognitive activities. Thereafter, they were supervised in monitoring their Sc changes after negative thought provoking situations (based on their previous performance video recordings). In the third group, Experimental Group II (Gr. III), individuals received electromyography (EMG) biofeedback intervention training. EMG biofeedback intervention was designed based on adaptive muscle contraction exercises, while changes in muscle potentiality was monitored and observed by the players themselves. They were guided to be able to contract and regulate their muscle activity to the desired extent. The protocol for therapeutic interventions was 15 mins/day, 2 days/week, for 12 weeks. The intervention trainings consisted of a total of 24 sessions.

Thus, after six weeks of intervention, mid-term analyses on all of the psychomotor, psychobiological and performance parameters were conducted for all of the participants to verify the effect of training onto dependent measures. Thereafter, therapeutic sessions continued for six more weeks, following a similar protocol. Finally, at the end of the 12<sup>th</sup> week, post-intervention, or final assessment, on all of the variables was conducted to verify the effect of training onto dependent measures.

The data were treated with SPSS 22.0. Descriptive analyses of data were carried out, and for analyses of mean differences, a two-way repeated measure of ANOVA was conducted. In order to ascertain predictive relationships between psychobiological and psychomotor variables, multiple linear regression analyses were also conducted.

## **Results**

Table 1 shows descriptive information and differences existent between the groups across the measurements obtained in different phases of intervention. Based on the results, the findings of the pre-intervention analyses revealed no pre-existing differences. However, at the post-intervention phase, improvements in shooting ability were observed amongst the participants of the experimental groups, hence, these alterations during the post-intervention analyses could rationally be attributed to the differential biofeedback therapy interventions introduced to the participants of the experimental groups.

**Table 1:** Mean values and differences in bilateral shooting ability observed amongst the soccer players.

Groups	Bilateral Shooting Scores (Numbers)		
	Pre-intervention	Mid-intervention	Post-intervention
Control	17	19	19
Sc Biofeedback	19	21	25
EMG Biofeedback	16	22	27
Mean Difference	-----	-----	**( $p < 0.01$ )

**Table 2:** Model *a* - Summary of multiple linear regression analysis (who received Sc biofeedback training).

Model <i>a</i>					
Dependent Variable – Bilateral Shooting ability	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
	(Constant)	-.467	.115		-4.071
Autonomic Latency	.197	.058	.268	3.401	.001***
Autonomic Recovery	-.215	.055	-.332	-3.909	.000***

<sup>a</sup>( $F(2, 14) = 6.61, P < 0.000$ ) Model Adj. $R^2 = 43.5\%$ .

**Table 3:** Model *b* - Summary of multiple linear regression analysis (who received EMG biofeedback training).

Model <i>b</i>					
Dependent Variable – Bilateral Shooting ability	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta	T	Sig.
	(Constant)	-.786	.142		-5.535
Maximal Voluntary Contraction	.432	.084	.268	5.143	.001***
Autonomic Recovery	-.351	.067	-.332	-5.239	.000***

<sup>a</sup>( $F(2, 13) = 9.24, P < 0.000$ ) Model Adj. $R^2 = 54.9\%$ .

In Table 2, the model *a* was significant, as the psychobiological measures such as latency and amplitude could explain 43.5% variance of changes in the extent of shooting ability observed in the players who received Sc biofeedback intervention training. Model *b* (Table 3), on the other hand, explained 54.9% of variances, in which the direct relationship between Maximal Voluntary Contraction (MVC) derived out of evaluation of electrical muscle potentiality and inhibitive impact of autonomic recovery on shooting ability were evident.

## **Discussion and Conclusions**

The findings obtained from Table 1 represented post-intervention differences observed amongst the participants of groups I, II & III on the bilateral shooting performance measures obtained from them, which implies that the participants of Gr. II & III (i.e., those who received differential biofeedback intervention training) were observed to be in an advantageous situation on shooting performance compared to their control condition counterparts (Gr. I).

These reports further revealed that players who received training of intervention techniques had relatively better pre-requisite extra-edges compared to the control condition players, which could either be in the form of faster autonomic adaptive qualities (Beauchaine, 2001; Saha et al., 2013a; Dawson et al., 2000); or in the form of enhanced muscle potentiality, in coordination of movement of body-segments, or any combination of these factors.

The outcome of multiple regression analyses is presented in Table 2, where model 'a' emerged as significant. This reveals that Sc biofeedback intervention was beneficial, and independent predictors such as autonomic latency and recovery time could predict 43.5% of changes in the extent of bilateral shooting performance outcomes observed in the soccer players who received Sc biofeedback. It is worthy to note the implication of this finding. From the direct relationships evident in model 'a', it could be postulated that the players who had relatively delayed autonomic latency exhibited faster, and more controlled and bilateral, shooting ability. The negative relationship between autonomic recovery and shooting performance scores implies that players who could have faster recovery from heightened autonomic arousal could display faster and better controlled shooting performance (Kellis et al., 2007; Saha Srilekha, Saha, & Chattopadhyay, 2013b). This type of explanatory relationship between psychobiological indices and shooting performance revealed that Sc composite biofeedback intervention training had helped the players in enhancing their ability to regulate heightened levels of autonomic activation successfully (Dawson et al., 2007; Saha et al., 2013a, 2013c, 2014c). Even if the players were observed as having relatively delayed latency, this was probably the reason that delay was not associated with delayed information processing caused due to neural processing irregularities. Based on the findings of Hugdahl (1995) and Dawson et al. (2000), the most probable reason behind delayed information processing could lie either in cortical irregularities in the pre-frontal cortex, or in the complex networks involving excitatory influence of amygdale and inhibitory effects from hippocampus (Dawson et al., 2007; Saha et al., 2013a, 2013c, 2014c).

The findings of model *b* (Table 3) showed that EMG biofeedback training was beneficial to the players of Group III, wherein independent predictors such as maximal voluntary control (MVC) and autonomic recovery time could predict 54.5% of changes in the extent of bilateral shooting performance outcomes. From the direct relationship evident in model 'b', it could be acknowledged that the players who had relatively higher MVC could display faster and better bilateral shooting performance. This finding regarding the facilitative relationship between MVC of the quadriceps rectus femoris muscle and bilateral shooting ability is in line with those observed by previous



researchers who focused on biomechanics and EMG activities related to soccer kicking performance (Kellis, Katis, & Gissis, 2004; McDonald, 2002; Orchard, Walt, McIntosh, & Garlick, 2002). A similar negative relationship between autonomic recovery and shooting performance scores was also evident in the case of those who received EMG biofeedback, which implied that among Group III players, those who were able to have faster recovery from heightened autonomic arousal could display faster and better controlled shooting performance (Kellis et al., 2007; Saha Srilekha et al., 2013b). In case of Group III players, efficacy of EMG biofeedback training was obvious, hence, as Manolopoulos, Papadopoulos, and Kellis (2006) highlight, the selection of the type of quadriceps muscles (in this study rectus femoris muscle was selected) for EMG biofeedback could produce a sufficient extent of MVC required for optimal performance in bilateral shooting performance.

Thus, in conclusion, based on the obtained findings, it may be concluded that both Sc and EMG biofeedback interventions had beneficial impacts on the level of bilateral shooting performance observed amongst the soccer players. Furthermore, since Sc biofeedback had a better edge over producing optimal autonomic regulation, EMG biofeedback training could facilitate better recruitment of a greater number of motor units, and a higher extent of maximal isometric effort, which had optimal beneficial impacts on bilateral shooting performance.

The outcome suggested that both of the interventions facilitated in improvements in bilateral shooting ability, which were mediated by differential physiological and psychobiological processes.

- Both of the interventions were observed as beneficial for improvement in soccer shooting performance.
- Sc biofeedback training was observed in improving bilateral shooting performance in soccer players, which was mediated by faster autonomic recovery.
- EMG biofeedback training evidently improved bilateral shooting performance, which was mediated by larger amplitude, as well as faster, autonomic recovery.

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