International Journal of Health, Physical Education and Computer Science in Sports
ISSN 2231-3265
Volume 40; Issue 1
ISRA Journal Impact Factor 7.217
A Peer Reviewed (Refereed) International Research Journal

Research Article

The effect of HRVB training on young soccer players' skill performance

Sara Majlesi[1], Lim Boon Hooi[1], Pooya Nekooei[2], Kamran Hosseinzadeh Ghasemabad[2], Behzad Alemi[2], Paria Nekouei[3]

[1]Centre for Sport and Exercise Sciences, University of Malaya, Kuala Lumpur, Malaysia, [2]Department of Physical Education and Sport Sciences, Faculty of Educational Studies, UPM University, Serdang, Selangor, Malaysia, [3]Department of Sport and Health, University of Paderborn, Paderborn, Germany

Received: 22-11-2020 **Acceptance:** 23-11-2020

ABSTRACT

The present study aimed to evaluate the influence of heart rate variability biofeedback (HRVB) training on selected soccer skills performance. The objective of this study was to evaluate the effect of HRVB on soccer players' reactive motor skill test (RMST), sprint time, reactive agility, passing time, and passing accuracy. Participants of this study were Malaysian high school soccer players (n = 32), with mean age of 15.21 ± 1.85, who were assigned randomly into two groups: Experimental groups and control group. Each group had 16 players who were assigned randomly through the fishbowl method. A pre-test and post-test design was used in this study to evaluate the effect of training on the players' skill performance. The experimental group received HRVB training for 8 weeks in addition to their regular soccer training, while the control group only attended their regular soccer training. The experiments developed in this study consisted of a 10-min breathing exercise using the Elite HRVB app to feedback players' breathing to 5.5–6 BPM resonant breathing. After the 8 weeks of training were completed, the RMST was administered to all participants to measure the changes in their RMST, sprint time, reactive agility, passing time, and passing accuracy. The data were analyzed with a factorial MANOVA test to evaluate the differences within and between groups. Research questions of the study were supported, and statistically significant effects of experimental training on players' performance were demonstrated. The multivariate results were statistically significant differences between and within groups, $F(5, 26) = 60.665$, $P \leq 0.001$, Wilks' $\Lambda = 0.079$. Furthermore, the univariate interaction effects result showed that all the dependent variables have statistically significant differences individually between experimental and control group as well as within experimental group. There was a statistically significant interaction effect between tests and type of intervention for RMST, $F(1, 30) = 119.692$, $P = 0.001$, sprint time, $F(1, 30) = 47.686$, $P = 0.001$, reactive agility, $F(1, 30) = 218.332$, $P = 0.001$, passing time, $F(1.30) = 42.354$, $P = 0.001$, and passing accuracy, $F(1, 30) = 21.544$, $P = 0.001$. The pre-test-post-test results showed that RMST, sprint time, reactive agility, passing time, and passing accuracy were statistically difference within experimental group. The findings of this study provide evidence that 8 weeks of HRVB training significantly improved soccer players' RMST, sprint time, reactive agility, passing time, and passing accuracy test results.

Keywords: Heart rate variability biofeedback, Soccer skills

INTRODUCTION

HRV is the most important marker of the autonomic nervous system (ANS) and also is a noninvasive way to identify ANS imbalances. HRV dynamics are sensitive to changes in one's physiological and emotional state as positive and negative emotions are distinguished by smooth or erratic heart rhythm patterns, respectively, (McCraty and Tomasino, 2004). It has been studied as an important marker of autonomic nervous system (ANS) modulation (Achten and Jeukendrup, 2003; Park *et al*., 2007; Sandercock, 2007). The ANS comprises two finely balanced opposing systems: The sympathetic nervous system (SNS), associated with the "fight or flight" response, and the parasympathetic nervous system (PNS), associated with rest and digestive activity (Lane *et al*., 2009; Thayer and Brosschot, 2005). Efficient functioning in a complex environment requires a dynamic interplay between SNS and PNS, and this interplay requires adequate prefrontal cortex (PFC) functioning, which

Address for correspondence:
Lim Boon Hooi,
E-mail: lboonhooi62@gmail.com

is thought to be involved in the inhibition of SNS activation (Friedman, 2007; Thayer and Lane, 2009). Attenuated SNS and increased PNS influence are associated with a high HRV, particularly the high-frequency component (HF), and are associated with higher PFC activity (Lane *et al*., 2009). Associations between ANS and PFC activity, using HRV and cognitive performance, have previously been reported by some researchers (Hansen *et al*., 2009; Thayer and Brosschot, 2005).

If an athlete's ANS system is in fight-or-flight mode, the variation between heart beats is low and if an athlete is in a more relaxed state, the variation between their heart beats is high. In fact, the healthier the ANS, the faster athletes are able to switch gears to show more resilience and reaction. A previous researches have shown a strong relationship between low HRV and poor reactive agility and attention (Drozd *et al*., 2010; Sutarto *et al*., 2010). Athletes who have a high HRV, have better cardiovascular fitness and are more resilient and flexible when facing stress (Drozd *et al*., 2010; Sutarto *et al*., 2010). HRV provides personal feedback about athletes' lifestyle and helps to motivate those who are considering taking steps to have a healthier life.

HRV is literally the variance in time between the beats of the heart. Hence, if an athlete's heart rate is 60 beats/min, it is not actually beating once every second. Within that minute there may be 0.9 s between two beats and, for example, 1.15 s between two others. The greater heart rate variability is a sign that an athlete's body is ready to execute at a high level of performance (Sutarto *et al*., 2010). Therefore, if an athlete's body be under stressed, then there is very little variability in their beat-to-beat heart rate but if their body is relaxed and aerobically fit and healthy, and then they will get a lot of variability from their heart rate. In other words, the heart's ability to vary the duration of time between beats is symptomatic of its ability to reflect changes in the rest of the athletes' body. When athletes begin using a heart rate variability monitor, they notice that their HRV varies greatly from day to day. Rather than comparing athletes' HRV to others, a more practical use of HRV is to follow their own trends. For example, if they are taking steps to improve their HRV, over time they should see a gradual increase in their average heart rate variability.

Sports match analyses have shown that more soccer goals are scored towards the end of a game (Nekooei *et al*., 2019; Pooya *et al*., 2016; Reilly and Gilbourne, 2003; Reilly and Thomas, 1976; Reilly and Williams, 2003). This is largely due to the detrimental effects of fatigue, which cause a decrease in HRV which is highly associated with playing errors, and also a debilitating effect from "mental fatigue" leading to lapses in concentration, associated with poor decision making and reactive agility (Reilly and Gilbourne, 2003; Reilly and Thomas, 1976; Reilly and Williams, 2003). Players have to decide quickly to pass, shoot, and change direction in a short time. Good reactive agility to pass, shoot, and change direction can help players decrease their playing errors. In addition to their physical ability and physical training, the soccer players' ANS plays an effective role. HRV biofeedback training (HRVB) with an effect on ANS response may help players improve their reactive agility and skill performance.

Biofeedback modalities are created to help athletes modulate their autonomic responses such as HRV, skin temperature, blood pressure, brain activity, and muscle contraction (Perry *et al*., 2011). HRV training with biofeedback devices (HRVB) are associated with improving sports performance with effects on ANS (Björkstrand and Jern, 2013; Hedelin *et al*., 2001). Therefore, it may help soccer players to reach autonomic modulation, which leads to performance improvements. Soccer players' skill performance and reactive agility may improve as a result of physiological balance in their ANS. Furthermore, concurrent training of HRVB and PETTLEP video imagery (mind and heart connection) can be a good invention to achieve better reactive agility and skill improvement in the game.

In biofeedback training, the clinician assists the client in identifying incoherent, or unhealthy biological responses, and implements adaptive practices such as paced breathing, positive self-talk, and emotional regulation (McCraty *et al*., 2001). The goal of biofeedback training is to develop strategies to gain voluntary control, or self-regulation of biological responses, and to transfer this ability to everyday situations without any instrumentation (Blumenstein *et al*., 2002). Biofeedback training conducted with athletes has demonstrated a variety of results, including the enhancement of self-control, the prevention, and treatment of overtraining and athletic injuries, the reduction of competition anxiety, and the encouragement of perceived control (Sime, 2003). As a mental skills training technique, an improvement in performance is the result of many biofeedback treatment interventions (Sime, 2003; Werthner *et al*., 2013).

Study literatures showed that biofeedback training is advantageous in reducing anxiety in athletes. However, increasing self-confidence should be the primary focus of biofeedback training, as this ultimately enhances performance (Davis and Sime, 2005). One of the most common techniques for self-regulation is HRV biofeedback training (HRVB). Heart rate variability (HRV) refers to an organism's ability to continuously adapt the interval between heartbeats to situational requirements (Aubert *et al*., 2003). Physical strain or mental stress results in a quickening of the heart rate, which falls again during relaxation and recovery. HRV can be a good sign of health status, stress tolerance, resilience, and biological age. Restricted heart rate variability is a sign of liable health, burnout, depressiveness, and a biological age that is higher than the actual age (Drozd *et al*., 2010). Biofeedback is used to assist one in developing an awareness of internal physiological processes that are not consciously controlled (Perry *et al*., 2011). Through a variety of feedback modalities, heart rhythm variability is considered as a good indicator of the client's psychological state and physiological response (Sutarto *et al*., 2010).

The scientific study of the variability in heart rate is fairly recent, and only in the past 10 years did it become possible to train human beings to change the variability in heart rhythms. Biofeedback practitioners have found that HRVB training can increase HRV through several parallel training pathways. The practitioner initially guides the subject to acquire three basic skills: (1) Relax physically and emotionally, (2) reduce anxious thoughts and negative emotions, and (3) engage in smooth full diaphragmatic breathing. Although researchers contend that HRVB training are effective means of enhancing performance (Hedelin *et al*., 2001), there has not been a clear consensus among them due to the limitations of psychological treatment precluded, and still, there is a disagreement among researchers as to whether HRVB training can be effective in improving players' skill performance. Thus, the present study attempted to determine whether HRVB training improves young soccer players' skill performance in terms of reactive motor skill, reactive agility, sprint time, passing time, and passing accuracy.

METHODS

Participants

The participants of the study were 32 young male Malaysian high school soccer players (age mean: 15.21 ± 1.85) from an international school, who played in the school team at the time of the study. They were assigned randomly into two groups, with 16 participants in each group, using the Fishbowl technique. The participants had minimum 2 years of experience in playing soccer at the school level. They did not have any health and psychological issues and participated in the school's soccer training three sessions a week for approximately 2 h per session. All participants and their guardians were informed about the test procedure, and consent letters were provided for all participants before conducting the study.

Equipment and Measurements

The equipment and material used in this study included reactive motor skills test (RMST) designed to test the players' passing time, passing accuracy, speed, and reactive agility. Elite HRV application (version 4.7) validated by Perrotta *et al*. (2017), Polar H7 heart rate sensor validated by Electro (2016), timing gates (Brower Timing System Speed Trap Ii) validated by Shalfawi *et al*. (2010), soccer balls (Adidas Brazuca size 5), headphones (Original Beats EP on-ear headphone), NEC projectors, and an Apple iPad. A soccer field and futsal court were also used for practice and experimental measurements. The equipment was internationally standard and calibrated before the intended testing according to the manufacturers' standardized procedures.

Data Collection

This study examined the effects of HRV biofeedback training on soccer players' skill performance. After gaining permission from the high school authorities to conduct the study using their facilities, and before the pre-test, the researcher explained the importance of this research, different training objectives, training length and procedure, of the RMST to the participants. On the 1st day, all participants were gathered in a sports hall and tested after doing specific soccer warm-up compiled by the researcher.

RMST was performed to test the players' sprint, passing time, passing accuracy, and reactive agility at the pretest. Each participant was performed the test for three times with 10 min rest between, the best timing was recorded for each participant for analysis. They were instructed to complete the test quickly and accurately. The performance outcome was assessed through the time spent on each section (sprint, passing, and reactive agility) and also the total timing of the RMST. After the pre-test, the participants were assigned to two groups and the HRV biofeedback training was implemented before players' usual soccer practice for 8 weeks in the experimental group twice a week. All players had their usual soccer practice after school three times a week.

In the first training session, the researcher explained HRV, HRVB training, and why HRVB training might help the players improve their performance through a PowerPoint presentation. The participants were instructed about their first session of HRVB training with the Elite HRV app, installed on iPads. Then, before their usual soccer practice, they had a session of HRVB training twice a week using the Elite HRV app connected to a polar belt (model: H7) to capture accurate R-R interval with Elite HRV. The training involved 10 min of breathing exercise using Elite HRV as it showed a blue and green circle to feedback players' breathing by decreasing and increasing the size and using audio feedback according to 5.5-6 BPM resonant breathing exercises. The training duration was calculated based on the literature (Lehrer *et al*., 1997; Lehrer *et al*., 2000; Moss, 2004). After HRVB training, players were sent to have their usual soccer training on the field. Participants in the control group had their usual soccer training organized and supervised by their school soccer coach and researcher. In the post-test phase of the study, the researcher implemented the exact procedure of the pre-test evaluation with the participants who had participated in all training sessions. Finally, the collected data during pre-test and post-test phases of the study were analyzed to determine the effectiveness of the HRVB training on the participants' performance of selected soccer skills.

RESULTS

Descriptive Statistics

Before the inferential analysis of the data, the descriptive statistics including normality test, homogeneity of variance test, and equality of groups at pre-test, were computed using exploratory data analysis. This analysis aimed to test the normal distribution of the variables and homogeneity of variance between groups before conducting inferential analyses. Then, inferential analysis of the data including paired and independent samples *t*-test was conducted to answer the research questions of this study [Table 1].

A normality test was run to evaluate the normal distribution of players in groups. To this end, the Shapiro–Wilk test was interpreted. As it is shown in Table 2, the assumption of normality for all dependent variables was satisfied for both groups, as assessed by Shapiro-Wilk's test ($P > 0.05$).

Homogeneity of Variables

The Levene's test was used for determining equality of variance in the groups. It tests whether the variances of two samples are approximately equal, so it tests our assumption of homogeneity of variance. As it is shown in Table 3, the groups' variances are not significantly different, so equal variances are assumed, and in this case, the probability is even >0.01. The assumption of homogeneity of variance has been met for both groups at pre-test.

Table 1: Descriptive analysis of dependent variables

	Group H		Group C	
	Mean	SD	Mean	SD
RMST time pre-test	7.71	0.17	7.75	0.17
RMST time post-test	6.94	0.28	7.67	0.18
Sprint time pre-test	1.36	0.03	1.37	0.04
Sprint time post-test	1.26	0.03	1.35	0.06
Reactive agility pre-test	1.92	0.11	1.94	0.08
Reactive agility post-test	1.67	0.11	1.93	0.09
Passing time pre-test	4.44	0.03	4.44	0.04
Passing time post-test	4	0.24	4.4	0.05
Passing accuracy pre-test	4.13	1.12	4.16	1.21
Passing accuracy post-test	5.44	1.03	4.25	1.39

Table 2: Shapiro–Wilk's normality test

Group	Group H		Group C	
	Statistic	*P* value	Statistic	*P* value
RMST time pre	0.979	0.957	0.974	0.892
RMST time post	0.972	0.863	0.951	0.511
Sprint time pre	0.895	0.067	0.953	0.539
Sprint time post	0.951	0.505	0.973	0.885
Reactive agility pre	0.97	0.837	0.964	0.726
Reactive agility post	0.892	0.06	0.946	0.435
Passing time pre	0.954	0.562	0.945	0.414
Passing time post	0.956	0.59	0.947	0.446
Passing accuracy pre	0.915	0.142	0.923	0.191
Passing accuracy post	0.859	0.019	0.819	0.005

Inferential Analysis

A factorial MANOVA was conducted. Due to having a repeated-measures variable that has only two levels, the sphericity assumption is met in this study. As presented in Table 4, the results of the multivariate test show that there were statistically significant differences between and within groups and also there was a statistically significant interaction effect between tests and groups of intervention, $F(5, 26) = 60.665$, $P \leq 0.001$, Wilks' $\Lambda = 0.079$.

As the univariate interaction effects in Nekooei, 2019. Show all the dependent variables have statistically significant differences individually between and within groups. There was a statistically significant interaction effect between tests and type of intervention for total time score, $F(1, 30) = 119.692$, $P = 0.001$, sprint time, $F(1, 30) = 47.686$, $P = 0.001$, Reactive Agility, $F(1, 30) = 218.332$, $P = 0.001$, passing time, $F(1.30) = 42.354$, $P = 0.001$, and passing accuracy, $F(1,30) = 21.544$, $P = 0.001$ [Table 5].

Effect of HRVB Training on Soccer Skill Performance

As presented in Table 6, the results of within-group comparison in all reactive agility skill parameters showed statistically significant differences. According to Table 6, the players' total time value is MD = 0.771, $P < 0.001$, sprint time MD = 0.091, $P < 0.001$, reactive agility time MD = 0.244, $P < 0.001$, passing time MD = 0.436, $P < 0.001$, and passing accuracy MD = 0.186, $P < 0.001$ for group HRVB that shows there was a statistically significant difference between pre-test and post-test in all of the RMST parameters including total time in the experimental group, while the value for control group was total time value is MD = 0074, $P < 0.109$, sprint time MD = 0.013, $P < 0.111$, reactive agility time MD = 0.014, $P < 0.221$, passing time MD = 0.047, $P < 0.277$, and passing accuracy MD = 0.094, $P < 0.617$, which was not statistically significant. The mean of HRVB group at pre- and post-test shows that the players' reactive motor skill performance in all of the parameters including total time were improved after 8 weeks of experimental training in the treatment group.

Table 3: Test of homogeneity of variances

Test of homogeneity of variances		
	Levene's statistic	*P* value
RMST time	1.505	0.222
Sprint time	2.308	0.086
Reactive agility	1.752	0.155
Passing time	2.318	0.085
Passing accuracy	0.174	0.913

Table 4: Multivariate test

Effect		Value	F	df	Error df	Sig.
Between subjects						
Intercept	Wilks' Lambda	0.000	32223.549b	5.000	26.000	0.000
Group	Wilks' Lambda	0.098	48.059b	5.000	26.000	0.000
Within subjects						
Tests	Wilks' Lambda	0.059	82.560b	5.000	26.000	0.000
Tests*Group	Wilks' Lambda	0.079	60.665b	5.000	26.000	0.000

Table 5: Univariate tests

Source	Type III sum of squares	df	Mean square	F	Sig.
Tests					
Total time	2.860	1	2.860	176.243	0.000
Sprint time	0.044	1	0.044	85.114	0.000
Reactive agility time	0.265	1	0.265	273.663	0.000
Passing time	0.934	1	0.934	65.204	0.000
Passing accuracy	7.910	1	7.910	28.683	0.000
Tests * Group					
Total time	1.943	1	1.943	119.692	0.000
Sprint time	0.024	1	0.024	47.686	0.000
Reactive agility time	0.212	1	0.212	218.332	0.000
Passing time	0.606	1	0.606	42.354	0.000
Passing accuracy	5.941	1	5.941	21.544	0.000
Error (tests)					
Total time	0.487	30	0.016		
Sprint time	0.015	30	0.001		
Reactive agility time	0.029	30	0.001		
Passing time	0.430	30	0.014		
Passing accuracy	8.273	30	0.276		

Furthermore, as shown in Table 7, a comparison between groups shows that there is a statistically significant difference between groups in all four component of reactive motor skill performance including total time after 8 weeks of experimental training. As it showed in Table 7, there were no any significant differences between groups in the pretest. The posttest value for group H versus Group C of the players' total time was MD = −0.738, $P < 0.001$, sprint time MD = −0.89, $P < 0.001$, reactive agility time MD = −0.254, $P < 0.001$, passing time MD = −0.398, $P < 0.001$, and passing accuracy MD = 1.188, $P < 0.01$. Hence, there was a statistically significant difference between the experimental group and the control group after 8 weeks HRVB training. This suggests that HRVB training had a significant effect on players' reactive motor skill component including total time.

The results presented above show that there were significant differences in all of the RMST component scores within and between groups, suggesting that HRVB intervention was positively effective on soccer players skill performance within the treatment group and also between the treatment and control groups.

DISCUSSION

This study examined the effect of HRVB training on soccer players' skill performance using RMST that measured sprint time, reactive agility, passing time, and passing accuracy. The research results showed that RMST component time including total time significantly improved within the experimental group after 8 weeks of HRVB training. Therefore, reactive agility time, sprint time, passing time, and passing accuracy improved in the experimental group, and these improvements affected total RMST time positively. The findings of this study are in line with the evidence from the previous research that shows HRVB training can improve sprint, passing time, passing accuracy, and reactive agility (Grillo *et al*., 2020; Kiviniemi

Table 6: Reactive motor skill within group comparisons

Pairwise comparisons within group							
Measure			**Mean difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence interval for difference[b]**	
						Lower bound	**Upper bound**
Total time							
HRVB	Pre	Post	.771*	0.045	0.000	0.679	0.863
Control	Pre	Post	0.074	0.045	0.109	-0.018	0.166
Sprint time							
HRVB	Pre	Post	.091*	0.008	0.000	0.075	0.108
Control	Pre	Post	0.013	0.008	0.111	-0.003	0.029
Reactive agility time							
HRVB	Pre	Post	.244*	0.011	0.000	0.221	0.266
Control	Pre	Post	0.014	0.011	0.221	-0.009	0.036
Passing time							
HRVB	Pre	Post	.436*	0.042	0.000	0.350	0.523
Control	Pre	Post	0.047	0.042	0.277	-0.040	0.133
Passing accuracy							
HRVB	Pre	Post	-1.313*	0.186	0.000	-1.692	-0.933
Control	Pre	Post	-0.094	0.186	0.617	-0.473	0.285

Table 7: Reactive motor skill between group comparisons

Pairwise comparisons between group							
Measure			**Mean difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence interval for difference[b]**	
						Lower bound	**Upper bound**
Total time							
Pre-test	HR	Control	−0.041	0.060	0.499	−0.164	0.082
Post-test	HR	Control	−0.738*	0.083	0.000	−0.907	−0.569
Sprint time							
Pre-test	HR	Control	−0.011	0.013	0.429	−0.038	0.016
Post-test	HR	Control	−0.089*	0.017	0.000	−0.123	−0.055
Reactive agility time							
Pre-test	HR	Control	−0.024	0.035	0.501	−0.095	0.047
Post-test	HR	Control	−0.254*	0.034	0.000	−0.324	−0.184
Passing time							
Pre-test	HR	Control	−0.009	0.013	0.517	−0.036	0.019
Post-test	HR	Control	−0.398*	0.061	0.000	−0.523	−0.273
Passing accuracy							
Pre-test	HR	Control	−0.031	0.411	0.940	−0.871	0.809
Post-test	HR	Control	1.188*	0.433	0.010	0.304	2.071

et al., 2007; Saha *et al*., 2013). This study confirmed the finding that improvement in each skill of the RMST will lead to an overall improvement in RMST (Bullock *et al*., 2012).

The results of this study showed significant sprint time improvement in HRVB group. It means that HRVB intervention improved players' sprint after 8 weeks, so it is an effective training method to be used by the coaches to improve soccer players' sprint time. In a study by Kiviniemi *et al*. (2007), 30 club runners were divided into three groups, one group was given a coach-designed training program, one group served as the control, and the third one had their training intensity guided by daily HRV readings. Although both coached and HRV groups showed improvements in maximum running speed (and speed at aerobic threshold), the improvements were significantly larger in the HRV group, which was also the only group to show an increase in VO2 peak. The findings of the present study support the findings of the above-mentioned research related to sprint time improvement. In addition, Oliveira *et al*. (2013) investigated the changes in physical performance in high-level futsal players and showed significant improvement in players' speed after they received HRVB training. Furthermore, Benítez-Flores *et al*. (2019) reported that HRVB training had a significant effect on sprint time. Although the findings of the present study show less speed improvement compared to other skills, they still support previous research findings on HRVB training and speed improvement. The results of the current study, which showed improvement in players' sprint after HRVB training, are in line with the findings of (Benítez-Flores *et al*., 2019; Kiviniemi *et al*., 2007; Oliveira *et al*., 2013). However, most of the previous researchers emphasized the need for further research on HRVB training regarding its impact on athletic performance (Goessl *et al*., 2017).

This study also investigated the effects of HRVB intervention on reactive agility and whether reacting to unpredictable stimuli could be improved using this intervention. The results showed significant improvements in players' reactive agility as a result of HRVB training in the experimental group of the study. The HRVB group showed significant improvements in players' reactive agility after receiving HRVB training for 8 weeks. HRVB training can reduce stress which may result in better decision making and reactive agility during the competition (Goessl *et al*., 2017). Therefore, it can be recommended for soccer players and athletes to use HRVB training along with their physical practice. One goal of this study was to apply HRVB training using Elite HRV application to improve players' reactive agility as the past researchers did not examine the effects of HRVB on soccer players' reactive agility. In fact, the current study reports new findings about the effect of HRVB training on soccer players' reactive agility. However, some previous studies on HRVB training and reactive agility in other sports are supported by the findings of this study (Goessl *et al*., 2017; Iftikhar *et al*., 2018; McNeil *et al*., 2019).

The Heart Math Institute's research has shown that HRVB training helps athletes reach the state of coherence and generating sustained positive emotions facilitates a body-wide shift to a specific, scientifically measurable state (Edwards *et al*., 2015). This state is termed psychophysiological coherence because it is characterized by increased order and harmony in both our psychological (mental and emotional) and physiological (bodily) processes. Psychophysiological coherence is the state of optimal functioning. Research shows that when we activate this state, our physiological systems function more efficiently, we experience greater emotional stability, and we also have increased reaction, mental clarity and improved cognitive function. Physiologically, the coherence state is marked by the development of a smooth, sine-wave-like pattern in the heart rate variability trace. This characteristic pattern of heart rhythm coherence is what the Elite HRV application measures and quantifies and is an indicator of psychophysiological coherence and important physiological changes occur in this state of coherence. It also shows that a number of important physiological changes occur during coherence. The two branches of the ANS synchronize with one another, and there is an overall shift in autonomic balance toward increased parasympathetic activity. There is also increased physiological entrainment as a number of different bodily systems are synchronized to the rhythm generated by the heart. Finally, there is increased synchronization between the activity of the heart and brain (Edwards *et al*., 2015). Therefore, athletes' heart and brain are synchronized as a result of HRVB training, which increases their coherence before receiving other types of training.

The findings of this study also showed that HRVB training improved the players' passing accuracy and passing time in the experimental group. This finding is in accord with the findings of the previous studies that revealed significant improvements in athletes' passing performance and accuracy after receiving HRVB training. The previous research findings on HRVB training showed increase in players' concentration, thus better concentration helps players enhance their passing time and passing accuracy in the game (Kiss *et al*., 2016). The goal of HRVB training is for athletes to gain control and awareness over their breathing during the training and they should be able to apply this knowledge without using any application or device after the training. The findings of the present study support some studies which have investigated the effect of HRVB training on athletes' performance. In fact, considerable evidence links the findings of this study regarding HRVB training and performance improvements to the findings of previous studies. A study conducted by Saha *et al*. (2013) examined the effect of different biofeedback training on soccer skill performance. The findings showed significant improvement in soccer juggling and passing performance in the heart rate biofeedback training group. Moreover, Morgan and Mora (2017) published a review of the studies on the effect of heart rate variability biofeedback training (HRVB) on sports performance. They reported that all previous studies had small sample sizes. In almost 85% of the studies, even with six participants, HRVB training helped athletes to improve their psychophysiological variables. Therefore, 16 participants were recruited in the current study to fill the research gap. However, this review concluded that despite the limited amount of experimental studies, HRVB is an effective, easy-to-learn, easy-to-apply, and safe method for both coaches and athletes to improve sport performance (Morgan and Mora, 2017).

CONCLUSION

The findings of the current study show that 8 weeks of HRVB training had a significant within- and between-group effect on the soccer players' RMST, passing time, passing accuracy, and reactive agility. The use of biofeedback devices in sport is limited because they are not easy to use and most of modalities need an expert to run the training or test. The other reason is that most of the biofeedback devices are expensive and not easy to carry everywhere. This study used Elite HRV biofeedback application which is easy to install on the computer or smartphone and there is no need to run the test by an expert. The application is connectable to Polar belt H7 to receive a reliable and valid heartbeat. Coaches and athletes can benefit from this application which is very convenient to use with a reasonable price. After HRVB training athletes learn how to gain control over their heartbeat by following the application's breathing feedback which helps the athlete to become ready to receive other types of training. HRVB training has been reported to lead to stress reduction and improvement in players' decision-making skill which leads to performance improvement, but this improvement may vary depending on the skill and sport.

This study proved the effectiveness of 8 weeks of HRVB training on young soccer players' skill performance. However, more longitudinal studies of physiological and psychological aspects of athletes' performance are needed to inform future interventions about the most effective constructs on which to focus for each level of performance. It is also recommended to conduct interventional studies with higher number of elite players to extend the findings of longitudinal studies and provide a deeper understanding of the psychological effects of training on athletes' performance. Finally, regarding the findings of this study, coaches and players are encouraged to include HRVB training in their training protocols to further improve athletic performance in different fields of sport.

REFERENCES

Achten J, Jeukendrup AE. Heart rate monitoring. Sports Med 2003;33:517-38.

Aubert AE, Seps B, Beckers F. Heart rate variability in athletes. Sports Med 2003;33:889-919.

Benítez-Flores S, Medeiros AR, Voltarelli FA, Iglesias-Soler E, Doma K, Simões HG, *et al*. Combined effects of very short "all out" efforts during sprint and resistance training on physical and physiological adaptations after 2 weeks of training. Eur J Appl Physiol 2019;119:1337-51.

Björkstrand S, Jern P. Evaluation of an imagery intervention to improve penalty taking ability in soccer: A study of two junior girls teams. Nordic Psychol 2013;65:290-305.

Blumenstein B, Bar-Eli M, Tenenbaum G. Brain and Body in Sport and Exercise: Biofeedback Applications in Performance Enhancement. United States: John Wiley & Sons; 2002.

Bullock W, Panchuk D, Broatch J, Christian R, Stepto NK. An integrative test of agility, speed and skill in soccer: Effects of exercise. J Sci Med Sport 2012;15:431-6.

Davis PA, Sime WE. Toward a psychophysiology of performance: Sport psychology principles dealing with anxiety. Int J Stress Manage 2005;12:363.

Drozd BL, Bates ME, Vaschillo EG, Vaschillo B, Lehrer PM. Heart rate variability biofeedback with collegiate student athletes. Appl Psychophysiol Biofeedback 2010;35:330.

Edwards DJ, Edwards SD, Buscombe RM, Beale JT, Wilson M. Effect of HeartMath workshop on physiological coherence, sense of coherence, zone, mood and resilience perceptions:: Health. Afr J Phys Health Educ Recreat Dance 2015;21:891-901.

Friedman BH. An autonomic flexibility-neurovisceral integration model of anxiety and cardiac vagal tone. Biol Psychol 2007;74:185-99.

Goessl VC, Curtiss JE, Hofmann SG. The effect of heart rate variability biofeedback training on stress and anxiety: A meta-analysis. Psychol Med 2017;47:2578-86.

Grillo A, Rogers A, Perry T. Association of Heart Rate Variability with Perceptual-motor Measures Among ROTC Cadets. ReSEARCH Dialogues Conference Proceedings; 2020. Available from: https://www.scholar.utc.edu/research-dialogues/2020/day2_posters/104.

Hansen AL, Johnsen BH, Thayer JF. Relationship between heart rate variability and cognitive function during threat of shock. Anxiety Stress Coping 2009;22:77-89.

Hedelin R, Bjerle P, Henriksson-Larsen K. Heart rate variability in athletes: Relationship with central and peripheral performance. Med Sci Sports Exerc 2001;33:1394-8.

Iftikhar MT, Mallett CJ, Javed MA. Imagery Improves Reaction Time in Elite Sprinters, 6th International Congress on Sport Sciences Research and Technology Support. Berlin, Germany: Springer; 2018.

Kiss O, Sydo N, Vargha P, Vago H, Czimbalmos C, Edes E, *et al*. Detailed heart rate variability analysis in athletes. Clin Auton Res 2016;26:245-52.

Kiviniemi AM, Hautala AJ, Kinnunen H, Tulppo MP. Endurance training guided individually by daily heart rate variability measurements. Eur J Appl Physiol 2007;101:743-51.

Lane R, McRae K, Reiman E, Chen K, Ahern G, Thayer J. Neural correlates of heart rate variability during emotion. Neuroimage 2009;44:213-22.

Lehrer P, Carr RE, Smetankine A, Vaschillo E, Peper E, Porges S, *et al*. Respiratory sinus arrhythmia versus neck/trapezius EMG and incentive inspirometry biofeedback for asthma: A pilot study. Appl Psychophysiol Biofeedback 1997;22:95-109.

Lehrer PM, Vaschillo E, Vaschillo B. Resonant frequency biofeedback training to increase cardiac variability: Rationale and manual for training. Appl Psychophysiol Biofeedback 2000;25:177-91.

McCraty R, Atkinson M, Tomasino D, Stuppy WP. Analysis of twenty-four hour heart rate variability in patients with panic disorder. Biol Psychol 2001;56:131-50.

McCraty R, Tomasino D. Heart Rhythm Coherence Feedback: A New Tool for Stress Reduction, Rehabilitation, and Performance Enhancement. Tamil Nadu: Proceedings of the First Baltic Forum on Neuronal Regulation and Biofeedback, Research Library Publication; 2004.

McNeil DG, Spittle M, Mesagno C. Imagery training for reactive agility: Performance improvements for decision time but not overall reactive agility. Int J Sport Exerc Psychol 2019;2019:1-17.

Morgan SJ, Mora JA. Effect of heart rate variability biofeedback on sport performance, a systematic review. Appl Psychophysiol Biofeedback 2017;42:235-45.

Moss D. Heart rate variability (HRV) biofeedback. Psychophysiol Today 2004;1:4-11.

Nekooei P, Tengku-Fadilah T, Amri S, Baki RB, Majlesi S, Nekouei PJ, *et al*. Anatomical shoulder movement strength imbalance among Water Polo Overhead Athletes Int J Kinesiol Sports Sci 2019;7:15-20.

Oliveira RS, Leicht AS, Bishop D, Barbero-Alvarez JC, Nakamura FY. Seasonal changes in physical performance and heart rate variability in high level futsal players. Int J Sports Med 2013;34:424-30.

Park SB, Lee BC, Jeong KS. Standardized tests of heart rate variability for autonomic function tests in healthy Koreans. Int J Neurosci 2007;117:1707-17.

Perrotta AS, Jeklin AT, Hives BA, Meanwell LE, Warburton DE. Validity of the elite HRV smartphone application for examining heart rate variability in a field-based setting. J Strength Cond Res 2017;31:2296-302.

Perry FD, Shaw L, Zaichkowsky L. Biofeedback and neurofeedback in sports. Biofeedback 2011;39:95-100.

Pooya N, Sara M, Gholamreza S, Tengku F, Paria NJ. Comparison of anthropometric parameters among Iranian and Spanish water polo players. Russian Open Med J 2016;5:e0204.

Reilly T, Gilbourne D. Science and football: A review of applied research in the football codes. J Sports Sci 2003;21:693-705.

Reilly T, Thomas V. A motion analysis of work-rate in different positional roles in professional football match-play. J Hum Mov Stud 1976;2:87-97.

Reilly T, Williams AM. Science and Soccer. United Kingdom: Routledge; 2003.

Saha S, Mazlan MA, Arriffin MI. Effect of emotional regulation on performance of soccer skills. Proc Soc Behav Sci 2013;91:594-605.

Sandercock G. Normative values, reliability and sample size estimates in heart rate variability. Clin Sci 2007;113:129-30.

Shalfawi S, Ingebrigtsen J, Rodahl S, Enoksen E, Tonnessen E. Validity and Reliability of the Brower Timing System Speed Trap II. Antalya, Turkey: 15th Annual ECSS Congress; 2010.

Sime W. Sports Psychology Applications of Biofeedback and Neurofeedback. Biofeedback: A Practitioner's Guide. United States: American Psychological Association; 2003. p. 560-88.

Sutarto AP, Wahab MN, Zin NM. Heart rate variability (HRV) biofeedback: A new training approach for operator's performance enhancement. J Ind Eng Manage 2010;3:176-98.

Thayer J, Lane R. Claude bernard and the heart-brain connection: Further elaboration of a model of neurovisceral integration. Neurosci Biobehav Rev 2009;33:81-8.

Thayer JF, Brosschot JF. Psychosomatics and psychopathology: Looking up and down from the brain. Psychoneuroendocrinology 2005;30:1050-8.

Werthner P, Christie S, Dupee M. Neurofeedback and biofeedback training with Olympic athletes. Neuroconnections 2013;2:32-8.