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Can Heart Rate Variability Biofeedback Improve Athletic Performance? A Systematic Review

by
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This systematic review was conducted to evaluate the effect of heart rate variability biofeedback (HRV BFB) on performance of athletes. Six electronic databases (Springerlink, SportDiscus, Web of Science, PROQUEST Academic Research Library, Google Scholar, and ScienceDirect) and article references were searched. Eligibility criteria were: 1. experimental studies involving athletes randomly allocated among groups (randomized control trial); 2. availability of HRV BFB as a treatment compared to a control condition (CON) that involves regular sport/dance training, a placebo (PLA) or other methods of BFB; 3. performance-related variables such as a dependent index; and, 4. peer-reviewed articles written in English. Out of 660 articles, six studies were included in the systematic review which involved 187 athletes (females: n = 89; males n = 98). Six studies compared HRV BFB with a CON, three studies compared HRV BFB with a PLA, and two studies differentiated HRV BFB with other methods of BFB. Findings support HRV BFB as a potential intervention to improve fine and gross motor function in athletes.

Key words: *heart rate variability, biofeedback, athletes, performance, resonant frequency breathing.*

Introduction

Biofeedback (BFB) as a performance enhancement strategy in athletes has been receiving notable attention among sports practitioners (Brown and Fletcher, 2016; Keilani et al., 2016; Pusenjak et al., 2015). BFB provides real-time understandable physiological information to an individual that enhances psychophysiological and affective indices (Galloway and Lane, 2005; Wilson et al., 2014). Among various approaches to BFB there is a breathing strategy known as heart rate variability biofeedback (HRV BFB) (Lehrer et al., 2000). HRV BFB is executed by paced breathing at a specific frequency, known as resonance frequency (RF), that elicits maximal heart rate oscillations. RF usually ranges from 4 to 6.5 breaths/min (Lehrer et al., 2000). In addition, RF exhibits a 0-degree phase shift between the heart rate and respiration as well as a 180-degree phase shift between the heart rate and blood pressure (Vaschillo et al., 2006). The physiological phenomena with HRV BFB are believed to improve autonomic function from baroreflex gain and vagal activation (Gevirtz, 2013; Lehrer et al., 2000; Lehrer and Gevirtz, 2014; Prinsloo et al., 2014; Vaschillo et al., 2006).

In an athletic setting, the first documented HRV BFB intervention was administered on wrestlers who exhibited reduced muscle relaxation disorders and an improved rate of relaxation (Vaschillo et al., 1998). A recent review conducted by Jiménez Morgan and Molina-Mora (2017) synthesized the effect of HRV BFB on athletic performance and found that 86% (n = 6) of studies reviewed performance enhancement via improvement in psychophysiological variables.

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One notable strength of the previous study was the employment of systematic procedures. On the other hand, the review included different quantitative study designs (two case reports, one quasi-experimental study, four experimental studies) which may have contributed to bias in findings. Thus, the purpose of this study was to conduct a systematic review of studies only employing randomized trials on the effect of HRV BFB on psychophysiology and exercise performance of athletes.

Methods

Search Strategy

The search was conducted between July 1st and August 31st 2017 using the search term "heart rate variability biofeedback" and (athletes or athletic population or sport or performance or sport performance) in electronic databases: Springerlink, SportDiscus, Web of Science, PROQUEST Academic Research Library, Google Scholar, and ScienceDirect (Jiménez Morgan and Molina-Mora, 2017). In addition, a manual reference search was administered on the records found. PRISMA guidelines were used for reporting.

Eligibility Criteria

To be included in the systematic review, the studies had to meet the following criteria: 1. experimental studies involving athletes randomly allocated among groups (randomized control trial); 2. availability of HRV BFB as a treatment compared with a control condition (CON)/ a placebo (PLA)/other BFB; 3. any performance-related variable as a dependent index; and, 4. peer-reviewed articles written in English.

Study Selection

Literature search and selection of studies were completed by a single investigator (JP). All studies were coded and organized in an Excel spreadsheet. The second investigator (YSC) evaluated data extraction. For each article included in the systematic review, the following data were encoded: author/s and year of publication, sample size information, intervention, measured performance variable/s, and results. These studies were also assessed for 'risk of bias' using an eight-point scale from Consolidated Standards of Reporting Trials (CONSORT) statement wherein each item is answerable by 0 (absently or inadequately described) or 1 (explicitly described and present). A study with a score of 0-2 is regarded as having a high risk of bias, 3-5 with medium risk of bias, and 6-8 considered as having low risk of bias (CONSORT, 2001). A consensus was reached between JP and YSC for any disagreement presented in data extraction and CONSORT output (Table 1).

Statistical Analysis

Independent T-tests using pre-post mean differences and standard deviation of variables from HRV BFB and groups' comparison were administered. Then, corresponding Cohen's d as effect size (ES) with 95% confidence limits were calculated (Cohen, 1988; Lee, 2016; Morris, 2008). Missing pre-post mean differences and SD in studies were computed based on previous methods (Gu et al., 2015; Zu et al., 2013). ES was interpreted as small (d = 0.20), medium (d = 0.50), or large (d = 0.80) (Cohen, 1988). Statistical power calculation from post hoc was also conducted using G*Power ver 3.1 (Faul et al., 2007). Indices with alpha = 0.00 were set at alpha = 0.01.

Results

Figure 1 shows the flowchart and selection process of the studies. The database search indicated 656 potential articles with an additional 4 identified articles from reference lists. After removal of duplicates (n = 90), 570 articles underwent initial screening based on the article title/abstract. This process led to excluding 557 articles after failing to meet all the items in the inclusion criteria. Further assessment for eligibility of 13 full articles led to removal of seven studies leaving six articles included in the analysis.

Participants

The six studies included a total of 187 (females: n = 89; males n = 98) athletes including: 60 (females: n = 27; males: n = 33) university, state, and national basketball athletes; 24 (females: n = 12; males: n = 12) university, state, and national standard long distance runners; 20 male professional soccer players; and, 84 (females: n = 51; males: n = 33) university student dancers.

Experimental protocols

Of the six studies included, all studies compared HRV BFB and a control condition (CON) wherein a CON involved regular dance/sport training. Three studies also compared

HRV BFB and a placebo (PLA) with two studies using motivational video (Paul and Garg, 2012; Paul et al., 2012) and one using choreology (Gruzelier et al., 2014). Two studies compared HRV BFB with the alternative BFB intervention neurofeedback (NFB) which utilized electronenchaphalogram (EEG) signals (Gruzelier et al., 2014; Raymond et al., 2005).

Interventions

The studies applied a variety of HRV BFB protocols. Two studies utilized 10 consecutive days of HRV BFB administered at 20-min/day (Paul and Garg, 2012; Paul et al., 2012). Other studies followed protocols for HRV BFB suggested by Lehrer et al. (2000) using 10 formal sessions with two 20-min daily sessions at convenience (Choudhary, et al., 2016; Gruzelier et al., 2014; Raymond et al., 2005). Two studies following a protocol set by Lehrer et al. (2000) lasted for 10 weeks, while the study of Raymond et al. (2005) was carried out for 4 weeks.

Rusciano et al. (2017) administered HRV BFB for fifteen 30-min sessions (twice a week). The first three sessions followed the protocol set by Lehrer et al. (2000). Then sessions 4 – 9 combined HRV BFB with other biofeedback schemes including a skin conductance level (SCL), electromyography (EMG) of masseter and a posterior cervical region and hand temperature. The remaining sessions (10^{th} – 15^{th}) integrated HRV BFB with math tasks, hyperventilation, and winning and losing video games.

Instruments

Different HRV BFB equipment was utilized for HRV BFB. Two studies utilized freeze-framer from Boulder Creek, California, US (Gruzelier et al., 2015; Raymond et al., 2005). Three studies used Biograph Pro Comp Infinity 5.0 from Thought Technology Ltd., Canada (Choudhary et al., 2016; Paul and Garg, 2012; Paul et al., 2012). Rusciano et al. (2017) used HRV BFB with Nexus 10 Mark II hardware and Biotrace1 commercial software from Mind Media, Herten, Netherlands.

Performance Evaluation

Studies included in the review assessed various performance related variables. Changes in performance (%) and effect sizes with 95% confidence limits of HRV BFB and groups' comparison, as well as study power are displayed in Table 2.

Choudhary et al. (2016) determined 5-km performance of track athletes. The study of Paul et al. (2012) assessed performance using movement and choice reaction time (RT) along with a 3-min shooting score. Paul and Garg (2012) measured weaving in and around cones whilst dribbling for 30 s, 30-s passing with specified targets on the wall, and 3-min shooting at marked perimeters. Rusciano et al. (2017) established visual tracking RT of professional soccer players with and without a target. Accuracy under congruent and incongruent stimuli using a Stroop task was also determined. Further, injury prevention was identified from attendance records (days present and absent or differential training days – the number of days on which athletes followed personalized training due to recent injuries). In the study of Gruzelier et al. (2014), four dance experts rated dance performance for artistry and technique. Raymond et al. (2005) utilised two qualified dance assessors that evaluated dance performance considering a technicality, musicality, timing, partnering skill, performing flair, and overall execution from a customized scale with scoring of one to five. In addition, rating scores were divided by the number of practice sessions for each dancer to derive "improvement per practice session". Then, scores were averaged to get the group score from "practice-corrected average difference". Characteristics of each study are presented in Table 3.

Performance Outcomes

HRV BFB vs. CON

For gross motor skill executed in relatively short duration comparing HRV BFB and a a CON, Paul and Garg (2012) demonstrated non-significant difference in dribbling between the HRV BFB and the CON group at $p = 0.06$, ES[95% CL] = 0.89[0.60, 1.18]. On the other hand, the HRV BFB group presented significant enhancement in passing and shooting at $p < 0.001$, 2.14[1.79, 2.49] and $p < 0.001$, 2.00[1.66, 2.34], respectively. In a similar study, Paul et al. (2012) found significant improvement in 3-min shooting after HRV BFB compared to a CON at $p = 0.01$, 1.38[1.07, 2.36]. Raymond et al. (2005) observed non-significant difference in performance scores of dancers at $p = 0.40$, 0.55[-0.06, 1.77]. No significant difference in practice-corrected difference scores at $p = 0.31$, 0.66[0.04, 1.89] was also found.

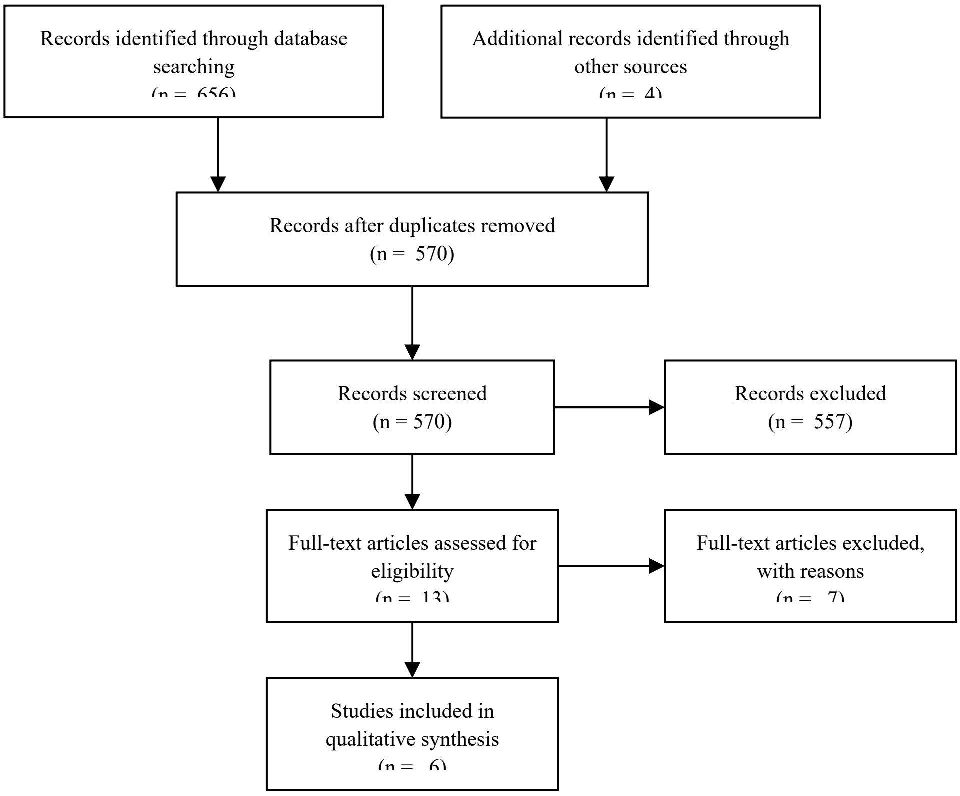

Figure 1

Flow diagram of the search process

Table 1

CONSORT scores of articles included for systematic review

References	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Total
Choudhary et al. (2016)	1	0	0	0	0	1	1	0	3
Gruzelier et al. (2014)	0	0	1	0	0	1	1	0	3
Paul and Garg (2012)	1	0	1	0	1	1	1	0	5
Paul et al. (2012)	1	0	1	0	1	1	1	0	5
Raymond et al. (2005)	1	0	1	0	0	1	1	0	4
Rusciano et al. (2017)	1	0	1	0	0	1	1	1	5

Item 1 *– Were the groups comparable at baseline on key characteristics?* ***Item 2*** *– Did the study include a true control group (randomised participants – not a comparison group)?* ***Item 3*** *- Was the randomisation procedure adequately described and carried out?* ***Item 4*** *– Did the study report a power calculation and was the study adequately powered to detect intervention effects?* ***Item 5*** *– Were the assessors blinded to treatment allocation at baseline and posttest?* ***Item 6*** *– Did at least 80% of the participants complete follow-up assessments?* ***Item 7*** *– Did the study analyses account for potential differences at baseline?* ***Item 8*** *– Did the study compute effect sizes?*

Table 2

Effect Size with 95% Confidence Interval of Studies in HRV BFB vs Comparison Group

Study	Parameter	% Change		p-value	ES	95% Confidence Interval		Power
HRV BFB vs CON		HRV BFB	CON			LL	UL	
Choudhary et al. (2016)	5-km running	-13.0	-0.71	0.16	-0.60	-0.84	0.22	0.51
Paul and Garg (2012)	dribbling	25.1	6.54	0.06	0.89	0.60	1.18	0.50
	passing	76.6	13.2	0.00	2.14	1.79	2.49	0.96
	shooting	104	9.43	0.00	2.00	1.66	2.34	0.93
Paul et al. (2012)	shooting	98.1	27.3	0.01	1.38	1.07	2.36	0.59
	movement time	-17.1	0.00	0.05	-0.95	-1.24	-0.02	0.52
	choice RT	-21.3	0.00	0.01	-1.23	-1.53	-0.27	0.47
Raymond et al. (2005)	dance performance	15.1	8.46	0.40	0.55	-0.06	1.77	0.56
	practice-corrected difference	NA	NA	0.31	0.66	0.04	1.89	0.53
Rusciano et al. (2017)	target absent RT	-29.4	-1.58	0.00	-1.72	-2.05	-0.70	0.82
	target present RT	-22.6	-11.0	0.31	-0.47	-0.72	0.42	0.53
	congruent task accuracy	10.5	0.57	0.00	2.64	2.26	3.84	1.00
	incongruent task accuracy	15.6	0.95	0.00	2.94	2.54	4.20	1.00
	days present	NA	NA	0.00	1.51	1.20	2.50	0.69
	days absent	NA	NA	0.00	-1.52	-1.83	-0.52	0.69
	differential training	NA	NA	0.18	-0.62	-0.90	0.28	0.51
HRV BFB vs PLA		HRV BFB	PLA					
Paul and Garg (2012)	dribbling	25.1	3.06	0.04	0.99	0.70	1.92	0.51
	passing	76.6	23.9	0.01	1.38	1.07	2.36	0.59
	shooting	104	28.8	0.00	1.63	1.31	2.64	0.77
Paul et al. (2012)	shooting	98.1	30.8	0.00	1.39	1.08	2.37	0.60
	movement time	-17.1	0.00	0.42	-0.37	-0.64	0.52	0.56
	choice RT	-21.3	0.00	0.00	-1.51	-1.82	-0.51	0.69
HRV BFB vs NFB		HRV BFB	NFB					
Raymond et al. (2005)	dance performance	15.1	12.2	0.86	0.12	-0.51	1.39	0.86
	practice-corrected difference	NA	NA	0.94	0.05	-0.58	1.31	0.94

***ES** - effect size; **LL** - lower limit; **UL** - upper limit; **NA -** not applicable*

Table 3a

HRV BFB and Athlete Performance

References	Participants			Training Modality	Conclusion/s
	N/sex/age	**Training**	**Discipline**		
Choudhary et al. (2016)	n = 24 12M; 12F 22.5 ± 1.72 yrs	regular sport training for HRV BFB/ CON	university, state, national level long distance runners	HRV BFB: once a week formal HRV BFB training; 2 x 20 min/day home practice	5-km time: HRV BFB ↔ CON
Gruzelier et al. (2014)	n = 64 22M; 42F NR	regular dance training for HRV BFB/ CON/ NFB	university dancers	HRV BFB: 10 HRV BFB sessions at 20 min/session NFB: 10 alpha/theta training at 20 min/session	Artistry: HRV BFB ↔ CON HRV BFB ↔ PLA HRV BFB ↔ NFB Technique: HRV BFB ↔ CON HRV BFB ↔ PLA HRV BFB ↔ NFB
Paul and Garg (2012)	n = 30 17M; 13F 21.1 ± 2.82 yrs	regular sport training for HRV BFB/ PLA/CON	university, state and national basketball athletes	HRV BFB: 10 consecutive HRV BFB at 20 min/session PLA: motivational video clips for 10 days at 10 min/day	Dribbling: HRV BFB ↔ CON HRV BFB >PLA Passing: HRV BFB > CON HRV BFB > PLA Shooting: HRV BFB > CON HRV BFB > PLA

HRV BFB *- heart rate variability biofeedback;* ***PLA -*** *placebo;* ***CON -*** *control;* ***NFB -*** *neurofeedback;* ***NR -*** *not reported;* ***SCL -*** *skin conductance level;* ***EMG -*** *electromyography;* ***RT*** *- reaction time*

Table 3b

HRV BFB and Athlete Performance

References	Participants: N/sex/age	Participants: Training	Participants: Discipline	Training Modality	Conclusion/s
Paul et al. (2012)	n = 30 16M; 14F 21.7 ± 2.71 yrs	regular sport training for HRV BFB/ PLA/CON	university, state and national basketball athletes	HRV BFB: 10 consecutive HRV BFB at 20 min/session PLA: motivational video clips for 10 days at 10 min/day	Choice RT: HRV BFB < CON HRV BFB < PLA Movement RT: HRV BFB ↔ CON HRV BFB ↔ PLA Shooting: HRV BFB > CON HRV BFB > PLA
Raymond et al. (2005)	n = 18 9M; 9F 21.6 yrs	regular dance practice for HRV BFB/ NFB./CON	university dancers	HRV BFB: 10 formal HRV BFB training at 20 min/session in 4 weeks NFB = 10 alpha/theta training sessions at 20 min/session	Performance HRV BFB ↔ CON HRV BFB ↔ NFB Practice-Corrected Difference Score HRV BFB ↔ CON HRV BFB ↔ NFB
Rusciano et al. (2017)	n = 20 20M 30.4 ± 4.10 yrs	regular sport training for HRV BFB/ CON	professional football players	HRV BFB: Fifteen 30-min biofeedback sessions at twice/week 4th-9th session: HRV BFB + SCL + EMG + hand temperature 10th -15th session: HRV BFB + math tasks + videos of matches won/lost	Target-Absent Visual Task RT: HRV BFB < CON Target-Present Visual-Task RT: HRV BFB ↔ CON Congruent Task: Accuracy: HRV BFB > CON Incongruent Task Accuracy: HRV BFB > CON Date Present: HRV BFB > CON Days Absent: HRV BFB < CON Differential Training Days: HRV BFB ↔ CON

Gruzelier et al. (2014) found that university dancers exhibited non-significant outcomes in artistry and technique between HRV BFB and CON groups.

In exercise of longer duration, Choudhary et al. (2016) reported no significant improvement in gross motor skill movement via 5-km performance between the HRV BFB group and a CON at p = 0.16, ES[95% CL] = -0.60[-0.84, 0.22].

In fine motor ability, Paul et al. (2012) found no significant reduction in movement time seen after HRV BFB and a CON at p = 0.05, -0.95[-1.24, -0.02]. On the other hand, there was significantly shorter choice reaction time found after HRV BFB compared to a CON at p = 0.01, -1.23[-1.53, -0.27]. Rusciano et al. (2017) detected significant improvement in visual tracking scores with a target absent stimulus among soccer athletes after HRV BFB compared to a CON at p = 0.00, -1.72[-2.05, -0.70]. However, visual tracking with a target present stimulus did not significantly improve after HRV BFB compared to a CON at p = 0.31; ES = -0.47[-0.75, 0.42]. Furthermore, soccer players after HRV BFB significantly increased accuracy under congruent stimuli at p = 0.00, 2.64[2.26, 3.84] compared to a CON. Similarly, the HRV BFB group showed significantly higher accuracy following incongruent stimuli compared to a CON at p = 0.00, 2.94[2.54, 4.20].

Rusciano et al. (2017) found significantly reduced absence from sport training sessions compared with a CON at p = 0.00, 1.51[1.20, 2.50]. The number of absences from training in the entire sport season that followed treatment from injury was also significantly lower in the HRV BFB group than a CON at p = 0.00, -1.52[-1.83, -0.52]. Differential training between the HRV BFB group and a CON was not significantly different, p = 0.18, -0.62[-0.90, 0.28].

HRV BFB vs. PLA

Paul and Garg (2012) discovered a significantly higher dribbling score in the HRV BFB group than a PLA at p = 0.04, 0.99[0.70, 1.92]. Passing also significantly improved in the HRV BFB group compared with a PLA at p = 0.01, 1.38[1.07, 2.36]. The HRV BFB group significantly increased shooting performance compared to a PLA, p = 0.00, 1.63[1.31, 2.64]. In the study of Paul et al. (2012), athletes after HRV BFB significantly increased shooting scores at p = 0.01, 1.39[1.08, 2.37]. In dance, artistry and technique were similar in both the HRV BFB and the PLA group (Gruzelier et al., 2014).

For fine motor task ability examining HRV BFB and a PLA, non-significant improvement in movement time was identified between the HRV BFB group and a PLA at p = 0.42, -0.37[-0.64, 0.52]. However, the HRV BFB group presented significantly lower choice reaction time than the PLA at p = 0.00, -1.51[-1.82, -0.51].

HRV BFB vs. other BFB intervention

Raymond et al. (2005) presented similar both performance and practice-corrected performance after HRV BFB and NFB at p = 0.86, 0.12[-0.51, 1.31] and p = 0.94, 0.05[-0.58, 1.31], respectively. Gruzelier et al. (2014) recorded non-significant difference in artistry and technique between HRV BFB and NFB.

Discussion

The purpose of this systematic review was to examine the effect of HRV BFB on performance indices of athletes. When compared to a control condition (CON) that involved regular training only, HRV BFB displayed contrasting effects on the gross motor skills during short duration performance. In addition, the effect of HRV BFB on gross motor function during exercise of longer duration is unclear. Confounding results in fine motor skills after HRV BFB were also identified in comparison with a CON.

In this study, short duration (< 10 minutes) gross motor tasks after HRV BFB delivered conflicting results. For example, Paul and Garg (2012) showed improved shooting and passing performance in basketball players after HRV BFB compared to a CON. However, non-significant difference in dribbling was seen after HRV BFB and a CON. In a similar study, Paul et al. (2012) recorded increased shooting following HRV BFB compared to a CON. Raymond et al. (2015) presented no significant difference in dance performance and practice-corrected difference in HRV BFB and a CON. The conflicting results in short duration gross motor ability can be attributed to underpowered trials (Table 3). Future research in HRV BFB and gross motor abilities should employ adequate sample size to facilitate enough power to detect meaningful difference (Biau et al., 2008).

The influence of HRV BFB on longer duration (> 10 min) gross motor performance in comparison with a CON is unclear due to limited literature. In the study of Choudhary et al. (2016), 5-km performance of athletes in the HRV BFB and the CON group was not significantly different. However, a notable trend in running enhancement of 13.0% (ES = -0.60) was demonstrated by athletes from the HRV BFB group. On the other hand, the CON group displayed a 0.71% change in performance. Better performance exhibited by athletes following HRV BFB suggests the positive influence of HRV BFB on longer duration gross motor ability. HRV BFB may have reduced physiological stress of athletes from increased blood flow to internal organs, elevated minimum left ventricular elastance, baroreflex sensitivity gain, and improved pulmonary function (Fonoberova et al., 2014; Lehrer et al., 2003; McEwen and Seewan, 2003). More studies are needed to establish the effect of HRV BFB on gross motor ability.

In another light, the fine motor ability of athletes after HRV BFB and a CON displayed conflicting results. Paul et al. (2012) observed improved choice reaction time after HRV BFB. Conversely, no significant enhancement in movement reaction time existed between the HRV BFB and the CON group. Rusciano et al. (2017) found enhancement in reaction time with a target absent stimulus after HRV BFB. However, there was no significant change in the target present stimulus in both groups. Non-significant findings in fine motor ability between HRV BFB and CON can also be due to insufficient sample size leading to low statistical power. In the study of Paul et al. (2012), employment of unequal sample size of males and females between groups may have influenced the non-significant results (Rusticus and Lovato, 2014). Males and females utilize different processing strategies in reaction time wherein males demonstrate faster reaction time than females (Adam et al., 1999; Dane and Ezurumluoglu, 2003). This can be supported by the greater vagal activity observed in females due to the presence of more oestrogen than in males (Dart et al., 2002; Du et al., 2006; Koenig and Thayer, 2016). Oestrogen improves the activity of choline uptake and synthesis of acetylcholine, thereby increasing vagal function (Dart et al., 2002). In addition to unequal distribution of males and females between groups, inclusion of athletes from various competitive levels in the study by Paul et al. (2012) may have increased the variability in fine motor skill execution (Carillo et al., 2011; Mückschel et al., 2014). Indeed, previous studies have shown better reaction times in elite athletes compared to non-elite athletes (Loureiro Jr and Freitas, 2012; van de Water et al., 2017; Verbugh et al., 2016). Addressing the aforementioned shortcomings when examining fine motor skill with HRV BFB training in future studies should be warranted.

Although inconsistent results were observed in HRV BFB and a CON, there is a favourable trend in performance enhancement towards HRV BFB in overall motor function. Possible physiological mechanisms of HRV BFB can be explained by the neurovisceral integration model (Porges, 2009; Thayer and Lane, 2009). HRV BFB increases activation of the vagal nerve (Gevirtz, 2013; Lehrer and Gevirtz, 2014). The vagal nerve is connected to the anterior cingulate cortex, the brain region that plays a crucial role for multi-component behaviour (Duncan, 2010; Mayer, 2011; Mückschel et al., 2014). HRV BFB may have facilitated the production of neurotransmitters responsible for improving fine and gross motor function (Beste et al., 2016; Hassert et al., 2004; Juster et al., 2010; Sellaro et al., 2015; Steenbergen et al., 2015; Yildiz et al., 2014). However, the exact mechanism affecting performance from improvement in vagal function is unknown. Future studies should be sufficiently powered, and include biochemical markers to elucidate the mechanistic properties of HRV BFB.

An interesting finding in this review is the increased attendance of athletes in training with HRV BFB. Rusciano et al. (2017) recorded an ~86% presence in training and ~4% absent rate out of 240 training sessions in soccer players in HRV BFB training. For athletes from a CON group, the rates of attendance and absence were ~73% and ~14%, respectively. Although differential training was not significantly different between groups, athletes following HRV BFB presented lower differential training of ~9% compared to a CON (~13%). The increased attendance, reduced absences, and a lower trend in differential training among athletes under HRV BFB may be related to improved physiological adaptations leading to resilience to stressors (Ivarsson and Johnson, 2010;

Porges, 2007, 2009; Thayer and Lane, 2009). Thus, HRV BFB can also be a promising intervention in increasing athlete's attendance in training by reduction of the risk of injuries.

Aside from comparing HRV BFB and a CON, the researchers also found improvement in short-duration gross motor performance with HRV BFB compared to a PLA. Paul and Garg (2012) displayed increased dribbling, shooting, and passing after HRV BFB compared to a PLA. Similarly, Paul and Garg (2012) showed improved shooting after HRV BFB compared to a PLA. Implications from these results point to HRV BFB as a superior alternative compared with a PLA in improving gross motor function of short duration.

The influence of HRV BFB on fine motor skill differentiated with a PLA is vague due to the scarcity of literature. Paul et al. (2012) recorded non-significant difference in movement time between HRV BFB and a PLA. On the other hand, HRV BFB presented enhanced choice reaction time in HRV BFB compared to a CON. Therefore, additional HRV BFB studies including a PLA are needed.

It is necessary to acknowledge that the outcomes of this study are limited to the type of athletes included in the analyses. Generalization of results should be avoided. In addition, this review evaluated performance indices to provide practitioners with a simple and direct link on HRV BFB and performance.

Conclusion

Findings of this study indicate the potential ergogenic ability of HRV BFB in improving fine and gross motor skills of athletes.

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