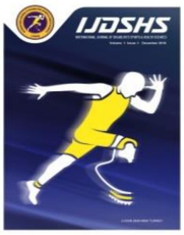

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RESEARCH ARTICLE

Heart Rate Variability Biofeedback and Cognitive Restructuring for Self-Regulation: A Case Study

Boram KIM[1], Seunghyun HWANG[*2] and Hoseok KANG[3]

[1,2]Department of Kinesiology, Kyungpook National University / Korea
[3]Korea Squash Federation / Korea
*Corresponding author: hwangsh@knu.ac.kr

Abstract
This study investigated the effects of a psychophysiological intervention programmed, comprising heart rate variability biofeedback (HRV BFB) and cognitive restructuring (CR), on the self-regulation skills of an 18-year-old female squash athlete who represents the Korean national team. The participant underwent ten programme sessions in a laboratory. HRV was measured during a 10-minute baseline period of natural breathing and during BFB-guided breathing exercises. Two questionnaires, the Competitive State Anxiety Inventory-2 (CSAI-2) and the Cognitive Emotion Regulation Questionnaire (CERQ), were used to assess the participant's psychological state. Descriptive statistics were employed to analyze changes in HRV and psychological state from the initial test to the post-test. Qualitative findings indicated improvements in the participant's self-regulation skills, particularly in her ability to transform negative thoughts. In conclusion, the intervention programme shows potential in enhancing self-regulation skills to the athlete. The combination of HRV biofeedback and cognitive restructuring appears to lead to positive changes in self-regulation, which could benefit athletes in managing their psychological state and improving competitive performance. Further research and practical applications are continued needed to fully explore the programme's efficacy.

Keywords
Athletes, Biofeedback Training, Breathing, Cognitive Restructuring, Heart Rate Variability, Self-Regulation

INTRODUCTION

Engaining in competitive sports frequently expose athletes into an amalgamation of physical and psychological challenges, sparking both somatic and cognitive anxiety. In the multidimensional model of anxiety (**Martens et al., 1990**), somatic anxiety is reflected in the physical responses driven by the autonomic nervous system (ANS), including sweating, changed breathing pattern, high blood pressure, and tremors. Simultaneously, cognitive anxiety involves psychological responses and can be rooted in negative cognition and distorted perceptions such as negative self-talk and imagery, worrying, and low self-evaluations. These findings imply that self-regulation within a psychophysiological state is critical for peak performance during competition (**Robazza et al., 2004; Davis et al.,2007; Lagos et al.,2008; Dupee et a.,2015; Hwang et al., 2016**). The intricate interplay between somatic and cognitive aspects of anxiety and their influence on athletic performance has been a longstanding concern in the field of sports psychology. The field strives to unravel the complexities of self-regulation within a psychophysiological context. Self-regulated ability is key factor as emerges as a critical determinant of peak performance in the competitive arena (**Lagos et al., 2008; Hwang et al., 2016; Thayer et al.,2009**).

Biofeedback (BFB) training has been suggested to improve self-regulation in sports

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(Ferguson & Hall, 2020). The BFB methodologies, which collect psychophysiological data and report on changes in psychological state, can help athletes not only understand their physiological responses but also improve their ability to regulate their psychological states. Previous BFB studies with athletes showed successful effects related to enhancing self-awareness, controlling anxiety, and improving performance (Lagos, 2008; Hong, 2011; Paul & Garg, 2012; Hwang et al., 2016). The representative physiological indices used in BFB training are electro myography, electro encephalography, heart rate, heart rate variability (HRV), respiration rate (RR), skin conductance, and temperature; among these, HRV is the most commonly used. HRV is a measure of changes in time intervals between heartbeats, which are controlled by the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) (Berntson et al., 1997), and it identifies imbalances in the ANS (Janelle & Naugle, 2012). Both branches of the ANS regulate heart rate, with SNS increasing the rate and PNS decreasing it, and HRV is the measure of the rate changes between heartbeats; these changes can be analysed by time or frequency. The time domain refers to the time intervals between heartbeats (i.e., RR interval parameters), and measures include mean HRV, standard deviation of all normal R-R intervals (SDNN), and root mean square of successive differences (RMSSD). On the other hand, the degree of ANS activation is measured in the frequency domain. This is done by analysing the spectrum, which produces three ranges: high frequency (HF: 0.15–0.4 Hz), low frequency (LF: 0.04–0.15 Hz), and very low frequency (VLF: 0.003–0.4 Hz); these frequency measures also include the LF/HF ratio (Park & Jeong, 2014).

HRV BFB via breathing training is a well-known approach to regulating both the SNS and PNS and enhancing external–internal synchronisation. HRV BFB is expected to produce positive effects (Dziembowska et al., 2016), such as reducing anxiety (Lagos et al., 2008; Prinsloo et al., 2011; Hwang, 2018); lowering stress levels (Kim & Min, 2015); enhancing self-control (Hwang, 2016); and improving sports performance (Strack, 2003; Paul & Garg, 2012). In an experiment, Choudhary et al. (2016) examined the effect of HRV BFB training on psychophysiological performance in 24 long-distance runners (5 km). The experimental group was instructed to practice resonance frequency breathing by performing four tasks during ten sessions of 30–40 minutes each, while the control group was instructed to do regular exercise. The HRV changes, along with blood volume, pulse, skin conductance and respiration, maximum oxygen consumption (VO2 max), and sports performance, were recorded and monitored during the breathing training and regular exercise; all of them showed significant differences between groups. In addition, in sports performance, the experimental group showed a more improved mean race record (15.89 seconds) than that of the control group (18.11 seconds).

In another study, Lagos et al. (2008) applied a 10-week programme of HRV BFB training to a high school golfer. The participant practiced breathing exercises each day for 20 minutes with a portable device. During the breathing exercise, HRV and breathing rate were measured, along with mood state, competitive anxiety level, and sports performance. After the training, the student's total HRV and LF had increased, and his heart rate and breathing patterns were more synchronised. Furthermore, his anxiety and negative emotions decreased, but his golf performance increased. Beauchamp et al. (2012) applied HRV BFB to an Olympic short-track speed skating team in six to ten sessions of 45 minutes combined with general psychological skill training and concluded that the HRV programme had contributed to arousal control and relaxation for warm-up, which resulted in improved performance in the Games. As Beauchamp et al. (2012) suggested, we focused on an integrated approach in this study to enhance self-regulation skills.

Even though BFB training alone can be beneficial for performance enhancement, integration with cognitive restructuring (CR) is more effective for treating anxiety among athletes. Cognitive Restructuring (CR) is a cognitive-behavioral therapy technique that aids individuals in identifying and altering negative thought patterns or cognitive distortions (Beck, 1988; Choi & Lee, 1998) CR extends Beck's cognitive therapy (1988) to correct extreme interpretations of physical sensations and cognitive errors of thought. Cognitive therapy focuses on correcting cognitive distortions that interpret body reactions as threats based on anxiety responses (Choi & Lee, 1998), and changing the cognitive interpretations of these body reactions can significantly reduce bodily sensations such as hyperventilation (Rapee, 1986; Beck, 1988; Clark, 1993; Choi & Lee, 1998). Salkovskis et al. (1991) found that implementing a CR programme to reconstruct misinterpretations of body reactions decreased anxiety symptoms, which implies that cognition can be a significant aid to athletes with chronic anxiety. Clark et al. (1994) compared the effects of three different treatments—cognitive therapy, applied relaxation, and imipramine—on 64 panic disorder patients and found that all three were effective, but cognitive therapy was the most effective. Clark et al. (1994) also followed up on the athletes' symptoms after 15 months and found that misinterpretations of bodily sensations were the most common recurring symptoms. This result suggested combining BFB training with CR; the combination increased breathing control and diminished irrational beliefs in a competitive context, which is expected to show better self-regulation skills for psychophysiological states (Clark et al., 1994). Athletes often experience anxiety in diverse ways, with unique cognitive patterns contributing to their distress. The integration of CR allows for a more individualized intervention, tailoring cognitive strategies to the specific cognitive challenges each athlete faces alongside the physiological feedback from BFB.

In total, athletes should be equipped with cognitive strategies and skills for regulating physical reactions to anxiety and stress that can hinder optimal performance. Based on a psychophysiology approach, we developed a programme consisting of CR and HRV BFB breathing training to reduce anxiety and increase self-regulation for one squash athlete who suffered from an anxiety disorder. We aimed at quantitative and qualitative evaluation of the programme that we developed for the athlete, and we hypothesised that the psychophysiology intervention programme would result in emotion regulation changes in the athlete's HRV, anxiety level, and cognitive skills

The specific research hypothesis based on the purpose of the study is as follows.

H1: The psychophysiological intervention programm is expected to increase resting HRV.

H2: Psychophysiological intervention programme is anticipated to decrease anxiety levels.

H3: Psychophysiological intervention programme is expected to enhance participants' cognitive-emotional regulation abilities.

MATERIALS AND METHODS

Case Study

This study's limited sample size to one participant is attributed to the unique nature of the research focus. This approach allows for an in-depth and detailed analysis of individual responses, contributing valuable insights into the specific phenomenon under investigation. While a larger sample size is typically sought for generalizability, the emphasis here is on the depth of understanding gained from an intensive examination of a singular case, providing context-specific findings.

Jenny (pseudonym), the participant in this study, was an 18-year-old squash athlete on the Korean national team. She had been experiencing anxiety in competitive contexts (e.g., national championship) in the past year; the competitive contexts caused psychophysiological problems that resulted in poor performance. Jenny described several panic episodes marked by difficulty in breathing, dizziness, rapid heart rate, sweating, and a fear of losing consciousness during competitions. She experienced breathing problems repeatedly while she was sleeping or practicing in the gym as well. A medical check-up indicated no physiological causes for Jenny's symptoms. Based on her statements and medical results, we concluded that her anxiety symptoms were caused by dysfunctional beliefs about competition and her lack of physical coordination in stressful situations.

This case study followed ethical standards and received approval from the Kyungpook National University Industry Foundation in South Korea with reference number [KNU-2021-0157]. Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

HRV BFB and CR Intervention Programme

HRV BFB training

Jenny was attended the intervention programme during the off-season. she maintained a consistent schedule of visiting the lab twice a week. this consistent attendance and the systematic upkeep up uniform conditions provides a robust foundation for assessing the intervention's impact.

The HRV programme included 10 sessions, including a pre- and a post-test, with each session lasting 20 minutes and taking place at the same place and time. After we obtained consent from the participant, her coach and her parents, she completed two questionnaires to measure her psychological states and was equipped with biosensors for measuring her baseline psychological (i.e., stress level, sleep quality, mood) and physiological states (i.e., heart rate, temperature, skin conductance, breathing patterns), including competitive anxiety and HRV. These psychophysiological values for her baseline were measured not for the analysis but for supplementary reference information. We explained all the procedures to Jenny and educated her on how to do abdominal respiration. Prior to the programme starting, we measured her physiological states for 10 minutes during natural breathing to set up a baseline for comparison.

While Jenny performed breathing training, we obtained her physiological state using a BFB device (Peak Performance Suite, Thought Technology Ltd.). She was seated on a comfortable chair in a silent laboratory, and she wore the sensors on her left hand and abdomen; the sensors were calibrated while she adapted to the laboratory environment. At the beginning of the session, we explained how the heartbeat and other physiological data were detected by each sensor to capture HRV and RR, which were displayed on a screen in real-time. At each session, we collected Jenny's baseline data as she breathed naturally for 10 minutes; then she was instructed to follow the HRV BFB breathing training (i.e., abdominal respiration to follow a breathing pace bar by inhaling through the nose and exhaling through the mouth for 10 minutes) to regulate her psychophysiological states. We explained to Jenny the changes in thedata shown on the screen. We asked her to describe the feelings she had felt during the BFB training and her psychophysiological changes in order to qualitatively evaluate any improvements in her self-regulation. Jenny had to do breathing training at home; thus, we gave her a portable Emwave 2 breathing training device (Heart Math Inc.) and told her to do it three times a day.

CR intervention

CR. After each session of HRV BFB training, we applied approximately 30 minutes of CR. Initially, we educated Jenny on distinguishing between cognitive and somatic symptoms in stressful situations, not only so she could recognise her anxiety symptoms as reactions to the triggers of stressful situations but also so she could recognise that most of her anxiety symptoms were caused by negative thoughts and cognitive errors. CR consisted of the following three phases: First, a focus on awareness aims to bring to consciousness experiences of disconcerting thoughts during practice and competition; for this study, Jenny described her emotions, negative thoughts, and physical symptoms during stressful situations she had experienced. Second, focusing on appraisal identifies cognitive errors such as overestimation, dichotomous thinking, personalisation, and catastrophising. In the last phase, “alternative,” people rethink certain situations and consider alternative ways to settle disputes.

Demographics

For her demographic information, Jenny completed a questionnaire including items related to personal characteristics (e.g., age, gender), health problems (e.g., medical history, injuries, mental illness), and athletic experience (e.g., winning record in competitions, psychological skill training, and BFB training).

HRV. We recorded HRV with the Peak Performance Suite that utilised electrodes connected to multi-modality encoders (Biograph ProComp Infiniti Encoder-8 channel, Thought Technology Ltd., Canada). The system was able to calculate HRV from the heart rate data derived from the blood volume pulse signals, which again shows changes in the ANS. We conducted the analyses by time and frequency, and the monitor displayed the real-time frequency domain results (VLF, LF, and HF) only; the system automatically stored the time domain results (SDNN, RMSDD) in the computer. We used LF power in normalised units (LF[ms2]/(total power[ms2]−VLF[ms2]) from 0.04 to 0.15 Hz, HF power in normalised units (HF[ms2]/(total power[ms2]−VLF[ms2]) from 0.15 to 0.4 Hz, and the LF/HF ratio in this study. For the time domain indices, we extracted and compared the pre/post SDNN and RMSSD.

CSAI-2. The CSAI-2 is a sport-specific state anxiety scale developed by Martens et al. (1990). It consists of a total of 27 items measuring three components: cognitive anxiety, somatic anxiety, and self-confidence. Each item is rated on a 4-point Likert scale from 1 (not at all) to 4 (very much so), and the total for each subscale ranges from 9 to 36. Cronbach's alpha coefficients for the CSAI-2 range from 0.80 to 0.88 (Lane et al., 2008), which shows that it is very reliable.

CERQ. The CERQ was developed by Garnefski et al. (2002). It consists of a total of 36 items measuring the following nine cognitive emotion regulation components: positive refocusing, positive reappraisal, refocus on planning, putting into perspective, acceptance, rumination, self-blame, other-blame, and catastrophising. Items on the CERQ are answered on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always), and each scale component consists of four items, for a possible score ranging from 4 to 20 for each component. In previous research on cognitive emotion regulation strategies, all subscales had high reliability, with Cronbach's alpha ranging between 0.75 and 0.87 (Garnefski & Kraaij, 2007).

Data Analysis

First, we quantitatively analysed the HRV changes by pre- and post-intervention data as mean ± standard deviation using Microsoft Excel. We also assessed the qualitative study data using content analysis, which entails interpreting meaning from interview data to identify important and meaningful aspects. At the end of each session, we rated Jenny's overall experiences, including her thoughts and opinions about the HRV BFB and the CR. We collected this descriptive data with three questions asked during a 10- or 15-minute session at the same place where the BFB training sessions occurred; a researcher asked follow-up questions when a response was bland:

Q1. Did you experience any positive aspects from the intervention?

Q2. Did you experience any negative aspects from the intervention?

Q3. Did you experience anything unusual? (body, emotions, thoughts)

RESULTS

Jenny described mostly the benefits of the psychophysiological intervention; the only negative aspect she cited was functional errorswith the Emwave2 device. Jenny described mostly the benefits of the psychophysiological intervention; the only negative aspect she cited was functional errors with the Emwave2 device. From her responses, we established that we appeared to have achieved our three goals: a) increasing the young athlete's awareness of her own mind and body; b) teaching her efficient breathing and psychological stability; and c) increasing her mind and body abilities. Below, we further discuss our findings, including comments directly from Jenny and both the quantitative and qualitative changes in Jenny's indicators from baseline to the end of the intervention. Changes in her negative thoughts, her ability to control herself (self-regulation), and her overall experiences with HRV BFB training were some of the qualitative results.

Quantitative Changes

HRV

SDNN reflects variability in individual components over a recording period and, as such, can represent total variability (Politano et al., 2008). Short-term or momentary increases in SDNN within a normal range could imply more effective activation between the SNS and PNS (Roberto & Attilio, 2018), which can be interpreted as effectively coping with internal and external stresses. Jenny showed a higher SDNN, from 336.87 ms2 to 339.53 ms2 at the end of the HRV BFB training than her initial reading with natural breathing. The RMSSD, which is well-known as a PNS activation index, also increased after the intervention, from 648.17 to 652.91 ms2 (Figure 1). Compared with Jenny's baseline values, normalised LF power increased and normalised HF power decreased with natural breathing (Figure 2). The LF/HF ratio reflects the balance between the SNS and PNS, and this ratio increased from 1.97 to 3.80 ms2 by the end of the HRV BFB training.

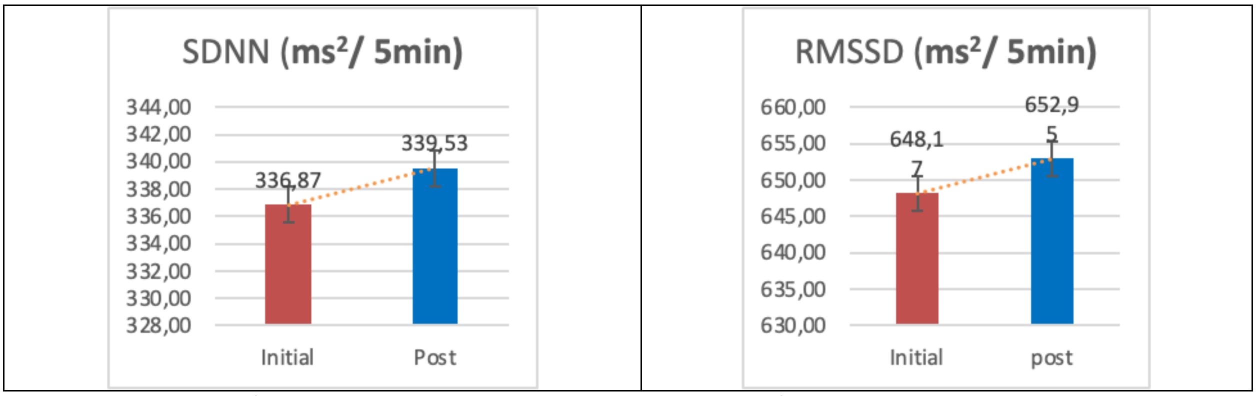

Figure 1. Distribution of mean pre- and post-test time-domain analysis results for heart rate variability
SDNN, standard deviation of all respiration rate intervals; RMSSD, root mean square of the sum of the squared differences between adjacent normal respiration rate intervals.

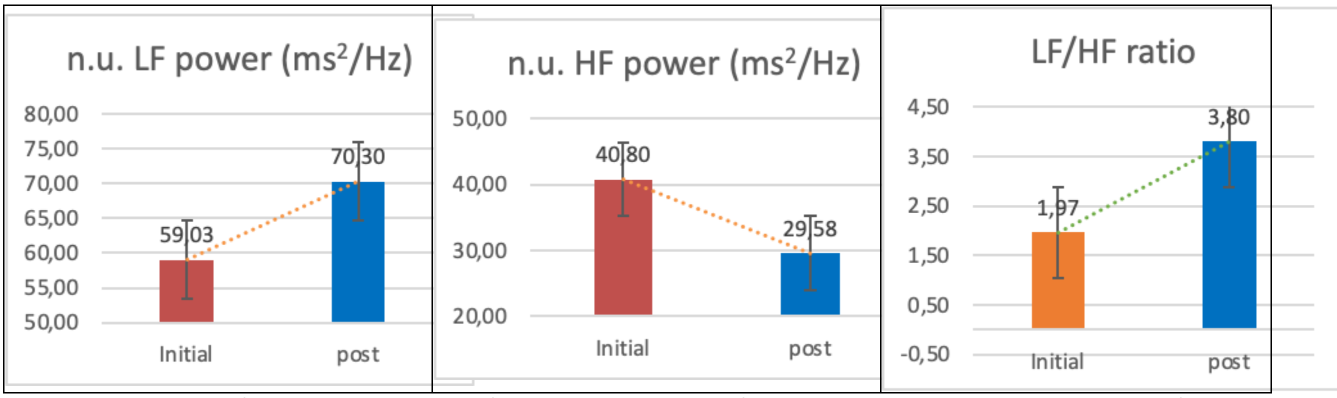

Figure 2. Distribution of mean pre- and post-test frequency domain results for heart rate variability. n.u. LF power, low-frequency power normalised units; n.u. HF power, high-frequency power normalised units; LF/HF ratio, balance between the low and high frequency bands.

Psychological state.

Jenny's scores on the CSAI-2 for both somatic (from 28 to 23) and cognitive (from 23 to 15) competitive state anxiety were much lower after the HRV BFB training. After the intervention, her state confidence in sports increased from 19 to 24 (Figure 3). Figure 4 displays the improvements in Jenny's cognitive emotion regulation. Her scores increased for the CERQ domains of putting things into perspective (from 7 to 11), refocusing on planning (from 14 to 16), positive refocusing (from 9 to 12), positive reappraisal (from 14 to 17) and acceptance (from 12 to 18). After the intervention, her scores decreased in the areas of self-blame (from 19 to 17) and catastrophising (from 20 to 12).

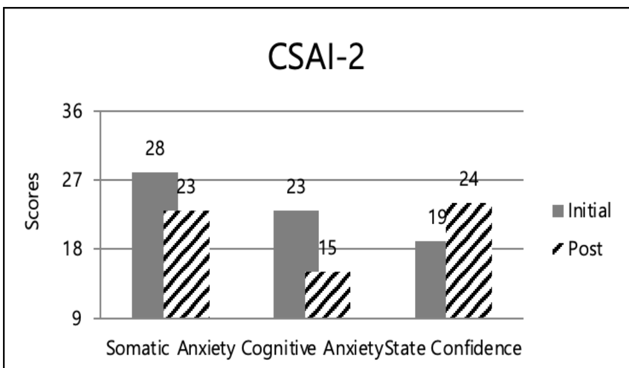

Figure 3. Pre- and post-test competitive state anxiety scores (range:9–36). CSAI-2, competitive state anxiety inventory-2

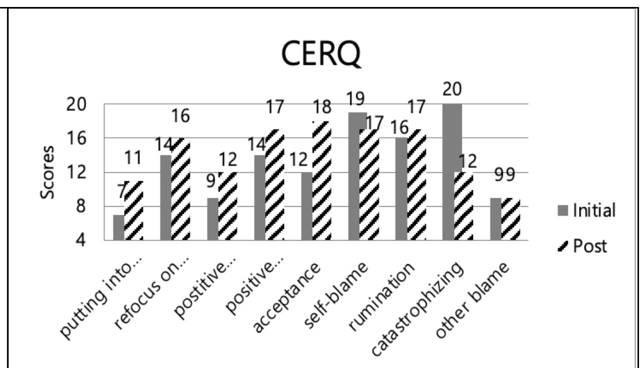

Figure 4. Pre- and post-test cognitive emotion regulation scores (range:4–20). CERQ, cognitive emotion regulation questionnaire.

Qualitative Changes

HRV BFB. Jenny reported her subjective feelings about her physiological and psychological changes after the intervention. She particularly highlighted how she was better at controlling her physiological reactions to stress through breathing.

"I think HRV BFB is helpful... After I am finished, I feel much lighter than before. It helped me to be aware that I am able to control myself." (Session 3) "I did the breathing training three times a day with Emwave2 at home. Honestly, I couldn't feel any dramatic changes yet, but I could tell you that I've slept like a baby these days." (Session 4)

"It used to be difficult to breathe when I was under too much stress. Since I started BFB training, my daily breathing pattern has changed in a good way. The best advantage of it is that I can see my physiological state in real-time. Through the feedback, I can breathe slower and deeper than before." (Session 6)

"I used to be careful at every moment of my breathing. I was too sensitive and felt keenly about my body's condition. Right now, I have confidence in being able to control my body." (Session 8)

"I don't have breathing problems anymore. When I had too much stress, I used to feel uncomfortable breathing smoothly, but I can handle it now. Before starting the competition or waiting for my turn, breathing training can be a good method for performance." (Session 9)

CR. Jenny also expressed that she had become better able to regulate her cognition. For instance, she tried to change her negative thoughts in a positive way to regulate her physical and mental state to help her performance:

"I thought that anxiety always had bad effects on my performance. So I hated it. From now on, I feel like I can see the good side of anxiety." (Session 2)

"I've never had specific strategies to change my negative thoughts and anxiety symptoms before. After writing CR, I could find different points of view. So, I feel like some negative parts have already been solved." (Session 3)

"When I felt too sensitive or someone made me nervous, I couldn't do anything for myself. I just tried to be patient. These days, I am trying to find myself in a state of balance and am changing my thoughts positively." (Session 5)

"It was the best experience to learn about how to change my own emotions. I can also have different points of view and control my emotional state in a positive way. That experience has given me more confidence in my ability to play squash." (Session 9)

DISCUSSION

The HRV BFB and CR programme based on psychophysiological approaches intended to improve self-regulation in a female squash athlete who suffered from competitive anxiety. Jenny, the participant of this study, was able to control her physiological and psychological state better due to this intervention programme. This helped decrease her state anxiety and improve her cognitive emotion regulation.

We observed differences in HRV indices in both the time and frequency domains between the initial and post-test indicators. Specifically, both SDNN and RMSSD as time domain indices were higher after the intervention. Greater HRV is generally associated with better balance of the ANS, which regulates negative psychological states such as stress, depression, and anxiety (**Lagos et al., 2008; Reiner, 2008; Beckham et al., 2013**), and a higher SDNN reflects greater HRV and physiological resilience against stress (**Kim et al., 2018**). In contrast to SDNN, RMSSD reflects markers of the PNS, which are highly correlated with HF, and HRV BFB training activates the PNS as well (**Lagos et al., 2008; Lehrer & Gevirtz, 2014**). **Muller et al**. (**2020**) applied HRV BFB training for five days to a 24-year-old female triathlete and found higher RMSSD after the training. In a similar study, **Gross et al**. (**2017**) found higher RMSSD and psychological confidence in an elite female shooter after resonant frequency BFB training. Consistent with these earlier studies, our data also presented positive relationships between HRV measured in the time domain and the psychological variables. That is, increased HRV could predict more regulated states (**Thayer et al., 2010; Prinsloo et al., 2014; Mueller et al., 2020**).

In addition, in the frequency domain of HRV, we observed changes in Jenny's LF, HF, and LF/HF ratio at the end of the intervention. LF is interpreted as activation of the SNS, which is related to increased stress or anxiety (**Appelhans & Luechen, 2006; D'Ascenzi et al., 2014; Kim & Min, 2015**). In contrast, HF reflects PNS, which is a relaxed state. A high LH/HF ratio indicates high SNS or low PNS activation (**Kim & Min, 2015**).

Theoretically, low HRV or increased LF is associated with negative responses to stress and anxiety (**Kim et al., 2017; Morales et al., 2019**). However, our study showed a contradictory result. After the intervention, LF increased and HF decreased, which resulted in a larger LF/HF ratio. **Lagos et al.** (**2008**) similarly reported higher total HRV and LF but lower HF during HRV BFB training. Dziembowska et al. (2016) also investigated the effects of a stress management programme based on rhythmic breathing with a BFB device. Dziembowska et al. divided 41 healthy male athletes into two groups and applied HRV BFB training to the experimental group in 10 sessions of 20 minutes. HRV indices changed significantly in only the experiment group, in which LF power and total power were elevated while HF power declined.

Fluctuations in HRV indices are expected during HRV BFB training because of changes in breathing patterns. Normal HRV BFB programme have paced breathing in the lower frequency band (**Lehrer et al., 2003**), and a slow breathing rate causes overlapping of HF and LF, which can lead to misapprehension of the LF power (**Strano et al., 1998**). Overall, it is clear that the BFB programme we designed helped the athlete improve breathing regulation and physiological and psychological state control.

Jenny demonstrated positive changes in anxiety reduction and adaptive strategies for cognitive emotion regulation, and these results are supported by the results of **Beck et al.** (**1992**), who studied 33 panic disorder patients. Those patients were randomly assigned to focused cognitive therapy (FCT) or brief supportive psychological therapy (BSP) for 12 weeks, and the FCT group showed significantly fewer panic symptoms and less general anxiety after the treatment than did the BSP group. These changes in anxiety levels and cognitive emotional strategies can be considered positive effects of CR.

An anxiety disorder or panic attack is caused by a catastrophic misinterpretation of bodily sensations. Indeed, in one cognitive treatment study (**Salkovskis et al., 1991**), two patients who presented with misinterpretations of bodily sensations and dysfunctional beliefs showed no changes until the cognitive treatment was applied. Among the cognitive emotion regulation and anxiety measures in this study, catastrophising and cognitive anxiety decreased considerably after the intervention. This result confirmed that CR is effective for changing negative mindsets, consistent with an earlier finding by **Clark et al**. (**1985**). These authors reported decreases in panic attacks among 18 panic disorder patients with two weeks of breathing training and cognitive reattribution training. In total, findings suggest that combining BFB and CR can support ANS balance and enhance self-regulation in the body and mind.
As observed in the results, implications for the sport field is profound, as the integrated programme can potentially aid in managing performance-related stressors and optimizing mental resilience.

In summary, the study's results contribute valuable insights to the sports field by highlighting the practical applications of the integrated programme in improving athletes' anxiety reduction and cognitive-emotional regulation. Understanding that the combination of Biofeedback and Cognitive Regulation (CR) can lead to decreased anxiety levels and improved cognitive-emotional strategies provides a valuable tool for optimizing athlete performance. Furthermore, sport psychologists can develop an expanded psychological programme to implement the combination of BFB and CR in supporting Autonomic Nervous System (ANS) balance and promoting self-regulation in both the body and mind.

The results of this study have significant implications; however, there are some limitations. This is a case study to see the changes of the participant with a support from the qualitative analysis mainly, however the quantitative results have limitations to interpret with higher statistical power. This limitation suggests a further study with a larger samples to enhance validity and reliability on the effect of the intervention programme. This is the first attempt to combine two interventions, HRV BFB and CR, to deal with psychological issues. The overall findings suggest this programme is effective for athletes in reducing competitive anxiety and enhancing skills of emotional regulation.

Conflicts of Interest

All other authors report no conflicts of interest relevant to this article.

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Ethical Clearance

Ethical approval for this study was obtained from the Kyungpook National University Industry Foundation in South Korea (KNU-2021-0157). The need for the study was explained and informed written consent was obtained from the participant. In addition, results of all the test parameters after the psychophysiology intervention programme were given to the participant.

Author Contributions

Study Design, BK and SH; Data Collection, HK; Statistical Analysis, BK; Data Interpretation, HK and BK; Manuscript Preparation, BK and SH; Literature Search, BK, and HK. All authors have read and agreed to the published version of the manuscript.

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