Effects of Biofeedback Training on Shooters' Performance, Stress Levels, and HRV

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Abstract

This study aimed to explore the impact of a 12-week biofeedback training on shooters' performance, stress levels, and heart rate variability (HRV). Thirty-six shooters aged 18-24 (18 subjects in each group) participated. The experimental group underwent 12 weeks of biofeedback and shooting training, while the control group only received shooting training. Results showed significant improvements in performance, stress levels, and HRV parameters in the experimental group, reflecting enhanced parasympathetic activity. It was further revealed that TP value was negatively correlated with stress level and positively correlated with performance, and stress level was negatively correlated with performance.

Keywords: Shooting athletes; HRV Biofeedback training; Stress levels; Shooting score

DOI: https://doi.org/10.21834/jabs.v9i28.446

1.0 Introduction

Athletes' exceptional performance during competitions results from a high degree of self-psychological regulation and optimal physical condition (Liu, 2024). In the current context of highly transparent information, athletes' physical and skill training methods are largely similar, and there is little difference in competitive levels. Thus, better regulating and controlling athletes' psychological emotions during competitions have become key factors in winning modern competitive sports. Particularly, negative emotions such as anxiety and tension before and during competitions often play crucial roles in influencing the outcomes of matches. Based on this phenomenon, this study aims to conduct a 12-week HRV biofeedback training (HRV-BF) for shooting athletes to explore its effects on shooting performance, sports stress level and HRV indicators, thereby reducing negative emotions such as anxiety and tension before and during the game.

2.0 Literature Review

Biofeedback has emerged as a valuable technique for athletes, offering means to enhance performance and well-being while managing the demands of competitive sports. This method employs sensors to monitor physiological responses like heart rate, breathing, and muscle tension, closely tied to performance and stress levels. Through biofeedback training, athletes can regulate these responses, optimizing mental and physical states for improved focus, concentration, and overall performance. Such control over stress and anxiety fosters resilience, aiding athletes in navigating competitive pressures effectively. In golf, studies by Lee et al. (2023) reveal biofeedback's efficacy in reducing anxiety and improving putting and swing accuracy. Similarly, in basketball, research by Peng et al. (2021) demonstrates its utility in enhancing shooting accuracy and reducing anxiety levels. In running, investigations by Brick et al. (2018) highlight how biofeedback improves performance by decreasing muscle tension and enhancing relaxation. Additionally, in swimming, research by Spencer et al. (2021) showcases how biofeedback enhances stroke efficiency and reduces muscle tension, thereby improving performance. In summary, biofeedback proves advantageous across various sports, including golf, basketball, running, soccer, and swimming, by reducing anxiety, increasing focus, alleviating muscle tension, and enhancing stroke efficiency, as evidenced by recent studies.

HRV training, a crucial biofeedback technique, helps understand athletes' psychological and physiological states. Heart Rate Variability (HRV) refers to the continuous fluctuation between heartbeats, known as instantaneous heart rate. It is a component of cardiovascular reactivity, also referred to as Heart Rate Reactivity (HRR) and Heart Period Variability (HPV). Under physiological conditions, HRV is primarily generated by the modulation of sinus node activity through the autonomic nervous system, central nervous system, pressure reflexes, and respiratory activity, resulting in subtle differences in the duration of each cardiac cycle. The analysis of heart rate variability involves quantitatively assessing these subtle temporal differences. Frequency domain analysis methods involve converting electrocardiographic signals into specific digital signals using specialized equipment, followed by rapid computational processing on a computer to decompose the signals into a sum of sinusoidal waves with different amplitudes and frequencies (Figure 1). Frequency domain analysis offers high accuracy and enables the separate evaluation of vagal nerve activity. Frequency domain indices include TP, VLF, LF, HF, and LF/HF ratios.

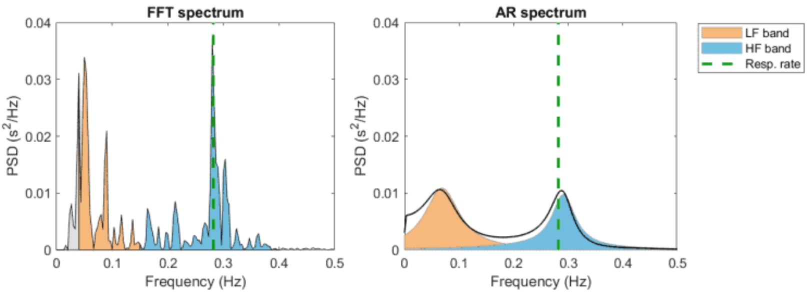

Figure 1: HRV spectrum estimates using FFT based Welch's periodogram method (left) and autoregressive (AR) modelling based spectrum estimation method.

HRV reflects the fluctuations in heartbeats, regulated by the autonomic nervous system (ANS), comprising sympathetic and parasympathetic branches. For individual athletes, both excessive sympathetic and parasympathetic activities are unfavorable for achieving their optimal competitive performance. Only when these two systems are balanced can athletes perform at their best competitive state. Studies, like Lehrer et al. (2020), showed after 10 days of 20-minute daily HRV biofeedback training, significant differences were observed in HRV, athletic performance, and attention between the experimental group and the control group ($p < 0.01$). These results suggest that biofeedback training assists athletes in controlling their psychophysiological processes, thereby helping them perform at their maximum potential. LF HRV variations over time within each group, along with an interaction of group and time ($F = 12.707$, $p < 0.001$), and all measures showed statistically significant intergroup differences ($p < 0.05$). These findings suggest HRV biofeedback lowers anxiety and potentially optimizes performance. Wahab (2015) correlated HRV parameters with training stress, aiding post-training recovery. Changes in HRV reflecting alterations in Autonomic Nervous System (ANS) patterns can serve as useful parameters for managing psychological pressure, physical fatigue, and determining exercise intensity for athletes. Barbosa's case study highlighted HRV biofeedback's role in competition pressure and neuromuscular function improvement for optimal performance. Sutarto's review further supported HRV Biofeedback as a potential intervention to enhance both fine and gross motor function in athletes. However, these studies used different frequencies and durations of HRV biofeedback training, highlighting the importance of HRV-BT for psychological health, but further scientific research is still needed to explore the relationship between HRV biofeedback training, exercise-related stress and anxiety levels, and athlete performance.

In shooting sports, achieving optimal performance demands precise aim, concentration, and focus, whether from a stationary or moving position. Mental preparedness plays a pivotal role, as highlighted by Hong et al. (2018), who stress the necessity of maintaining composure and focus under pressure for effective performance. Similarly, Granic et al. (2022) advocate for visualization techniques to enhance performance by bolstering confidence and focus. Stress is a known detractor from shooting accuracy, with Heart Rate Variability (HRV) serving as a predictor of stress's impact on performance (Stephenson et al, 2021). HRV, indicative of physiological stress and recovery, is recognized as a predictor of athletic performance across various sports (Coelho et al, 2019). Biofeedback training provides a method for athletes to regulate HRV, offering real-time feedback on physiological responses and teaching techniques to manage these responses. Several studies have explored interventions to enhance HRV regulation and shooting performance. For instance, Pinc et al. (2023) investigated the use of biofeedback training to improve HRV regulation and shooting accuracy in police officers. Michela et al. (2024) examined relaxation training's impact on shooting accuracy in military personnel. Additionally, Rees et al. (2011) studied the effects of a 4-week mindfulness-based intervention on HRV and shooting performance in athletes, finding improvements in HRV regulation, and shooting performance. However, the association between HRV biofeedback methods and shooting performance and psychological anxiety in shooting sports remains insufficiently explored. Thus, there is a clear need for further research in this area to better understand the potential benefits of HRV regulation techniques on shooting performance and athletes' psychological stress.

The purpose of this study is to conduct a 12-week experiment using HRV biofeedback training (HRV-BF) on shooting athletes, exploring its effects on shooting performance, sports stress levels, and HRV indicators of the athletes， and explore the correlation among the three.

3.0 Methodology

3.1 Participates

This study recruited 36 participants of shooter aged 18–24 years (M = 20.7, SD = 1.7) from Xinxiang Vocational and Technical College, China. Inclusion criteria included a minimum of 2 years of 10m air rifle training or participation in provincial-level competitions, good health, and no medication use; participation was voluntary. They were evenly divided into experimental (n=18， male=15， female=3) and control (n=18， male=15， female=3) groups, matched for age, gender, training frequency, and experience to minimize bias.

3.2 Procedure

Both the experimental group and the control group were required to participate in the same 12-week 10m air rifle training task arranged by the coach, and both groups were required to participate in the HRV biofeedback test, shooting test and sport anxiety scale in the first week and the 10th week. However, the experimental group needs to participate in an additional 8 weeks (4 times/week/30 minutes) of HRV biofeedback training and 3 HRV biofeedback tests from the second to the ninth week and participate in an additional HRV biofeedback test after follow-up. (Figure 2 shows the details).

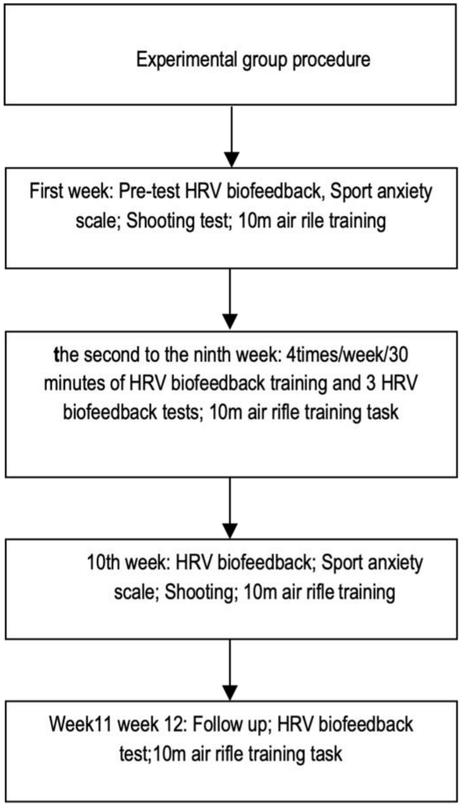

Figure 2: Experimental procedure

Breathing, often overlooked, profoundly impacts health beyond oxygen exchange. Research shows conscious breath control benefits physical and mental wellbeing, affecting brain connections, ANS balance, vagal tone, and emotion regulation pathways. Regular breathing exercises reduce stress and boost HRV levels. To apply Resonance Frequency Respiration (Figure 3 shows the Resonance Frequency Respiration Steps.) and Heart Rate Variability (HRV) practically, we propose integrating them into shooting tests. Participants engage in 5s RFR to enhance parasympathetic dominance and HRV coherence, monitored with emWave pro devices for real-time feedback.

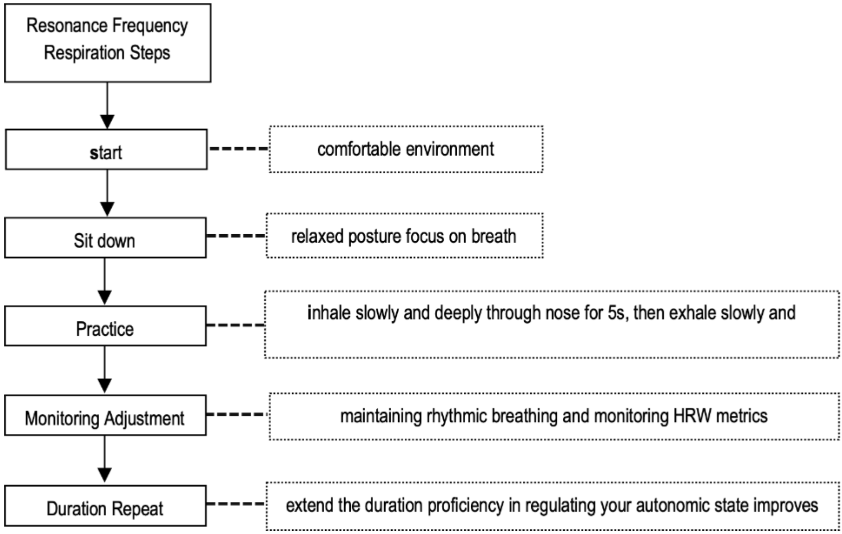

Figure 3: Resonance Frequency Respiration Steps

3.3 HRV Biofeedback Training Protocol

The purpose of HRV biofeedback training is to improve participants' HRV coherence, shooting performance and reduce participants' stress level. Before commencing HRV-BF training, participants are invited into the laboratory, where they are seated on a sofa and allowed a 2-minute rest period. The researcher proceeds to connect the equipment, initiate the system, and select the "emWave" icon before clicking on the participant's username. Following this, the researcher allocates 3 minutes to explain the operation of the instrument and adjustment procedures, aimed at preventing physiological and psychological tension in athletes. Subsequently, a 5-minute interval is designated for guiding breathing, incorporating warm-up and cool-down exercises. Moreover, the researcher then elucidates the three-step voluntary breathing method: Firstly, participants are instructed to focus their attention on the heart, conceptualizing it as a command center dispatching instructions to the brain and body. Secondly, they engage in even and deep breathing, exhaling for 5 seconds to expel excess gases and inhaling for 5 seconds to envision oxygen permeating the body for clearer thinking, while controlling the rhythm between breaths to maintain consistency in depth. Lastly, they are encouraged to cultivate positive emotions, enveloped by sensations of happiness and self-assurance. This breathing rhythm is sustained until the conclusion of the biofeedback training session. Participants are then positioned in front of laptops, with the researcher attaching the sensor to each participant's earlobe. A 20-minute biofeedback training ensues, comprising balloon and garden games segments, each lasting 10 minutes. These biofeedback training sessions adopt a comprehensive approach, integrating breath relaxation techniques with real-time physiological feedback through engaging laptop games. The incorporation of guided breathing, cool-down, and warm-up exercises enhances the efficacy of the training regimen (Figure 4 illustrates the entire protocol). Additionally, the HRV-BF training took place in the resting room for shooting athletes at Xinxiang Vocational and Technical College in China, a laboratory environment characterized by minimal disturbance, devoid of sound and motion. Supervised and led by the primary author, Huang Donghai, all training sessions were conducted with meticulous attention to detail.

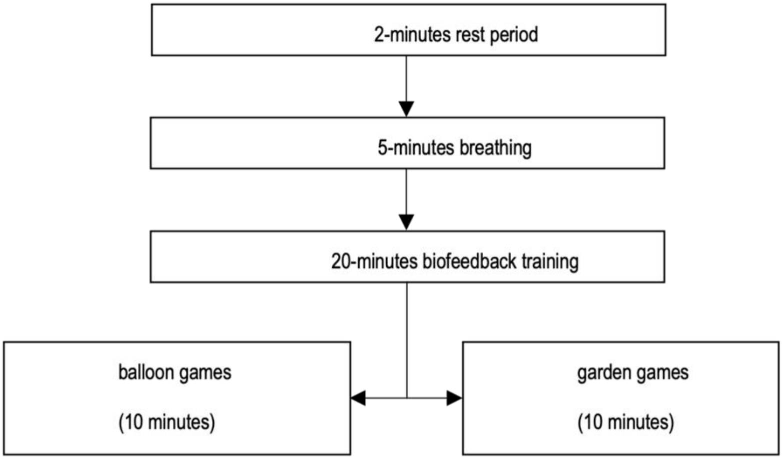

Figure 4: HRV Biofeedback Training Protocol

3.4 Measurement

HRV indicators were collected using emWave Pro from the HeartMath Institute, recording data with an earlobe pulse sensor and analyzing it with Kubios software. The Sports Anxiety Scale will evaluate stress levels in shooting sports, covering worry, concentration disruption, and somatic trait anxiety scores. Participants will fill out the scale online in Week 1 and Week 9. Shooting tasks involve firing 60 shots in 75 minutes at a 10-meter air rifle target, assessed for accuracy by mean radial distance from the target center. Shooting performance will be evaluated in the 1st, 9th, and 12th weeks to analyze performance variability. Figure 5 clearly shows the measurement method.

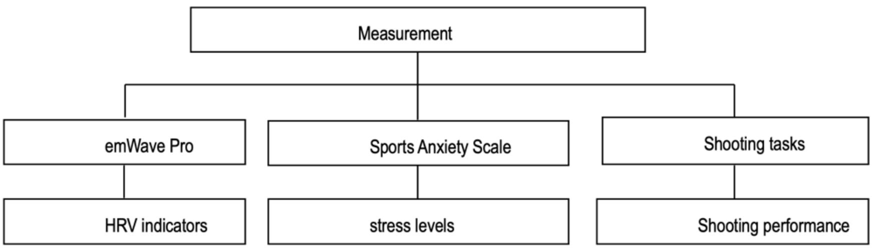

Figure 5: Data Measurement

3.5 Statistical Analysis
Data were analyzed using IBM SPSS version 22. Descriptive statistics, including mean, standard deviation, and normality tests. Comparisons between pre- and post-intervention HRV indicators, stress levels, and shooting performance for both groups were made using independent samples t-tests for inter-group and paired samples t-tests for intra-group comparisons, with a significance level of $p < 0.05$.

4.0 Results

4.1 Analysis of Changes in HRV Indicators Before and After Biofeedback Training Experiment

4.1.1 The Total Power (TP)
Total Power (TP) represents the area below 0.4Hz on the spectrum graph and reflects autonomic nervous system influence on cardiovascular function. TP indicates overall HRV changes, and studies suggest psychological interventions can raise TP values, signifying increased HRV. Before the experiment, TP values didn't differ significantly between groups. Post-intervention, the experimental group's TP values significantly increased compared to pre-test ($p<0.05$), while the control group's increase wasn't significant ($p>0.05$). After the experiment, the experimental group's TP values remained significantly higher than the control group's ($p<0.05$), indicating biofeedback training enhances TP values and HRV. During follow-up, the experimental group's TP values slightly decreased without significance ($p>0.05$), while the control group showed a slight increase ($p>0.05$), maintaining lower TP values than the experimental group ($p<0.05$). TP value reflects the overall trend of HRV changes. Numerous studies indicate that under normal conditions, correct psychological interventions can increase athletes' TP values, meaning an increase in their heart rate variability (Aubert et al,2003; Mosley et al, 2022). The results of this study prove that this study is consistent with previous studies.

4.1.2 HF
HF value in heart rate variability analysis reflects parasympathetic nervous system (PNS) activity, responsible for various bodily functions like pupil constriction and heart rate regulation. Compared to pre-training, control group athletes had significantly lower HF values ($p<0.01$), while the experimental group's decreased without significance ($p>0.05$). Post-training, experimental group athletes had significantly higher HF values than controls ($P<0.01$). During follow-up, experimental group HF values slightly decreased without significance ($p>0.05$), indicating biofeedback's lasting effect. This contrasts with control group values, showing no significant change. This suggests biofeedback training enhances PNS activity, crucial for maintaining psychological balance during high-pressure competitions, benefiting athletes' overall performance. Schwarz et al. (2003), through psychological monitoring of track and field athletes before competition, found a general

downward trend in HF values among participants. The results of this study indicate that after biofeedback training, there was a downward trend in HF values among all athletes, consistent with the findings of Schwarz et al. However, post-experiment, the HF values of experimental group athletes were significantly higher than those of the control group, demonstrating that the activity of the parasympathetic nervous system in the experimental group athletes was significantly higher than in the control group athletes.

4.1.3 LF

From Tables 1 and 2, it's clear that compared to pre-experiment, control group athletes had unchanged LF values ($p>0.05$, MD=195.3), while experimental group values significantly increased ($p<0.05$, MD=3153.06). Post-training, experimental group LF values surpassed controls significantly ($p<0.01$, $t=7.832$). LF values reflect sympathetic nervous system activity akin to VLF values. However, despite similar meanings, they showed opposite trends post-biofeedback. This disparity underscores the intricate physiological mechanisms at play, influenced by both sympathetic and parasympathetic nervous systems. During follow-up, LF values decreased in both groups without significance ($p>0.05$) but remained higher in the experimental group ($p<0.05$). This suggests lasting impact from biofeedback training, enhancing autonomic nervous system control over cardiac activity, crucial for psychological stability in high-pressure sports like shooting. Athletes' psychological realities directly clash with the competitive situation, with no intermediary or buffering stage, highlighting the critical importance of athletes' psychological stability, especially during decisive moments, where stable psychological qualities are key to success (Zhang et al, 2022). Therefore, biofeedback training can enhance the autonomic nervous system's dual control capability over cardiac activity. Due to the complexity of the mechanism underlying the autonomic nervous system's dual control capability, controlling biofeedback training poses challenges, but it significantly enhances athletes' autonomic nervous system's dual control capability.

4.1.4 LF/HF

In heart rate variability analysis, the LF/HF ratio reflects sympathetic and parasympathetic nervous system balance, gauging cardiac activity equilibrium. Lower ratios signify greater psychological stability. Previous reference values, outdated by 20 years, don't align with our study's adolescent athlete focus. Comparing pre-biofeedback data, LF/HF ratios increased post-experiment. Control group ratios surpassed experimental group post-experiment significantly ($p<0.01$, MD=10), while experimental group ratios rose insignificantly ($p>0.05$, MD=1.3). Elevated LF/HF post-experiment doesn't necessarily imply decreased psychological stability due to heightened stress before major competitions. At follow-up, the ratio of the experimental group did not decrease significantly, while that of the control group decreased significantly ($p<0.05$), indicating that biofeedback training helps maintain a lower LF/HF ratio and thus achieve optimal exercise performance, which is very close to the results of Yijing et al. (2015). Studies support biofeedback's role in regulating sympathetic and parasympathetic activity balance, thus enhancing psychological stability. This indicates that biofeedback training can assist in regulating the balance between cardiac sympathetic and parasympathetic activity, thereby enhancing psychological stability.

Table 1: Independent sample T test on the experimental results

Group		Pre-test			Post test			follow-up		
		Mean±SD	t	p	Mean±SD	t	p	Mean±SD	t	p
HF (ms^2)	Experiment-group	5247.6 ±2568.39	1.432	0.883	3903.4 ±2053.63	2.942	0.00	3803.4 ±2391.80	2.048	0.00
	Control group	5329.6 ±2496.46			1000.8 ±728.71			1389.4 ±929.35		
LF/HF ratio:	Experiment-group	1.8 ±0.62	1.341	0.291	3.1 ±2.25	5	0.00	2.8 ±1.35	5.17	0.00
	Control group	1.7 ±0.67			11.7 ±8.14			14.2 ±10.38		
Total Power	Experiment-group	836.3±484.71	0.732	0.673	2505.9 ±1244.29	4.832	0.00	2307.7 ±1027.31	4.181	0.00
	Control group	854.8±463.96			931.4 ±514.14			940.5 ±405.18		
LF (ms^2)	Experiment-group	544.4±265.80	0.583	0.853	3697.46 ±1431.87	7.832	0.00	3213.86 ±1200.54	4.716	0.00
	Control group	538.9±279.45			734.2 ±480.09			699.4 ±352.19		

Table 2: Repeated measures analysis of variance and post hoc multiple comparison results of HRV

Time1	Time2	HF (ms^2)		LF/HF ratio:		Total Power		LF (ms^2)	
Exp		MD	P	MD	P	MD	P	MD	P
Pre-test	second	-305.52	0.483	0.3	0.284	776.1	0.903	1196.16	0.738
	third	-774.4	0.372	0.1	0.173	557.2	0.829	987	0.803
	fourth	-1127.3	0.272	0.5	0.132	1178.4	0.001	2256.34	0.001
	Post	-1344.2	0.173	1.3	0.112	1669.6	0.013	3153.06	0.002

	Follow	-1444.2	0.493	1	0.101	1471.4	0..050	2669.46	0.012
second	third	-468.88	0.432	-0.2	0.984	-218.9	0.738	-209.16	0.948
	fourth	-821.78	0.382	0.2	0.973	402.3	0.563	1060.18	0.901
	Post	-1038.68	0.310	1	0.653	893.5	0.002	1956.9	0.000
	Follow test	-1138.68	0.283	0.7	0.651	695.3	0.000	1473.3	0.849
third	fourth	-352.9	0.382	0.4	0.862	621.2	0.904	1269.34	0.739
	Post	-569.8	0.273	1.2	0.673	1112.4	0.007	2166.06	0.000
	Follow test	-669.8	0.201	0.9	0.573	914.2	0.001	1682.46	0.036
fourth	Post test	-216.9	0.133	0.8	0.737	491.2	0.703	896.72	0.803
	Follow test	-316.9	0.102	0.5	0.482	293	0.505	413.12	0.540
Post-test	Follow test	-100	0.281	-0.3	0.837	-198.2	0.704	-483.6	0.894
Control		MD	P	MD	P	MD	P	MD	P
Pre-test	Post-test	-4328.8	0.000	10	0.000	76.6	0.903	195.3	0.738
	Follow test	-3940.2	0.000	12.5	0.000	85.7	0.832	160.5	0.693
Post-test	Follow test	388.6	0.672	2.5	0.000	9.1	0.704	-34.8	0.894

4.2 The Effect of the Biofeedback Training Towards Shooting Athlete Stress Level

Paired-sample t-tests were used to assess psychological stress level changes within groups pre- and post-biofeedback training. Table 3 indicates that there was no significant difference in psychological stress levels among the control group before and after the experiment ($P > 0.05$, $t = 1.197$, $t = -0.181$, $t = 1.598$). The average Concentration disruption score before the experiment was lower than after ($t = -0.181$), suggesting an increase in

Concentration disruption scores in the control group, which could impede athletes' performance. However, the average worry and somatic trait anxiety scores before the experiment were higher than after (t = 1.197, t = 1.598), indicating a decrease in worry and somatic trait anxiety scores after the experiment, although not significantly different (P > 0.05). In contrast, the experimental group showed significant differences in psychological stress levels compared to before the experiment (p < 0.01, t = 5.912, t = 9.892, t = 9.857). The average worry score, Concentration disruption score, and somatic trait anxiety score before the experiment were all lower than after. Overall, the control group showed no significant change in psychological stress levels after routine training, while the experimental group experienced a significant reduction in psychological stress levels through HRV biofeedback training, indicating that HRV biofeedback training can decrease psychological stress levels among shooting athletes.

Table 3: Dependent t-test for paired samples for athletic stress level

			Control group			Experimental group		
		test	Mean±SD	t	p	Mean±SD	t	p
Pair 1	worry score	pre	19.17±4.793	1.197	0.248	20.61±5.669	5.921	0.000
	worry score	post	18.78±4.570			12.67±6.325		
Pair 2	Concentration disruption score	pre	15.44±3.072	-0.181	0.859	15.28±3.409	9.892	0.000
	concentration disruption score	post	15.50±3.204			8.06±2.313		
Pair 3	somatic trait anxiety score	pre	34.72±6.479	1.598	0.129	35.22±7.134	9.857	0.000
	somatic trait anxiety score	post	33.78±6.358			15.67±5.881		

Independent-sample t-tests compared psychological stress levels pre- and post-biofeedback training between groups (table 4). Initially, both groups had similar stress levels (p > 0.05). Post-experiment, significant differences emerged (p < 0.01). The control group exhibited higher stress levels than the experimental group (t = -3.323, t = -7.993, t = -8.872). Notably, the experimental group showed lower stress levels, indicating biofeedback training reduced psychological stress, aiding in competition and training adaptation for optimal performance. Before training, athletes' psychological challenges included excessive focus on results, strong desires to win, fear of disappointing others, concentration difficulties, and poor emotion regulation. Post-training, stress levels decreased, indicating improved psychological regulation and competition focus, affirming the efficacy of biofeedback training.

Table 4. Independent samples t-test for athletic stress level

		Pre-test			Post-test		
	group	Mean±SD	t	p	Mean±SD	t	p
worry score	experiment	20.61±5.669	0.826	0.859	12.67±6.325	-3.323	0.002
	control	19.17±4.793			18.78±4.570		
concentration disruption score	experiment	15.28±3.409	-0.154	0.736	8.06±2.313	-7.993	<0.001
	control	15.44±3.072			15.50±3.204		
somatic trait anxiety score	experiment	29.61±8.879	-1.619	0.335	15.67±5.881	-8.872	<0.001
	control	33.78±6.358			33.78±6.358		

4.3 The Effect of the Biofeedback Training Protocol Towards Shooting Performance

Paired-sample t-tests were conducted to analyze the differences in shooting performance within groups before and after biofeedback training (table 5). According to Table 5, compared to pre-training data, there was a significant difference in shooting performance in the experimental group post-training (p < 0.001, t = -6.007), whereas the control group showed a slight increase compared to pre-training but lacked significant difference (p > 0.05, t = -0.174).

Table 5: Dependent t-test for paired samples for shooting performance

		Experimental group			Control group		
		Mean±SD	t	p	Mean±SD	t	p
Shooting score	pre	580.922±26.860	-6.007	<0.001	583.294±34.435	-0.174	0.841
	post	591.950±28.504			585.544±34.445		

Independent-sample t-tests compared shooting performance between groups pre- and post-biofeedback training (table 6). Pre-training, both groups had similar scores (p > 0.05). Post-training, the experimental group had a significantly higher average score than the control group (p < 0.01, M = 591.950, M = 585.544), indicating biofeedback training's positive impact. In the ten-meter air rifle competition, athletes execute various actions for each shot. Excessive, prolonged, fast, or slow movements are considered abnormal. During the final testing phase, observations revealed nervousness signs in control group athletes, such as flushed complexion and rapid breathing. Experimental group athletes exhibited fewer excess movements, suggesting a better psychological state and performance.

Table 6. Independent samples t-test for shooting performance

		Pre-test			Post-test		
	group	Mean±SD	t	p	Mean±SD	t	p
Shooting record	experimental group	580.922±26.860	0.796	0.859	591.950±28.504	3.236	<0.001
	Control group	583.294±34.435			585.544±34.445		

4.4 the correlation of achievement, shooting performance and stress level

From Table7, it is evident that using Pearson Correlation analysis on TP (Total Power), performance, and stress level reveals significant positive correlations between Achievement and shooting score at the 5% significance level. This indicates that performance increases with rising TP (Total Power), further demonstrating the beneficial effect of biofeedback training on improving shooting performance.

Additionally, TP values exhibit a significant negative correlation with stress score at the 5% significance level. stress scores decrease as TP values increase or increase as TP values decrease. Since lower stress level are advantageous for shooting athletes to control anxiety levels, and TP values are associated with the duration and frequency of biofeedback training experiments, biofeedback training is beneficial for reducing athletes' levels of psychological pressure.

Moreover, shooting performance show a significant negative correlation with stress level at the 5% significance level. Shooting scores increase as stress values decrease or decrease as stress values increase. The magnitude of stress values also correlates negatively with biofeedback training, indicating that longer durations or more frequent biofeedback training sessions result in smaller stress values and consequently higher shooting performance. This study aligns with Kim's findings, suggesting that current neurobiological evidence indicates that HRV is influenced by stress and supports its use for objective assessment of psychological health and stress. Lee (2023) suggests that biofeedback training programs elicit psychophysiological changes, leading to improved performance.

Table7: Pearson Correlation Analysis for TP (Total power), Performance and Stress level

	Achievement	shooting score	SAS
TP (Total Power)	1		
Performance	0.813**	1	
Stress level	-0.627**	-0.765**	1

*Note: The asterisk ***, **, and * represent related of significance at 1%, 5, and 10% respectively.*

5.0 Conclusion & Recommendations

Following emWave-based biofeedback training, shooters' HRV increased, indicating enhanced psychological relaxation ability. Total power (ms^2) and LF indicators showed a rising trend. Moreover, shooters could consciously control the reduction in sympathetic nervous system activity, lowering the balance ratio between the sympathetic and parasympathetic nervous systems, thereby enhancing their ability to regulate the autonomic nervous system. This, in turn, led to an increase in shooters' dual dominance over the autonomic nervous system, resulting in enhanced psychological stability. Additionally, after emWave-based biofeedback training, the training and competition stress levels of shooters decreased, aiding in improving training effectiveness and ensuring shooters perform at their best in major competitions. The training significantly aided in improving shooters' competition results and stabilizing their performance during competitions. After relevant research, it was found that TP value was negatively correlated with stress level and positively correlated with performance, and stress level was negatively correlated with performance. Although biofeedback training has a variety of positive effects on athletes' psychology, this study still has certain limitations, such as: the proportion of female participants is small, which may lead to biased results due to gender differences;

this experiment only tested athletes with 10m air rifles and did not classify athletes of various shooting types (pistols, sniper rifles, etc.), which may lead to the experimental results not being universal.

Based on these research findings, it's recommended that biofeedback training be integrated into athletes' training programs to enhance psychological relaxation and improve performance outcomes. Furthermore, the management should consider incorporating other psychological training methods alongside biofeedback training to comprehensively address athletes' psychological issues. This study only analysed HRV (HF, LF/HF, TP, LF) indicators. These indicators are representative but not comprehensive enough. It is hoped that in future studies, we can focus on other HRV indicators (SDNN, RMSSD, PNN50, etc.) to further verify the psychological impact of HRV biofeedback training on athletes. This is also a valuable research direction in the future.

Acknowledgement

The authors would like to express their gratitude to Dr. Muhammad Nubli Abdul Wahab, Dr. Zhang Xiuling and Ji Dongya for their guidance and assistance in the preparation of this thesis project.

Article Contribution to Related Field of Study

This study explored the possibility of improving shooting athletes' performance and reducing psychological stress by proposing a personalized training program and incorporating biofeedback into sports training. The practical application is not limited to shooting sports, but also helps other types of athletes (diving, skiing, etc.) to improve their performance by using this stress management method. These findings provide a reference for coaches and sports science practice policies and promote the advancement of training programs.

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