Effectiveness of an Integrated Mental Skills and Biofeedback Training Program on Sport Shooters

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Abstract

As winning margins narrow in competitive elite sports, the management of psychological and physiological states are critical to ensure optimal performance, especially in closed skill accuracy sports. This intervention study examines the effectiveness of an integrated mental skills and biofeedback training program on fifty air rifle and air pistol shooters from a school air weapons team. The experimental group participated in an intervention program focused on self-talk, relaxation, imagery, and automaticity (or routines), together with HRV biofeedback training. Post-intervention, the experimental group had significantly higher pre-performance HRV and had higher scores for self-talk, relaxation, imagery, and automaticity compared to the control group. Although shooting scores improved at the end of the intervention, the increase was not statistically significant but has great practical implications in elite sport. The improvement in HRV together with the higher shooting scores post-intervention shows improved psychophysiological control which was translated into better performance.

Keywords: heart rate variability, mental skills, biofeedback, shooting, psychophysiology.

Winning margins in elite sports are getting smaller as it was discovered that the difference between the first and fourth place at rowing events at the 2008 Olympics was only about 1% (Birrer & Morgan, 2010). Many believe that the difference between first and fourth is largely psychological, since mental factors account for forty to ninety percent of success in sports performance (Williams & Krane, 2001). Indeed, psychological factors play a critical role in the acquisition of skills and development of expertise in sports (Baker & Horton, 2004). Through mental skills training, athletes are taught essential skills to cope with both training and competition stress. Specifically, psychological skills can help the athlete across a myriad of situations such as learning a new skill (Waskiewicz & Zajac, 2001), coping with difficult situations like injury (Rose & Jevne, 1993), as well as performing at important competitions (Gould et al., 1992a; Gould et al., 1992b).

Jackson and colleagues (2001) looked at psychological skills and the flow state and discovered a positive relationship between flow and the use of psychological skills, providing indirect support for the notion that greater use of mental skills will improve sports performance. Research on mental skills training effectiveness has been generally positive with a meta-analysis of the effectiveness of psychological interventions having moderate to large positive effects on sport performance (Myers, Whelan, & Murphy, 1996). Mamassis and Doganis (2004) proposed that mental skills training (MST) programs enhance performance in athletes by changing their pre-competition anxiety levels to be more accurate and optimistic. MST involves the use of sport-specific mental skills like goal setting, relaxation, imagery, self-talk (Vealey, 2007; Williams, 2010), the four basic mental skills often cited in the literature on mental skills training (Hardy et al., 1996).

A mental skills training intervention study that examined if mental skills training on relaxation, imagery, self-talk, and goal setting was effective in improving running performance over a 1,600m distance found that running times did indeed improve and a positive correlation emerged between use of mental skills and running performance (Patrick & Hrycaiko, 1998). Likewise, Thelwell and Maynard (2003) developed a mental skills training program for cricketers, focusing on five cricket-specific mental skills of goal setting, activation regulation, self-talk, imagery, and concentration. After weekly mental skills training held over twelve weeks conducted by a British Association of Sport and Exercise Science (BASES) accredited sport psychologist, the performance of the cricketers not only improved but was found to be more consistent. Specifically, the use of mental skills and subjective performance were found to be positively correlated, with athletes who felt they performed better using more mental skills (Thelwell & Maynard, 2003). However, as these studies were both correlational and had small sample sizes of three and sixteen participants, cause and effect could not be ascertained.

At the same time, Thelwell and Maynard's (2003) study was conducted on adult semi-professional cricket players and Patrick and Hrycaiko's (1998) study was also conducted on adult elite runners and triathletes, so its effects on developmental or younger athletes cannot be established. Sharp and colleagues (2013) argue that most of the research on mental skills and sports performance has mainly focused on elite level athletes who already have the necessary physical, mental, technical, and tactical qualities required for successful performance, neglecting the impact of such training on youth athletes. According to Tremayne and Tremayne (2004), mental skills training programs are beneficial for youth athletes as it aids their psychological development in competitive youth sports that may even be transferred to other aspects in life such as school. It is believed that youth athletes reap greater benefits from mental skills training than older athletes (Vealey, 1988). Developing mental skills amongst youth athletes has been found to account for 50% of their ability to progress effectively in their sport (Kunst & Florescu, 1971, as cited in MacNamra, Button, & Collins, 2010). At the same time, young athletes who use mental skills early in their sports career were found to have enhanced coping skills when they grew older (Lane, Harwood, Terry, & Karageorhis, 2004). In support of these claims, an intervention study on 36 young developmental swimmers found that a seven-week mental skills training program was effective in improving swimming performance as well as positive psychological functioning (Sheard & Golby, 2006).

In a qualitative study that looked at the effectiveness of mental skills training on youth athletes, it was discovered that mental skills training programs increased athletes' knowledge of mental skills, improved team cohesion, and increased openness, honesty, as well as self-regulation (Sharp, Woodcock, Holland, Cumming, & Duda, 2013). At the same time, for mental skills training programs to be effective, they need to be customized to address the specific needs of the sport and the young athletes in that sport (Sharp et al., 2013). Tailoring interventions based on type of sport, such as closed and open skill sports, may be of critical importance. A study that examined the differences in a mindfulness and acceptance intervention and a mental skills training intervention on elite youth golfers found that a mindfulness and acceptance intervention was effective in improving performance, with all the seven golfers improving their national rankings while only two out of six golfers in the mental skills training group improved their rankings (Bernier, Thienot, Codron, & Fournier, 2009). They argued that it was the increased awareness of the mindfulness and acceptance intervention that allowed them to manage their physiological and mental states better (Bernier et al., 2009). Golf is a closed skill accuracy sport like shooting, where awareness of psychophysiological state is paramount and this study lends further support for psychophysiological measures to be built into intervention programs for closed skill accuracy sports.

Physiological state is one of the sources of self-efficacy as identified by Bandura (1977). Stressful tasks commonly elicit negative emotions and a cardiovascular response (Feldman et al., 1999). Therefore, when an athlete is able to manage the negative effects of the stress response, it is likely to lead to enhanced self-efficacy, or an increased belief in one's ability to perform the skills required for the sport. One possible indicator of an athlete's physiological state could be heart rate variability (HRV). Normal heart rate varies and this variability reflects ability to respond to dynamically changing environments (Porges, 1992). HRV is the temporal beat-to-beat changes in heart rate (Kemp & Quintana, 2013) and having high levels of HRV indicates a healthy autonomic nervous system that is reflective of calmness, concentration, and emotional control (Strack & Gevirtz, 2011).

Ortega and Wang (2017) conducted a study on 61 air rifle and air pistol shooters in Singapore of different experience levels, novice, intermediate, and advanced. Significant differences were found in the use of mental skills and pre-performance heart rate by experience levels, with advanced shooters using more mental skills and had lower average heart rate as compared to novice and intermediate shooters (Ortega & Wang, 2017). They measured ultra-short term HRV of one minute using time frequency HRV analysis, assessing both standard deviation of normal-to-normal intervals (SDNN) and root mean squared standard deviations (RMSSD; Ortega & Wang, 2017). Although HRV did not differ significantly across the three groups of shooters, HRV measured by SDNN was found to be the only significant predictor of shooting performance (Ortega & Wang, 2017). HRV measured by RMSSD was not a significant predictor, even though RMSSD was believed to be the best indicator of ultra-short term HRV measurements of one minute or less (Esco & Flatt, 2014; McNames & Aboy, 2006; Nussinovitch et al., 2011). Based on these findings, the authors postulated that SDNN could be a better reflection of an athlete's psychophysiological state as compared to RMSSD which may be more reflective of the athlete's physical state (Ortega & Wang, 2017). Past research on RMSSD measured resting HRV without stress and this could be the main differentiating factor between RMSSD and SDNN (Esco & Flatt, 2014; McNames & Aboy, 2006; Nussinovitch et al., 2011). In the pre-performance state, athletes would experience some levels of stress and as such, it could explain why SDNN is more accurate gauge of an athlete's pre-performance psychophysiological state (Ortega & Wang, 2017).

HRV biofeedback training involves teaching individuals to take slow deep breaths from the diaphragm to synchronize their heart rate with their respiration rates (Strack & Gevirtz, 2011). Maman and Garg (2012) conducted an intervention study that looked specifically at the effectiveness of HRV biofeedback training in improving sports performance and self-efficacy levels of thirty basketball players. While the control group showed no changes, the placebo group showed significant improvements in self-efficacy and performance, whereas the experimental group showed the greatest effects with significant improvements in self-efficacy, HRV, and performance (Maman & Garg, 2012). The researchers argued that HRV biofeedback training improved performance because of lowered anxiety levels, and as such, was effective in improving an athlete's ability to self-regulate physiological responses to stress (Maman & Garg, 2012). Another study supported this claim that athletes improved their self-regulation skills through HRV biofeedback training, as those who received HRV biofeedback training reported greater reductions in psychological responses to injury and pain while HRV increased (Rollo, 2014).

When biofeedback is integrated with psychological skills training, the athletes' self-regulation skills improved (Blumenstein, Bar-Eli, & Tenenbaum, 2002). Research on the effectiveness of integrating biofeedback training with mental skills training has been limited but early research has found that this integrated approach has improved performance in athletes such as swimmers and speed-skaters (Bar-Eli & Blumenstein, 2004; Beauchamp, Hardy, & Beauchamp, 2012; Prapavessis, Grove, McNair & Cable, 1992). Prapavessis and colleagues (1992) conducted an intervention case study on an elite rifle shooter that combined both mental skills and biofeedback training and found state anxiety decreased and shooting performance improved post-intervention. Bar-Eli and Blumenstein's (2004) research on pre-elite swimmers showed that biofeedback and psychological skills training resulted in improved performance when compared to the relaxation training alone group. Similarly, an integrated program on the Canadian National Short Track Speed skating team for three years in the lead-up to the Vancouver Winter Olympics in 2010 involved a program approach based on Thomas (1990), where psychological skills training was integrated with biofeedback training (Beauchamp, Hardy, & Beauchamp., 2012). The athletes from this program performed well at the Olympic Games – the team won two gold, two silver, and one bronze medals, had fourteen finalists at the games, and individual and team rankings improved during this time period (Beauchamp, Hard, & Beauchamp, 2012). Although causality could not be determined as it was not an empirical study, it lends to the supporting literature that an integrated psychological skills training and biofeedback training program can improve performance.

Anderson, Hanrahan, and Mallet (2014) advocated the need for traditional sport psychology practices to be more specific in targeting athlete's self-regulation skills so that they can effectively self-regulate to achieve peak performance in sport. Since both MST and biofeedback training have the same objective of improving the athlete's self-regulation skills and self-efficacy to enhance performance, integrating biofeedback into a MST program is a sensible progression that could potentially be the answer to Anderson and colleagues' (2014) challenge to sport psychologists around the world.

An earlier study by Ortega and Wang (2017) uncovered that advanced shooters were found to use more self-talk, relaxation, imagery, and automaticity compared to novice shooters in Singapore. As such, it is reasonable to assume that these four specific mental skills are required to optimize their physiological arousal levels for optimal performance in shooting. It was also discovered that advanced shooters had significantly lower average heart rate before shooting compared to both the novice and intermediate shooters (Ortega & Wang, 2017). Therefore, the four mental skills of self-talk, relaxation, imagery, and automaticity (or routines), together with HRV biofeedback training will be incorporated into a series of three workshops designed specifically for shooters. The program was deliberately designed to be a short-term intervention to fit into the busy schedules of student-athletes in Singapore so as to ensure their full commitment to the program. Although frequency and length of biofeedback training sessions were highlighted as a major methodological concern (Shellenberger & Green, 1986), it is argued that HRV biofeedback training programs in particular can be shorter in duration since breathing is a skill that can be practiced anytime and anywhere. The HRV biofeedback training will also be integrated with the mental skills training and made relevant specific to the mental demands of sport shooting to ensure maximum effectiveness and buy-in from the participants.

In agreement with the need to focus on the effectiveness of mental skills training for youth sport athletes rather than elite athletes, as well as the need to customize mental skills training programs and build in psychophysiological interventions, this study focused on youth athletes – school shooters in Singapore within the age range of 13 to 18 and the intervention program was tailored to suit the needs and demands of young sport shooters. The quantitative nature of this research study will expand on earlier qualitative findings and allow for cause and effect relationships to be determined. It was expected that the shooters who participated in the intervention would have higher self-efficacy, heart rate variability, use of mental skills, as well as shooting scores post-intervention as compared to the pre-intervention phase.

Method

Participants

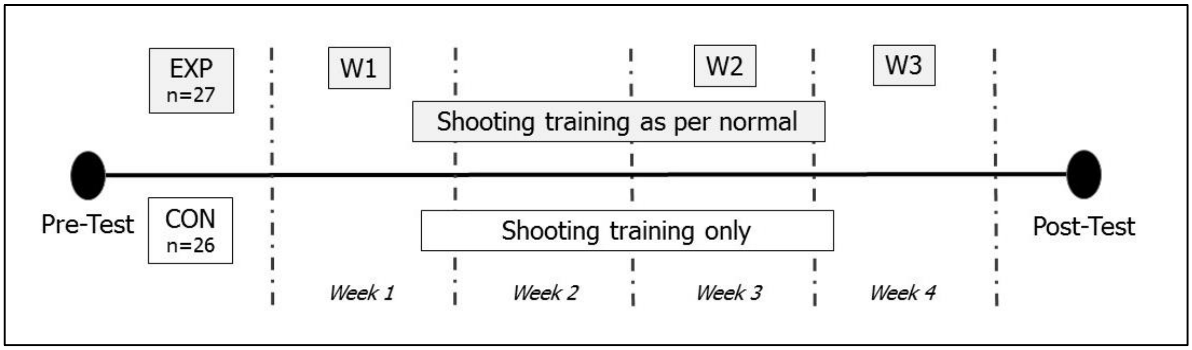
The overall sample consisted of 33 females (66.00%) and 17 males (34.00%), with 23 pistol shooters (46.00%) and 27 rifle shooters (54.00%). The unbalanced gender sample was due to the natural gender bias within the school's air weapons team, where there were more females than males. On average, the 50 shooters in this study had 1.69 years of experience shooting (SD = 1.21) and the average age was 14.98 years (SD = 1.39). All the participants were divided into two groups, with 25 (50.00%) participants in the experimental group and 25 (50.00%) participants in the control group using matched assignment based on weapon type, gender, age, and shooting experience.

The control group comprised of 15 air rifle shooters (60.00%) and 10 air pistol shooters (40.00%), with an average age of 14.88 years (SD = 1.42). The control group had an average of 1.86 years (SD = 1.25) of shooting experience, and there were 9 males (36.00%) and 16 females (64.00%). The experimental group was matched with age, gender and experience as closely as possible, but due to participant withdrawals, only age, gender, and experience could be matched closely, and not weapon type. Both groups had shooters with zero to five years of shooting experience and the age range for each group was also the same at 13 to 18 years. The experimental group had 12 air rifle shooters (48.00%) and 13 air pistol shooters (52.00%). The gender distribution of the experimental group consisted of 8 males (32.00%) and 17 females (68.00%). The average age of the experimental group was 15.08 years (SD = 1.38), and the shooters in this group had an average of 1.52 years (SD = 1.17) of shooting experience.

Experimental Design

A single case research design (A-B-A) was used to examine differences in dependent variables in the pre- and post-intervention phases of the study. The A-B-A design allows for a stronger argument that the intervention was responsible for the changes in the dependent variables (Gast & Ledford, 2014). The pre- and post-intervention phases were conducted within a week each, sandwiched by a 4-week intervention for the experimental group. The control group continued with training during the intervention period, while the experimental group had three workshops of about an hour's duration on week 1, week 3, and week 4, on top of their usual training. There was a one week break between workshop one and two due to school holidays and school functions. However, shooting training still continued during the second week. The school adopts a flexible training policy, requiring every shooter to train a minimum of once a week. This means that during the four weeks of the study from the pre to the post test, there was a maximum of 20 training days and a minimum of 4 training days that every shooter could attend. However, as part of the school policy, the older shooters were required to stop their attendance at shooting to focus on their upcoming major examinations. As such, there were shooters who only trained once during the four-week intervention. Figure 1 shows the overall design of this intervention study.

Figure 1. Intervention Study Design



Measures

Pre-Test Questionnaire. A four-part shooting questionnaire consisting of demographic details, a ten-item shooting-specific self-efficacy questionnaire, the 32-item TOPS2 Training (Thomas et al., 1999), and shooting performance evaluation was administered. In the first section, participants were required to state their demographic details together with a prediction of the overall shooting scores they believed they could attain as well as to define what they believed constituted good and bad shots, ranging from 10.9 to 0. The definitions and individualized range for a good and bad shot was to ensure that participants understood what "good shots" and "bad shots" in the subsequent self-efficacy rating scale meant.

Shooting Self-Efficacy. A shooting-specific self-efficacy scale was used, in accordance to Bandura's (1986) micro-analytic approach to measuring self-efficacy. Participants rated their confidence levels on ten shooting-specific tasks that were important for optimal performance in shooting training. Examples of statements of shooting-specific tasks include "achieve my overall score", "hit three of more consecutive good shots", and "stay calm and composed throughout each series".

TOPS2 Training. The TOPS2 Training questionnaire required participants to rate how often they felt each statement applied to them specifically in the training context on a 5-point

Likert scale (1 = never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always). The TOPS2 training scale measures eight factors – self-talk, emotional control, automaticity, goal setting, imagery, activation, relaxation, and attentional control (Thomas et al., 1999).

Post-Test Questionnaire. There was a slight variation in the demographic details for the post-test questionnaire, with number of training sessions attended and frequency of use of mental skills for the experimental group since the pre-test asked instead of the demographic details in the pre-test questionnaire. The control group's post-questionnaire required participants to state how many training days they participated in from the time of the pre-test till the day of the post-test. In addition to this question, the experimental group's post-questionnaire had two more questions, one asking how often the participant used the mental skills taught in the workshops in shooting, while the other asked how effective the workshops were in improving their shooting. For both these questions, a seven-point Likert type scale was used with descriptors of the response anchors based on recommendations by Vagias (2006).

Shooting Performance Evaluation. Shooting scores were counted manually on the paper targets by the shooters in accordance to International Sport Shooting Federation rules for competition qualifying rounds (ISSF, 2013). Participants were asked to rate their shooting performance and were also allowed to write feedback about their own shooting performance.

Heart Rate Variability. HRV was measured in the pre- and post-test using Thought Technology's ProComp Infiniti hardware and BioGraph Infiniti software (Thought Technology, Montreal, Canada), together with the compatible Polar H7 EKG Belt (Polar Electro Oy, Kempele, Finland) used with Thought Technology's Polar EKG sensor, as well as Thought Technology's respiration belt. Each shooter wore the Polar EKG belt with the H7 Bluetooth module around the chest while the respiration sensor was placed around the abdomen.

Procedure

This study was approved by the university's Institutional Review Board. As participants were all below the age of 18, parental consent forms were obtained before commencement of the study. Informed consent was also sought from each shooter during the briefing of the study.

The study took place in a room located at the schools' air weapons range. For the pre-test, participants were briefed about the objectives and procedures of the study in detail and shown how to put on both the Polar EKG belt and Thought Technology's respiration belt. Thereafter, each participant was provided with a clipboard and pen with a full set of the four-part questionnaire. Participants were instructed to complete the first three parts of the questionnaire before shooting, and the last part of the questionnaire after shooting. On average, it took approximately ten minutes to complete the questionnaire before shooting. After completing the first part of the questionnaire, each participant's heart rate variability was measured individually using both the ProComp Infiniti. Participants were seated comfortably in front of a laptop with the customized Biograph Infiniti screen that captured heart rate and respiration rate and they were instructed to relax as they normally would before a competitive shoot. Each participant completed their heart rate measurements in 1.5 minutes to ensure that the HRV data can be compared across participants (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Participants then proceeded to do the standardized competition procedures for the 10m air rifle and air pistol events as set by the International Sport Shooting Federation (ISSF). This included 15 minutes of preparation and sighting shots, followed by 40 competition shots in 60 minutes. Once participants completed their 40 competition shots, they then completed the last part of their questionnaires. Thereafter, participants were debriefed and thanked for their participation.

The pre-tests were completed for all participants within two weeks. Thereafter, the experimental group went through three workshops of approximately one hour in duration covering four mental skills as identified in the earlier study of relaxation, self-talk, routines, and imagery. During the workshops, the participants also underwent basic HRV training, learning slow diaphragmatic breathing at six breaths per minute. Importantly, participants were reminded to practice the breathing technique every day and taught how to integrate relaxation, self-talk, routines, and imagery as well as the diaphragmatic breathing technique into their shooting routines.

Workshop groups were kept small and divided into five smaller subgroups of four to six participants to enable personalized interventions and to ensure that there was adequate time for each shooter to do individual biofeedback training. This meant that each workshop was repeated five times across the five days in a week to accommodate for the students' hectic schedules, grouping by weapon type for more relevant instruction, as well as to maximize learning outcomes. Having small groups in the workshops is useful for teaching as it has been found to increase interest, retention of knowledge and skills, and improve self-directed learning (Meo, 2013).

The three workshops were completed within three weeks and during which, both control and experimental groups continued with their training sessions as per normal. To ensure participation throughout the study, during the first workshop, participants were reminded of the importance to commit to all three workshop sessions and not to miss workshops. Participants were also given the flexibility to attend other workshop groups in the event that they could not attend a workshop due to school commitments. Although undesirable, this was done because the students' school schedules were somewhat unpredictable and a degree of leeway was needed to ensure maximum participation and minimize dropout rates.

After all workshops were completed, both the experimental and control groups did the post-test within the last two weeks of the study. The post-test was conducted exactly the same as the pre-test but the control group completed a slightly different questionnaire from the experimental group, as outlined in the measures section. To ensure the shooters felt the significance of the post-test shoot, it was conducted as part of their school team's internal competition, where all shooters were required to complete one competition qualifying round of either 40 or 60 shots for females and males respectively in their respective disciplines and they were ranked according to their scores.

Results

The pre-test measures were first analyzed to ensure homogeneity between the control and experimental group. By chance, the control group shooters had a higher shooting score of 329.76 (*SD* = 39.29), while the experimental group shooters had a lower shooting score of 307.20 (*SD* = 52.46), but this was found to lack statistical significance. There were no significant differences for all variables across both groups.

On average, the shooters from both the experimental and control groups attended shooting training for 6.66 days (*SD* = 3.34) in the four weeks from the pre-test to the post-test, out of the maximal 20 days of shooting training. The control group shooters reported training for an average of 6.76 days (*SD* = 3.23), while the experimental group shooters reported a similar number of training days (*M* = 6.56; *SD* = 3.30).

Subjective feedback regarding the workshops were gathered from the experimental group, and they reported using the mental skills taught to them about 50% of training time (M = 4.52, SD = .71), and felt that the workshops were moderately effective in helping them to improve their shooting performance (M = 4.88, SD = .73).

On average, during the pre-test, the experimental group predicted that they would score 319.68 (SD = 38.52) and scored lower at 307.20 (SD = 52.46). During the post-test, the difference in predicted and actual scores was diminished with a prediction of 323.12 (SD = 41.44) and an average score of 322.20 (SD = 36.65). On the other hand, the control group predicted their scores to be about 333.12 (SD = 34.56) during the pre-test, yet scored lower at 329.76 (SD = 39.29). For the post-test, the control group also estimated a higher average score of 335.92 (SD = 26.68) but likewise scored lower with an average shooting score of 332.24 (SD = 33.97). Both groups scored higher during the post-test. Table 1 shows the differences in predicted and actual scores for both groups in the pre- and post-test conditions.

Table 1.

Differences in Predicted and Actual Scores Pre- and Post-Test

	Control Group				**Experimental Group**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Predicted Score	333.12	34.56	335.92	26.68	319.68	38.52	323.12	41.44
Actual Score	329.76	39.29	332.24	33.97	307.20	52.46	322.20	36.65
% Change	-1.02		-1.11		-4.06		-.29	

Table 2 shows the means and standard deviations for the control and experimental groups in the pre- and post-test for self-efficacy, HRV, TOPS2 variables (attentional control, goal setting, self-talk, emotional control, activation, relaxation, imagery, and automaticity), as well as their actual shooting scores.

Table 2.

Descriptive Statistics of Variables Pre- & Post-Test

	Control Group				**Experimental Group**			
	Pre-test		**Post-test**		**Pre-test**		**Post-test**	
Variables	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
Self-Efficacy	7.00	1.52	6.90	1.74	6.24	1.71	6.56	1.44
HRV (SDNN)	56.14	23.22	62.52	22.30	49.95	24.29	70.75	33.00
Attentional Control	3.24	.55	3.30	.48	3.03	.51	3.11	.65
Goal Setting	3.23	.60	3.24	.60	3.13	.83	3.11	.67
Self-Talk	3.12	.85	3.08	.69	2.90	.88	3.40	.67
Emotional Control	3.28	.64	3.25	.70	3.17	.68	3.15	.52
Activation	2.88	.65	3.07	.53	2.89	.68	3.09	.57
Relaxation	2.99	.60	2.93	.64	2.67	.74	3.14	.56
Imagery	3.00	.53	3.07	.71	2.85	.66	3.13	.63
Automaticity	3.42	.59	3.51	.69	3.21	.48	3.45	.51
Actual Shooting Score	329.76	39.29	332.24	33.97	307.20	52.46	322.20	36.65

After attending three workshops, the experimental group shooters had improved self-efficacy, HRV, and shooting scores. A repeated measures ANOVA was used to assess the effectiveness of the intervention program on self-efficacy, HRV, and shooting score. Although all three measures improved post-intervention for the experimental group, only the increase in HRV was statistically significant, F (1, 48) = 8.27, p = .01, partial η^2 = .15, with the experimental group having much higher HRV in the post-test (M = 70.75, SD = 33.00) compared to the pre-test (M = 49.95, SD = 24.29).

As Hardy and colleagues (2010) recommended that the analysis of each subscale on the TOPS2 should be kept separate, a series of paired samples t-tests were run to determine if there were any statistically significant differences for each of the TOPS2 training subscales before and after the intervention. There were no statistically significant differences in each subscale for the control group. However, the experimental group had significantly higher scores for four measures of the TOPS2, self-talk, relaxation, imagery, and automaticity, the same four mental skills that were targeted for improvement in the design of the integrated mental skills and biofeedback training program. Self-talk significantly improved for the experimental group post-intervention, t (24) = -3.24, p = .00, from 2.90 (SD = .88) to 3.40 (SD = .67). The use of relaxation in training was also significantly improved, t (24) = -2.86, p = .01, from 2.67 (SD = .74) to 3.14 (SD = .56). Imagery skills was also used more in training after the intervention from 2.75 (SD = .66) to 3.13 (SD = .63), t (24) = -2.25, p = .03. Finally, the participants from the experimental group used more automaticity skills in training after the intervention, t (24) = -2.58, p = .02, with the average increasing from 3.21 (SD = .48) to 3.45 (SD = .51).

Discussion

The main purpose of this intervention study was to assess the effectiveness of an integrated mental skills and biofeedback training program on performance of developmental air rifle and air pistol shooters. After the intervention, statistically significant improvements were found for HRV, self-talk, relaxation, imagery, and automaticity for the experimental group. On the other hand, the control group reported no significant changes across all measurements.

It was predicted that the experimental group would have significantly higher self-efficacy, HRV, use of mental skills, and shooting scores after the intervention, and there was partial support for this hypothesis. After a three-week intervention, participants from the experimental group had significantly higher HRV compared to the participants from the control group. HRV improved from 49.95 in the pre-test to 70.75 in the post-test, showing a significant increase due to the intervention. Although statistically insignificant, self-efficacy and shooting scores both improved after the intervention for the experimental group. In particular, the experimental group increased their average shooting score by 15.00 points, while the control group only increased their average shooting score by 2.48 points. This increase in scores may not have been statistically significant but an increment of 15 points has practical significance on performance that could decide the gold medal from a non-medal, since the differences between Olympic gold medalists and fourth place finishers were found to be statistically insignificant at approximately 1% (Birrer & Morgan, 2010). In fact, at the Rio 2016 Olympics, the average difference in scores between the first and eighth qualifier in the men's and women's 10m air rifle event and 10m air pistol event was 4.75 and 8.00 respectively. The experimental group shooters improved their performance by some 5%, while the control group shooters only had a 1% increase in shooting scores from pre- to post-test.

HRV increased significantly for the experimental group shooters from pre- to post-test after three sessions of HRV biofeedback training. This increase in HRV indicates that the experimental group shooters had better management of psychophysiological states before competition with reduced anxiety and enhanced vagal tone (Friedman, 2007). Athletes need to manage their anxiety well as it can cause the athlete to lose focus and make poor decisions (Wilson & Pritchard, 2005), two critical mental skills required for closed skill accuracy sports such as shooting.

In addition to the increased HRV, the shooters from the experimental group reported greater use of self-talk, relaxation, imagery, and automaticity compared to the control group. These four mental skills were specifically taught to the shooters during the workshops. This increase in the use of mental skills was supplemented with the subjective feedback about the intervention study, where participants from the experimental group reported using the mental skills about 50% of the time in training and found the workshops to be moderately effective in improving their shooting performance. The greater use of the four mental skills coincided with the improved performance of the shooters, and this is in line with earlier studies that found improved performance after psychological skills training (Bernier et al., 2009; Myers et al., 1996; Patrick & Hrycaiko, 1998; Sheard & Golby, 2006; Thelwell & Maynard, 2003). The findings also lend support to Jackson and colleagues' (2001) findings where greater use of mental skills were associated with the flow state, and as such, improved performance.

The lack of statistical significance for self-efficacy and shooting scores are contrary to Maman and Garg's (2012) intervention study, where both performance and self-efficacy levels were found to significantly increase after HRV biofeedback intervention. However, it is important to note that unlike Maman and Garg's (2012) earlier study, this study used an objective performance measure of shooting scores rather than skill based measures of dribbling, passing, and shooting. At the same time, self-efficacy was measured using a generic coping self-efficacy scale in the earlier study, whereas this study measured self-efficacy using a shooting-specific scale. Therefore, the differences in performance and self-efficacy measures could have made the achievement of statistical significance more stringent, although more importantly, the trends of increased self-efficacy, HRV, and performance were evident in this study.

At the end of the intervention program, the coach of the school's shooting team reported that his "shooters look different and know how to compete like real shooters now" (E. Lim, personal communication, 9 September 2016). This observation from the coach was supplemented with notable performance accomplishments from shooters in the experimental group, with four shooters achieving career personal best scores in the post-test shoot. On the other hand, none of the shooters from the control group reported achieving personal bests.

This research study has shown that a short intervention program that is specific to the mental demands of the sport is an effective means of improving performance and pre-performance psychophysiological state of sport shooters. Psychological intervention programs should be as sport-specific as possible to reap maximum benefits, in line with previous research by Sharp et al. (2013). In addition, since there have been few intervention studies that looked into integrating both biofeedback and mental skills training programs, this research study provides further evidence for the efficacy of integrating the two interventions, particularly for closed skill sports like shooting.

In addition, this study has brought to light the efficacy of short duration HRV biofeedback programs, lending support that duration should not be the main factor in the design of such interventions even though “insufficient duration” was highlighted in earlier research as a potential pitfall (Shellenberger & Green, 1986). In the specific instance of HRV biofeedback training, short duration interventions may be just as effective as longer duration interventions. Previous HRV biofeedback intervention programs were based on six to ten sessions (Lehrer et al., 2000; Maman & Garg, 2012; Rollo, 2014), and this study reveals the efficacy of having just three workshops of HRV biofeedback training. As diaphragmatic breathing is a skill that can be easily practiced and is a particularly important skill for sport shooters and other closed skill accuracy sport athletes, it is proposed that HRV biofeedback training sessions can be just as effective if its relevance to the sport is highlighted and integrated into their shooting routines.

In spite of the attempts to control for confounding factors in this intervention study, it was apparent in the data collection process that the attitude of each participant was the one thing that could not be controlled for. As highlighted by Massey et al. (2015), the athlete’s willingness to use mental skills to improve sports performance can influence the efficacy of the mental skills training program. To illustrate the importance of having the right attitude, there was one particular participant in the experimental group who scored a career personal best during the post-test. He was very happy with his results and shared openly that the workshops helped him tremendously to become a more confident shooter. When probed about the amount of practice he put in, he shared that he was very diligent in practicing the mental skills every night before he went to bed. Although he was a positive example of the anticipated benefits of such an intervention program, the same could not be said about the rest of the participants. When probed on how often they practiced their mental skills, some shooters shared that they practiced but mostly in the shooting range and this was not regular, while others did not practice the skills outside of the shooting range at all. This was supported by the questionnaire data, where the amount of time spent practicing the mental skills was only 4.23 out of 7.00.

The idea of using one school for this intervention study was to ensure that all the participants were engaged in the same shooting training program, and it was anticipated that the number of training days would also be consistent throughout. However, this was not the case as there was a lot of flexibility in allowing the shooters to decide how often they wanted to train, with only one compulsory training session a week set as the minimum criteria. That meant that there were shooters who did not attend shooting training sessions after the workshops, and this lack of shooting practice in the actual training environment may have been a potential confounding factor in this study. On average, in the four weeks that lapsed between the pre- to the post test, the shooters averaged just 6 to 7 days of training. As shooting is a skill-based sport, the power of practice is even more pertinent (Cote, Baker, & Abernethy, 2007).

In future similar intervention studies, it is recommended that the number of actual sports training sessions should be fixed to ensure participants have the fullest opportunities to practice the mental skills acquired in the workshops in the actual training environment. Nonetheless, this study shows great potential in improving shooting performance in a short three-session intervention that is sport-specific and incorporates both mental skills and biofeedback training. As such, it is recommended that sport psychology interventions should be focused on a similar framework to improve performance of athletes from other closed skill sport. The findings of this study can also be extended to other closed skill sports such as swimming and track and field.

Future studies could potentially explore the role of frequency domain HRV analyses such as high frequency (HF) HRV and/or low frequency (LF) HV. Although high HF HRV was found to result in feelings of calmness and alertness (Brown & Gerbarg, 2005), HF HRV is dependent on breathing rate (Ritz, Thomas, & Dahme, 2001). Perhaps the LF/HF ratio could be explored in future studies and correlated with time domain analyses to determine the best objective HRV indicator of an athlete's pre-performance psychophysiological state.

By empowering shooters with the essential sport-specific mental skills and self-regulation strategies, HRV levels before competing can be increased, allowing the shooter to perform optimally under pressure. This study showed that SDNN HRV improved significantly after a short 3-session intervention that was specific to the sport and made relevant and relatable to the shooters. Additionally, the improved shooting scores, achievement of personal bests, closer predictions of predicted and actual shooting scores, as well as anecdotal feedback from the coach all lend support to the efficacy of integrating mental skills and biofeedback training. As athletes source for means to improve performance in sports, this study highlights the potential of integrated mental skills and biofeedback training programs in providing athletes with the extra performance boost that they seek, particularly so for closed skill accuracy sports.

Compliance with Ethical Standards

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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