Biofeedback Use in Sport

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Abstract

The general purpose of this dissertation was to examine the effects of biofeedback training on sport performance. This dissertation was divided into three studies. Study 1 qualitatively explored athletes’ perspectives of biofeedback post-intervention. Five varsity athletes were provided with a five-session biofeedback intervention training respiration rate, heart rate variability, and skin conductance. Following the intervention, an interview was conducted. Athletes perceived biofeedback to enhance self-regulation skills both in sport and academics, contributing to perceptions of superior performance.

To further examine perspectives of biofeedback training, Study 2 qualitatively explored mental performance consultants’ use of biofeedback and their perceptions of the tool. Ten experienced mental performance consultants were interviewed. Consultants indicated that biofeedback can provide athletes with the self-awareness and self-regulation skills intended for optimal performance, but that there are limiting factors to the biofeedback device (e.g., high cost, time constraint, limited education and training).

Once perceptions were attained, a biofeedback intervention was designed to investigate the practice effect of biofeedback and to determine if sessions could be optimized with the integration of imagery (i.e., Study 3). 27 varsity athletes were assigned to one of three groups (biofeedback, imagery, comparison). The biofeedback group participated in five, 15-minute biofeedback training sessions. The imagery group participated in five, 10-minute biofeedback training sessions and each session was interspersed with an imagery script. The comparison group participated in five, 10-minute biofeedback training sessions and each session was interspersed with a rest period. There was a significant Group x Time interaction ($p < .05$), indicating differences
in respiration rate, heart rate variability, and skin conductance across groups over time. Specifically, it was found that athletes who take rest periods between biofeedback training can regain resonance frequency and physiological control once biofeedback resumes. Therefore, it may be worth interspersing biofeedback with imagery to enhance the quality of the session.

Overall, this dissertation supported the use of biofeedback to enhance sport performance in high performance varsity athletes. From a practical standpoint, mental performance consultants and/or sport psychologists who offer biofeedback may optimize delivery and performance outcomes by including imagery to generate the management of both psychological and physiological processes.

*Keywords*: high performance sport, biofeedback, imagery, mental performance consultant, self-regulation, performance optimization
Lay Summary

The general purpose of this dissertation was to examine the effects of biofeedback training on sport performance. Biofeedback is a technique that provides psychophysiological assessments in real-time to enhance awareness of thoughts and emotions. The application of biofeedback in the sport context has been widely recognized as a technique for enhancing athletic performance. This dissertation was divided into three studies. Study 1 gave athletes a voice by qualitatively exploring their perspectives of biofeedback post-intervention. Five varsity athletes were provided with a five-session biofeedback intervention. Following the intervention, an interview was conducted. Athletes perceived biofeedback to enhance self-regulation skills both in sport and academics, contributing to perceptions of superior performance.

To further examine perspectives of biofeedback training, Study 2 qualitatively explored mental performance consultants’ use of biofeedback and their perceptions of the tool. Ten experienced mental performance consultants were interviewed. Consultants indicated that biofeedback can provide athletes with the self-awareness and self-regulation skills intended for optimal performance, but that there are limiting factors to the biofeedback device (e.g., high cost, time constraint, limited education and training).

Once perceptions were attained, a biofeedback intervention was designed to investigate the practice effect of biofeedback and to determine if sessions could be optimized with the integration of imagery (i.e., Study 3). 27 varsity athletes were assigned to one of three groups (biofeedback, imagery, comparison). The biofeedback group participated in five, 15-minute biofeedback training sessions. The imagery group participated in five, 10-minute biofeedback training sessions and each session was
interspersed with an imagery script. The comparison group participated in five, 10-minute biofeedback training sessions and each session was interspersed with a rest period. It was found that athletes who take rest periods between biofeedback training can quickly gain control over their bodily functions once biofeedback resumes. Therefore, it may be worth interspersing biofeedback with imagery to enhance the quality of the session.

Overall, this dissertation supported the use of biofeedback to enhance sport performance in high performance varsity athletes.
Co-Authorship Statement

The work presented in this dissertation is my original work. However, I would like to acknowledge my supervisor, Dr. Craig Hall, Professor in the School of Kinesiology at Western University, for his help, guidance, and contributions for all three research studies. I would also like to thank Dr. Alison Divine, University of Leeds, for her support and direction with data analysis for Study 3.
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**Introduction**

An athlete’s ability to manage the inherent stress, anxiety, and pressure of high performance sport (i.e., varsity sport) is critical in order to excel at the highest level. Thoughts and emotions, particularly during competition, can have a dramatic impact on sport performance (Weinberg & Gould, 2014; Woodman & Hardy, 2003). High performance athletes are in constant search of methods to optimize not just their physical performance but their mental performance as well. Mental performance consultants and sport psychologists can help athletes develop strategies to manage and control the physiological, psychological, attentional, and behavioural responses that could be detrimental to performance (Bar-Eli & Blumenstein, 2004; Blumenstein, Bar-Eli & Tenenbaum, 2002; DeWitt, 1980; Dupee, Werthner, & Forneris, 2015; Jiménez Morgan & Molina Mora, 2017; Paul & Garg, 2012; Perry, 2018; Woodman & Hardy, 2003). To reach performance potential, a variety of mental strategies have proven to be successful in aiding an athlete’s development of self-awareness and self-regulation (Dupee et al., 2015; Paul & Garg, 2012; Perry, 2018).

The concept of self-regulation is broadly recognized in the field of sport psychology. It is an underlying factor in athletic performance and can be defined “as the ability to control inner states or responses with respect to thoughts, emotions, attention, and performance” (Bell & Deater-Deckard, 2007, p. 409). Developing an athlete’s self-awareness in regards to how thoughts, emotions, and physiological states influence performance can often lead to self-regulation, or to an athlete’s ability to manage those states during athletic performance (Dupee et al., 2015). The connection between thoughts and emotions affecting our ability to perform is prominent in a number of theories in the
field of sport psychology, such as cognitive behavioural therapy (Lagos et al., 2008; Whelan, Mahoney, & Meyers, 1991; Williams & Leffingwell, 2002). When athletes experience negative thoughts and emotions, undesirable performance outcomes can arise. With practice, an athlete has the ability to manipulate, manage, and control these outcomes by gaining strategies to regulate their responses. Research suggests that the practice of both physical and mental strategies can create faster improvement, consistency, accuracy, efficiency, an increase in self-confidence and self-efficacy, as well as more facilitative interpretations of symptoms associated with competitive anxiety, stress, and pressure (Bar-Eli, Dreshman, Blumenstein, & Weinstein, 2002; Callow, Hardy, & Hall, 2001; DeWitt, 1980; Dupee et al., 2015; O, Munroe-Chandler, Hall, & Hall, 2014; Perry, 2018). Therefore, enhancing an athlete’s ability to self-regulate can positively influence sport-related outcomes.

**Biofeedback in Sport**

Similar to the practice of physical skills and techniques, mental skills can be learned and practiced. First, it is important for an athlete to build self-awareness and determine how their thoughts, emotions, and feelings interact with their physiological states. Since the 1960’s, research in the area of biofeedback has shown that humans can, in fact, alter their physiological functioning by controlling their inner states when provided with accurate and reliable feedback (Green, Green, & Walters, 1970; Hefferline & Perera, 1963; Kimmel & Hill, 1960; Shapiro & Crider, 1967). Biofeedback is the use of sophisticated equipment to note psychophysiological responses to stress through analog or binary, auditory, and/or visual feedback signals (Schwartz, 2010; Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011). When applied, athletes have the ability to control
and change physiological functions such as heart rate variability, respiration rate, skin conductance, electromyography (muscle tension), and temperature. Administering biofeedback occurs through the use of a specific device (for the purpose of this dissertation, the Procomp Infiniti T7500M Biofeedback System manufactured by Thought Technology), which measures, records, and provides physiological feedback in real-time to the participant. Various sensors and electrodes are connected to the body, sending signals about the body through the biofeedback encoder and to a computer. The computer software then processes the physiological feedback, presenting the participant with specific measures of the modalities in use (e.g., heart rate, respiration rate in the form of breaths per minute). These measures may be displayed in the form of a bar graph, line graph, or a pacing stimulus, which in the case of respiration measures breathing rate from a strain gauge placed around the abdomen. The real-time feedback helps an individual become aware of how their physiology reacts and changes with the ability to learn and practice self-regulation in a controlled setting. The intuitive information that biofeedback can provide about psychophysiological activity could prove essential to an athlete’s ability to recover from the stress, anxiety, and/or pressure encountered during athletic performance (Blumenstein et al., 2002).

Researchers examining the effects of biofeedback on sport performance have used a combination of modalities (e.g., Dupee et al., 2015) or a single modality (e.g., DeWitt, 1980) to reveal changes in the autonomic nervous system (Sime, 2003). Biofeedback training can positively influence athletic performance by facilitating relaxation (DeWitt, 1980), decreasing sympathetic arousal (Divsarnaz, Khalifeh, Divsarnaz, & Azimipoo, 2012), reducing muscle tension (Bennett & Hall, 1979), increasing coping strategies for
competitive stress and anxiety (Paul & Garg, 2012), and fostering the development of self-awareness and self-regulation (Bar-Eli & Blumenstein, 2004; Blumenstein et al., 2002; DeWitt, 1980; Dupee et al., 2015; Jiménez Morgan & Molina Mora, 2017; Paul & Garg, 2012; Perry, 2018). Although researchers have shown the positive effects biofeedback training can have on sport performance, there are limitations to its use. Based on findings from Study 2 and previous research, biofeedback lacks ecological validity (i.e., use is often restricted to lab), the cost of equipment is not conducive to mental performance consultants and/or sport psychologists, there is limited education and training on the tool, the preparation and set-up is extensive, and the data presented can be complex (Giblin, Tor, & Parrington, 2016; Perry, Shaw, & Zaichkowsky, 2011).

In an attempt to bypass the limitation of ecological validity, the Wingate five-step approach (Blumenstein, Bar-Eli, & Tenenbaum, 1997; 2002) was developed to provide structure and guidance to the delivery of biofeedback. This model was created to help athletes gain greater control over their physiological and psychological functions during biofeedback training, as biofeedback cannot be used during actual competition. The Wingate five-step approach consists of: (1) introduction (i.e., learning self-regulation techniques such as abdominal breathing, imagery); (2) identification (i.e., identifying most efficient biofeedback modalities); (3) simulation (i.e., the practice of self-regulation skills with simulated competitive stress); (4) transformation (i.e., transfer self-regulation techniques into the sport setting); (5) realization (i.e., using techniques learned in the competitive setting; Blumenstein et al., 1997; 2002; Blumenstein & Weinstein, 2011; Hall, Duncan, & McKay, 2014). The first three steps occur in the lab setting and 10-15 meetings are recommended, 2-3 times per week, lasting 50-60 minutes per session, per
step. The last two steps take place in the sport setting.

Research integrating the five-step approach has shown a positive correlation between intervention effects and performance outcomes (i.e., performance enhancement). For example, this approach was used with a sample of young swimmers ($N = 38; M_{age} = 12.84$) where swimming speed and technique were evaluated by expert coaches following the approach. Significant improvements in swimming speed and technique were found in comparison to the control group (Bar-Eli, 2002). Similarly, Galloway (2011) found that tennis serving accuracy and consistency were improved during all phases of the program among six national junior male tennis players. Further, in a sample of Israeli pre-elite swimmers ($N = 40; M_{age} = 16.70$), Bar-Eli and Blumenstein (2004) found that the experimental group who utilized the approach decreased both running and swimming times in comparison to the relatively stable performances of a control group.

Moreover, interventions not following the Wingate approach have also found positive effects on performance outcomes. In a case study conducted by Lagos et al. (2008), it was found that a heart rate variability biofeedback intervention positively influenced performance, decreased anxiety and stress, and provided self-regulation strategies for an elite youth golfer. Lagos et al. (2011) extended these finding with a 21-year-old female competitive golfer to determine if similar results would be found. Comparable results were found as the athlete experienced a decrease in anxiety intensity, improved performance, and increased self-regulation skills that enabled the athlete to control negative thoughts and emotions. Dupee et al. (2015) found that a biofeedback intervention including all training modalities (i.e., heart rate variability, respiration rate, skin conductance, electromyography, temperature) enhanced performance in a sample of
high-performance freestyle skiers \((N = 15; M_{age} = 25.1)\). Further, participants increased their world ranking and improved their self-regulation skills. In addition, research led by Paul and Garg (2012) found that heart rate variability biofeedback can decrease negative anxiety symptoms by providing psychophysiological control through self-regulation techniques (i.e., breathing at resonant frequency) with a sample of basketball players \((N = 30; M_{age} = 21.13)\).

For the purposes of this research, three modalities were the focus, including heart rate variability, respiration rate, and skin conductance. Heart rate variability refers to the beat-to-beat changes in the electrocardiogram (Lagos et al., 2008). Heart rate variability training with the use of biofeedback can assist athletes in regulating competitive anxiety, decreasing tension, increasing self-confidence, regulating emotions, and enhancing performance (Edvardsson, Ivarsson, & Johnson, 2012; Lagos et al., 2008; Sime, 2003). With biofeedback, athletes have the ability to learn techniques to increase heart rate variability, which can be associated with faster reaction times and a better ability to manage fluctuations in internal and external stimuli. A decrease in heart rate variability can be associated with slower reaction times and a reduced ability to manage changes in internal and external stimuli (Lagos et al., 2008; 2011; Lehrer, Vaschillo, & Vaschillo, 2000).

Respiration rate, the process of inhaling and exhaling, can expand heart rate variability. Breathing at a certain pace (e.g., about six breaths per minute) can increase an athlete’s heart rate variability through rhythmical stimulation, creating a smooth sinusoidal wave where heart rate and respiration rate begin to cohere during each inhale and exhale (Lagos et al., 2008; 2011; Paul & Garg, 2012). Reaching coherence or
resonance frequency (i.e., about six breaths per minute or a resonance frequency close to 0.1 Hz) can optimize performance by regulating the emotions associated with a decline in performance (i.e., stress, anxiety, pressure; Dupee et al., 2015; Lehrer et al., 2000; Meuret, Wilhelm, & Roth, 2001). Lastly, skin conductance measures the skin's ability to conduct electricity (Blumenstein et al., 1997; 2002), which influences psychophysiological activation (Peek, 2003). Increased anxiety and changes in an athlete’s mood can have an immediate impact on skin conductance (Sime, 2003). These changes can elevate skin conductance, which can lead to deterioration in performance (Blumenstein et al., 2002; Dupee et al., 2015; Paul & Garg, 2012). Emotions that athletes experience (i.e., anxiety before a competitive event) can often affect breathing patterns (i.e., respiratory rate) and thereby the heart rate variability graphical curve (i.e., decrease in heart rate variability), often resulting in psychophysiological activation (i.e., increases in skin conductance) (Blumenstein et al., 2002; Dupee et al., 2015; Paul & Garg, 2012). Pairing and training these three functions with the use of biofeedback can provide athletes with necessary self-awareness and self-regulation strategies to counteract the negative psychophysiological effects that athletes may experience and to improve performance.

Imagery in Sport

Imagery is one of the most researched mental skills in the sport and performance literature. Many researchers have demonstrated the positive effects it can have on an athlete’s sport performance (cf. Munroe-Chandler & Morris, 2011; Morris, Spittle, & Watt, 2005). Imagery can be described as “an experience generated from memorial information, involving quasi-sensorial, quasi perceptual, and quasi-affective
characteristics, that is under the volitional control of the imager, and which may occur in
the absence of real stimulus antecedents normally associated with the actual experience”
(Morris et al., 2005, p. 19). Imagery is a multisensory construct where an athlete can
incorporate kinesthetic, visual, auditory, tactile, olfactory, and gustatory modalities when
imaging a skill. Imagery that encompasses all of the senses can lead to a more effective
imagery experience (Moran, 2013; Vealey & Greenleaf, 2010). Furthermore, the better an
athlete is at imaging (i.e., imagery ability), the more effective the outcomes will be
(Munroe-Chandler & Hall, 2007).

Imagery serves both cognitive and motivational functions, operating at specific
and general levels (Paivio, 1985). Hall, Mack, Paivio, and Hausenblas (1998) identified
five functions of imagery use in sport: (1) cognitive specific imagery pertains to images
of sport specific skills, (2) cognitive general imagery involves mentally rehearsing
strategies of play and/or routines, (3) motivational specific imagery entails imaging
achievements or goal-oriented responses, (4) motivational general-arousal involves
images related to regulating arousal, stress, and anxiety, and (5) motivational general-
mastery pertains to images of feeling self-confident, focused, and mentally tough.

In the sport and performance literature, imagery interventions have shown the
effectiveness these functions have on athletic performance. Moreover, researchers have
found imagery to have a positive effect on an athletes’ self-efficacy, self-confidence,
ability to control emotions, flow, and interpretations of symptoms associated with
competitive anxiety (Callow et al., 2001; Jones, Mace, Bray, MacRae, & Stockbridge,
2002; Mellalieu, Hanton, & Thomas, 2009; Munroe-Chandler, Hall, Fishburne, Murphy,
Overview of the Present Research

Although research examining the effects of biofeedback on sport performance has provided valuable insight into self-awareness and self-regulation strategies to manage and control psychophysiological stress states, there are large gaps in the literature that need to be explored. It is evident that research quantitatively supports the use of biofeedback in terms of performance quality. However, little research exists that explores athletes’ perspectives on the use of biofeedback and whether the skills acquired are perceived to optimize performance. The aim of Study 1 was to fill this gap by first providing participants with a five-session biofeedback intervention, training heart rate variability, respiration rate, and skin conductance, and second giving athletes a voice in regards to their thoughts and beliefs on the use of biofeedback.

Adding to this, it was important to gain a further understanding on perceptions of biofeedback training by those who offer this technique to athletes. Therefore, the goal of Study 2 was to explore mental performance consultants’ use of biofeedback, including their exposure, knowledge, and use of the tool, as well as the positive implications and practical limitations of its use. Based on the positive perspectives uncovered from Study 1 and Study 2, a biofeedback training intervention was designed to investigate the practice effect of biofeedback and to determine if sessions could be optimized with the integration of imagery. Researchers indicate the positive effects that both biofeedback and imagery training can have on sport performance (Dupee et al., 2015; Mellalieu et al., 2009; Morris et al., 2005; Munroe-Chandler & Morris, 2011; O et al., 2014; Perry, 2018). However, the combination of these skills has not been investigated. The purpose of Study 3 was to examine the practice effect of biofeedback in high performance varsity athletes;
more specifically, if athletes who practice biofeedback continuously are able to self-regulate by reaching resonance frequency and gaining physiological control quicker than if practice time integrates imagery training or a rest period. In addition, Study 3 explored if athletes believe that employing imagery can simulate a sport experience, contributing to the effectiveness of a biofeedback intervention, and if athletes think that five, 10-15 minute biofeedback training sessions is an adequate amount of time to gain physiological control.

This dissertation follows an integrated-article format. Each research study has been prepared to be published in an academic journal. Therefore, some redundancy exists between the content of the introductions and discussions within each study.
References


Green, E. E., Green, A. M., & Walters, E. D. (1970). Voluntary control of internal states:


Study 1
A Voice Unheard: A Qualitative Exploration of Varsity Athletes’ Perspectives on the Use of Biofeedback Post-Intervention

For sport psychologists and mental performance consultants, their primary objective is to help athletes identify the emotions, thoughts, and feelings that reflect optimal performance in performers. The ability to manage the inherent stress, anxiety and pressure of high performance sport is a critical skill that athletes need to develop to reach performance potential. Thus, a variety of mental training techniques have been suggested, reflecting various strategies intended for athletes' self-regulation or an athlete’s ability to manage those states during athletic performance (e.g., imagery, self-talk, cognitive restructuring, biofeedback). In the sport and performance literature, researchers have utilized biofeedback as a tool to influence successful performance by providing self-awareness and self-regulation techniques to positively influence performance and cognitions. Biofeedback provides psychophysiological assessments in real-time through the use of sensors, providing visual feedback in regards to a participant’s anatomic response to neutral and aversive stimuli (Blumenstein, Bar-Eli, & Tenenbaum, 2002; Schwartz, 2010; Tan, Dao, Farmer, Sutherland, & Gevirtz, 2011). This type of psychophysiological assessment is becoming more and more relevant in competitive sport because of the inherent psychological and physiological stress endured (Dupee, Werthner, & Forneris, 2015; Perry, 2018).

1A version of this study has been submitted to the International Journal of Sport and Exercise Psychology and is currently under review.
Biofeedback has been found to be one of the most influential practices for facilitating self-regulation in athletes (Dupee et al., 2015; Jiménez Morgan & Molina Mora, 2017). In addition, various biofeedback training interventions have been utilized in an attempt to counteract the psychophysiological effects of stress and anxiety on sport performance. Numerous studies have demonstrated the facilitation of self-regulation, and in turn performance enhancement, through the use of biofeedback. For example, Dupee et al. (2015) conducted a biofeedback training intervention that focused on enhancing an athlete’s self-regulation ability and overall performance in a sample of high performance freestyle skiers ($M_{age} = 25.1$, $SD = 2.7$). A significant correlation between elite athletes’ overall self-regulation ability and their ranking at the world level was found, indicating that improving self-regulation ability, can improve performance. Further, Bar-Eli (2002) used a biofeedback training approach with a sample of young swimmers ($N = 38$; $M_{age} = 12.84$) where swimming speed and technique were evaluated by expert coaches following the approach. Significant improvements in swimming speed and technique were found in comparison to the control group. Similarly, Galloway (2011) measured performance outcomes during a biofeedback training intervention, which found that tennis serving accuracy and consistency were improved during all phases of the program among six national junior male tennis players. Further, in a sample of pre-elite swimmers ($N = 40$; $M_{age} = 16.70$), Bar-Eli and Blumenstein (2004) found that the biofeedback group decreased both running and swimming times.

With biofeedback, various biological functions (e.g., heart rate variability, skin conductance, electromyography, respiration rate, and temperature) can be measured and trained to allow participants to gain voluntary control over both psychological and
physiological responses. Many researchers have used a combination of these modalities (e.g., Dupee et al., 2015) or a single modality (e.g., DeWitt, 1980) to reveal changes in the autonomic nervous system (Sime, 2003). Subtle yet dramatic changes biofeedback training can create, can positively influence sport performance by decreasing sympathetic arousal (Divsarnaz, Khalifeh, Divsarnaz, & Azimipoo, 2012), reducing muscle tension (Bennett & Hall, 1979), providing coping strategies for competition anxiety (Paul & Garg, 2012), facilitating relaxation (DeWitt, 1980), and enhancing athletes’ use of self-regulation skills (Dupee et al., 2015).

For the purposes of this research, only three modalities were trained, including respiration rate, heart rate variability, and skin conductance. Respiration is the process of inhaling and exhaling. To achieve optimal performance, Meuret et al. (2001) recommend breathing at resonance frequency. Slow and controlled breathing at or near six breaths per minute (i.e., resonance frequency) can positively contribute to an athlete’s ability to manage psychophysiological responses to stress, anxiety, and pressure (Dupee et al., 2015; Lagos et al., 2008; Lehrer, Vaschillo, & Vaschillo, 2000; Meuret, Wilhelm, & Roth, 2001). Resonance frequency exists at a specific frequency for each individual and can be detected through biofeedback as the frequency at which maximum heart rate variability is produced (Lehrer et al., 2000). Thus, resonance frequency is generated by paced breathing and can be achieved by the breathing tools created within the biofeedback software.

Heart rate variability refers to the wave of beat-to-beat changes in the electrocardiogram (Lagos et al., 2008). Heart rate variability training can teach athletes to regulate competitive anxiety, decrease tension, and increase self-confidence (Lagos et al.,
In addition, when an individual breaths at or near resonance frequency, their respiration rate and heart rate begin to cohere, meaning as an individual inhales their heart rate increases and with each exhale, it decreases (Paul & Garg, 2012). Achieving resonance frequency can increase heart rate variability, which can be associated with faster reaction times, a better ability to manage fluctuations in internal and external stimuli, and facilitate emotion regulation.

Skin conductance measures the skin's ability to conduct electricity. Increased anxiety and changes in an athlete’s mood can have an immediate impact on skin conductance (Sime, 2003). As anxiety levels increase, skin conductance begins to follow this pattern through psychophysiological activation (Sime, 2003). An athlete’s ability to control how he/she responds to such emotions can have an immediate impact on performance (Blumenstein et al., 2002; Dupee et al., 2015; Paul & Garg, 2012; Sime, 2003). Therefore, pairing and training these three functions (respiration rate, heart rate variability, skin conductance) with the use of biofeedback may provide athletes with the necessary self-awareness and self-regulation strategies to manage and control the psychophysiological responses that could be detrimental to performance.

Beyond sport, biofeedback is often considered a type of alternative or complimentary medicine. With biofeedback training, individuals have the ability to control automatic and involuntary bodily functions, helping to manage many physical and mental health concerns. Researchers have found that biofeedback training can have a positive effect on chronic stress and anxiety (Steffen, Austin, & DeBarros, 2017), asthma (Lehrer et al., 2004), attention deficit disorders (Arns, Ridder, Strehl, Breteler, & Coenen, 2009), high blood pressure (Olsson, Alaoui, Calberg, Carlbrigh, & Ghaderi, 2010) and
additional health related issues. Moreover, neurofeedback, which is a specific form of biofeedback, is used for examining brain activity and cognitions. It is a form of behavioural training aimed at developing skills for self-regulation of brain activity (Heinrich, Gevensleben, & Strehl, 2007). Similar to biofeedback, there is evidence supporting the clinical efficacy and effectiveness of neurofeedback. It is effective in neuropsychiatric disorders, especially attention deficient disorders and epilepsy (e.g., Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003; Walker & Kozlowski, 2005). Researchers have also found a positive correlation between neurofeedback training and autism (Scolnick, 2005), schizophrenia (Gruzelier, Hardman, Wild, & Zaman, 1999) and learning disabilities (Fernandez et al., 2003). While neurofeedback is beyond the scope of this study, it has had significant implications in sport (see Cheng et al., 2015; Mirifar, Beckmann, & Ehrlenspiel, 2017; Christie & Werthner, 2015).

Although biofeedback training has been found to be a successful tool for self-regulating psychophysiological responses, a recurring limitation continues to affect research outcomes. The ability for athletes to transfer the facilitated skills from laboratory to field settings cannot be measured, thereby affecting the ecological validity of biofeedback research. With the current technology (e.g., encoders, wires, sensors, and electrodes connected to the body), it is impossible to evaluate psychophysiological data during actual sporting events (Collins & McPherson, 2006; Dupee et al., 2015). In an attempt to bypass this limitation, the Wingate approach (Blumenstein & Bar-Eli, 2005; Blumenstein et al., 2002) was developed. The Wingate approach is composed of five stages: (1) introduction (i.e., learning self-regulation techniques such as abdominal breathing); (2) identification (i.e., identifying efficient biofeedback modalities); (3)
simulation (i.e., simulated competitive stress); (4) transformation (i.e., transfer techniques into practice); (5) realization (i.e., using techniques learned in training in a competition setting; Hall, Duncan, McKay, 2014). This approach serves many benefits, however measuring real-time psychophysiological activation during competition has yet to be accomplished. Although this approach was not used in the current study, it is important to recognize that this approach does not fully bypass the limitation of ecological validity.

Since this limitation continues to impact the outcome of most biofeedback research, recognizing the athlete by qualitatively exploring their perceptions of this tool could help to identify and describe athletes’ perspectives on the use of biofeedback. This could inform service providers on strategies, suggestions, and recommendations for future use, improving the quality of delivery and sport performance outcomes.

To date, a large gap in the sport and performance literature exists that qualitatively explores athletes’ perspectives on the use of biofeedback. Qualitative results could provide support for the efficacy of biofeedback training in improving mental skills adherence. Qualitative research of this nature could bring awareness on the implications and practical limitations of such interventions by revealing the subtle details that may be lost during quantitative analysis (Smith & McGannon, 2018; Bar-Eli, Dreshman, Blumenstein, & Weinstein, 2002). It can provide credible information to sport psychologists, mental performance consultants, coaches, and athletes in regards to perceptions of usefulness and value, and how biofeedback training can contribute to overall performance quality. Thus, the purpose of this study was to not only provide an intervention that promotes self-regulation techniques, but to give athletes a voice to their thoughts and beliefs on the use of biofeedback. This study allowed the researchers to
discuss the impact of a biofeedback intervention with each participant, adding to the credibility level of the biofeedback intervention.

**Method**

**Approach to Research**

This study was exploratory and the purpose required an approach that focused on detailed descriptions of experiences, highlighting implications, limitations, and suggestions for future use from the perspective of the athlete. Thus, a qualitative descriptive research approach (Knight & Holt, 2013; Sandelowski, 2000; 2010) was deemed most suitable for the intended purpose. A qualitative descriptive approach is not underpinned by pre-existing philosophical or theoretical foundations (Sandelowski, 2000). In particular, “qualitative descriptive studies tend to draw from the general tenets of naturalistic inquiry” (Sandelowski, 2000, p. 337). Therefore, this approach was used to gain a detailed description of the athletes’ perspectives and experiences of biofeedback post-intervention, contributing empirical and applied suggestions to the sport and performance literature. Moreover, qualitative description provides answers to questions that have implications for practitioners (Sandelowski, 2000), lending valuable information to sport psychologists and mental performance consultants in regards to service delivery.

**Participants**

This study included five high performance varsity athletes (4 female; 1 male) between the ages of 19 and 25 ($M_{age} = 20.4$, $SD = 1.14$). Participants were purposefully sampled from a post-secondary school in Southwestern Ontario, Canada who met the following criteria: a) had a minimum of two years experience in varsity sport, b) trained
on average 10 hours per week, and c) had no prior experience or knowledge of biofeedback. Varsity coaches from soccer, swimming, and basketball were contacted by the primary investigator via email with a letter of information outlining the purpose of the study. In addition, coaches were asked if there was a suitable time for the primary investigator to come to a practice to discuss the study in person and to recruit athletes who met the recruitment criteria. These sports were chosen as recruitment took place during the summer months and these particular athletes were currently in their training season and were frequently on campus. Five athletes provided the investigator with enough data to explore and describe the phenomenon of interest.

**Data Collection**

Ethics approval for this study was obtained from the affiliated university’s human research ethics board (see Appendix F). The study was divided into two phases (Phase 1: intervention; Phase 2: post-intervention interview) and all participants were provided with a letter of information outlining the purpose of the study, participants’ rights and information on confidentiality, any potential risks and/or harms, the use of data, and the reasons for audio recordings of interviews.

**Phase 1.** After consent was obtained, participants completed Phase 1, the five-session biofeedback intervention. The rationale for this experimental design (i.e., five training sessions) was based on previous pilot research where session one and two focused on the athletes’ ability to learn resonance frequency breathing from the instructions and feedback provided. During sessions three through five, it became evident that the skills had been practiced and acquired as little instruction was provided and athletes were able to guide themselves. This specific population of high performance
athletes was able to apply the skills and techniques quickly. Therefore, based on the pilot, a five-session biofeedback intervention seemed appropriate given the exploratory nature of this study. The intervention occurred over a 4-week period and each participant met with the investigator for individual sessions. The intervention aimed to provide techniques to enhance sport performance through training respiration rate, heart rate variability, and skin conductance. Measuring these parameters involved connecting participants to respiration (e.g., a strain gauged belt was placed around the mid-section of the abdomen), heart rate (e.g., blood volume pulse detection sensor placed around thumb), and skin conductance (e.g., two separate sensors connected to the fingers) sensors that displayed physiological activation through visual feedback. Each session included the same parameters and training techniques for the span of 15 minutes.

During session one, participants were instructed to practice abdominal breathing (i.e., balance between their inhalation and exhalation) with a pacing stimulus set at the target respiration rate of six breaths per minute on the respiration training screen. The purpose of the pacer was explained to each participant and they were instructed to inhale as the dot moved up, and to exhale as it moved down. Participants were prompted that if six breaths per minute felt too slow, the pacer would be adjusted accordingly. However, each participant was comfortable with the set pace. Each participant was then told to put their hands over their belly button and to visualize their abdomen as a balloon. This idea of balloon imagery (i.e., trying to fill the balloon with each inhale, and deflate the balloon with each exhale) was introduced to facilitate abdominal breathing (Khazan, 2013). The primary investigator also demonstrated this technique while the participant was practicing. Any questions that the participants had were addressed at the time. Following
session one, participants were asked to practice on their own time before the next session. During sessions two through five, the primary investigator continued to guide athletes by reminding them about using their belly to breathe. The pacer stimulus was used as a guide for athletes to breath at or near the target respiration rate of six breaths per minute. This protocol was followed in each session.

The feedback was given to the participant in the form of respiratory rate, beat-to-beat heart rate, and skin conductance rate over the span of 30 seconds on the screen. Monitoring of all physiological variables was carried out by the Procomp Infiniti T7500M Biofeedback System manufactured by Thought Technology. For the purposes of this study, these parameters are not reported, as the aim was to qualitatively explore perspectives of biofeedback post-intervention.

**Phase 2.** For Phase 2, data were collected through individual semi-structured interviews. The script was developed (see Appendix A) to provide the same systematic and comprehensive inquiry with each participant (Patton 2014). Interviews were conducted in a private office space and participants were informed that all information provided would be anonymous. With the exploratory nature of this study, the interview guide was created to uncover the athletes’ experiences and perspectives on biofeedback training post-intervention. The interview guide began with an introductory question pertaining to the athletes’ perspectives on what they learned. The main questions focused on participants’ general experiences in regards to how the training may contribute to their sport performance. In addition, questions were formulated to reveal detailed descriptions about the intervention process (e.g., number of sessions, length of sessions) and how biofeedback may or may not affect other areas of their life (e.g., academics). The
questions were open-ended and probes were used to inquire about positive and negative experiences of the intervention to allow for a balanced approach (Knight & Holt, 2013). Interviews lasted, on average, 25.90 minutes ($SD = 4.72$ minutes).

**Data Analysis**

All interviews were audio recorded and transcribed verbatim, resulting in 62 pages of transcripts (11-point font, single-spaced). The objective of the analysis was to organize categories that emerged from the unstructured data to describe the athletes’ perspectives on the use of biofeedback post-intervention. Inductive reasoning was used to guide the analysis of the interview transcripts, as the analysis was reflective of the content and not a pre-existing theory (Braun, Clarke, & Rance, 2015). A thematic analysis, which is typically used in qualitative descriptive studies (Sandelowski, 2010), was conducted to identify and interpret the detailed accounts outlined in the data (Braun & Clarke, 2006; 2013; Braun et al., 2015).

To generate accurate categories, themes, and sub-themes to describe and understand the athletes’ perspectives, Braun and Clarke’s (2006) six-phase approach was followed. For phase one, the primary investigator fully immersed themselves in the data by transcribing the audio recordings followed by reading and re-reading the transcripts to become familiar with the data and the context of each interaction. This led into the coding process (i.e., phase two) where succinct labels were generated and identified pertaining to the aim the study. The initial codes helped to convey various idiographic indications of each conversation’s context. For phase three, codes were examined to identify broader patterns of meanings where codes were compared and organized based on common themes. Initial themes were then reviewed (i.e., phase four), refined, combined, or
discarded to allow for further analysis to be conducted. To develop a detailed analysis of each theme, the fifth phase consisted of producing clear, informative names for each theme. The development of sub-themes and overarching categories were then outlined to capture the essence of the story. Lastly, the data extracted was contextualized to relay the empirical evidence constructed from the data.

A critical friend, familiar with qualitative research, participated in phases three through five to follow recommendations suggested by Smith and McGannon (2018). In addition, the primary investigator and the critical friend engaged in critical dialogue in which interpretations of the results were challenged, leading to the development of new ideas and understandings of the findings. The results section was then sent to each participant for member reflection, a process that allows participants to explore interpretations of the findings and to generate additional data and insight with the primary investigator (Smith & McGannon, 2018). Member reflection has been deemed a more rigorous technique than simply verifying results through member checking (Smith & McGannon, 2018).

Results

Analysis led to the identification of three categories, four themes, and seven sub-themes. The sub-themes are explored under each category and theme heading. Each sub-theme is accompanied by quotations to enhance the clarity of the data presented. Table 1 illustrates a full breakdown of categories, themes, sub-themes, and the number of responses associated with each sub-theme. To protect identities, pseudonyms were assigned to each participant.
Table 1
*Post-intervention categories, themes, sub-themes, and number of responses*

<table>
<thead>
<tr>
<th>Categories</th>
<th>Themes</th>
<th>Sub-themes</th>
<th>Number of participants making reference to the sub-theme (N = 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding of Biofeedback</td>
<td>Knowledge of tool</td>
<td>Synchronization of physiological functions</td>
<td>4</td>
</tr>
<tr>
<td>Post-Intervention</td>
<td></td>
<td>Psychophysiological control</td>
<td></td>
</tr>
<tr>
<td>Positive Perspectives of the Use of Biofeedback Post-Intervention</td>
<td>Enhanced self-regulation skills</td>
<td>Pre-performance routine</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coping with adversity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Breathing techniques</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use of skills outside of sport</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Academic performance</td>
<td>5</td>
</tr>
<tr>
<td>Practical Limitations</td>
<td>Application of biofeedback</td>
<td>Application in sport</td>
<td>1</td>
</tr>
</tbody>
</table>

**Understanding of Biofeedback Post-Intervention**

**Knowledge of the tool.** Following the intervention, two sub-themes developed from the main theme: synchronization of physiological functions and psychophysiological control.

**Synchronization of physiological functions.** Most of the participants discussed how the training helped to synchronize their physiological functions, particularly heart rate and breath rate, which can be achieved when participants breathe at the recommended six breaths per minute. This sensation was described thoroughly in this quote: “It is literally training yourself to sync your breath rate with your heart rate to achieve physiological control. In the span of a few minutes you can see your heart rate following your breath rate” (Brad). Another participant added that achieving this synchronization can in fact help with performance: “Training yourself to breathe at a
certain pace to sync your heart rate and your breath can help us perform better” (Sam). It was also noted that when a participant is first hooked up to biofeedback, the training screen can look disorganized prior to achieving this synchronization: “Your heart rate looks really sporadic and disorganized and within the span of 3 or 4 breaths you can bring that in sync with each other” (Mia).

**Psychophysiological control.** The second sub-theme related to knowledge of the tool was psychophysiological control. It was described as “training your body to remain calm while dealing with [situations] with your brain” (Hana). One participant noted that “thoughts can impact [the] body’s reactions so being able to remain calm in stressful situations through these techniques [is critical] to remain in control and not let those thoughts negatively impact [performance]” (Brad). Lastly, it was implied that “seeing the effects of your thoughts on your physiology [was] pretty powerful” (Mia). In sum, it was evident that participants realized the effects that biofeedback training can have on controlling psychophysiological reactions and how that directly impacts performance.

**Positive Perspectives of the Use of Biofeedback Post-Intervention**

**Enhanced self-regulation skills.** During the post-intervention interview, many positive perspectives of the use of biofeedback were conferred. The first main theme, enhanced self-regulation skills, can be explored through the three sub-themes drawn from the data: pre-performance routine, coping with adversity, and breathing techniques.

**Pre-performance routine.** All five participants spoke about how the skills attained from the intervention will contribute to their pre-performance routines. This sentiment is captured in the subsequent quote:

This will be helpful in my preparations [be]cause I tend to do a very long almost
ritualistic approach to my races like I need to be behind the blocks by a certain time and if I get nervous I feel like I can work the breathing into my pre-race ritual to just kind of calm myself down, which I think will be good. (Lily)

Relatedly, as stated by Brad, “in preparation it will be beneficial, adding it to my pre-race routine [and] knowing that I should take a few minutes to think about my breaths and how that is impacting my body and mind and in turn performance”. It was also noted that anxiety experienced before an event can be eased with the strategies gained: “I get nervous and anxious before and I, um, start to feel my heart rate going up so just breathing through that [I] know it will help” (Sam). Through the training, participants realized that although “athletic performance is physical, you also need the mental side of it” (Hana).

Coping with adversity. The second sub-theme that was emphasized in terms of self-regulation was coping with adversity. Brad said, “when I mess up or make a bad play [it can help me] bounce back from that so it has less of a chance of hindering future performance”. Two other participants agreed that the intervention provided skills to bounce back after a setback: “I think the techniques learned will help [me] bounce back after a mistake or like a setback. Being able to think about the strategies and know you have to control your mind and body to get back” (Sam). Comparably, Lily said, “if I am upset after my race and I need to bounce back really quickly I feel like this is something I could use to kind of clear myself out of any negativity and then refocus for my next race”. It was clear that these participants believed that the intervention provided strategies to use when faced with adversity in their sport.
**Breathing techniques.** Breathing techniques was the third sub-theme to emerge from the interviews. One participant noted that being able to physically see how the body responds to the training helped her understand how important breathing at a certain pace can be. This can be comprehended in the subsequent quote: “I didn’t know that it can regulate our body so that was neat to see and to actually see how your body is responding on the computer like you can actually see how breathing properly impacts your functioning” (Sam). Another participant revealed how breathing at the recommended pace began to feel very natural and he could begin to feel the positive influence it had on his functioning: “Learning overall breathing strategies that help with overall functioning like breathing at 6 breaths per minute and knowing that my body is at its peak and feeling that way, it feels so natural now and good” (Brad). Conclusively, Lily said, “breathing at 6 breaths per minute, which I didn’t know was supposed to like calm you down [is] going to be helpful [in sport and other situations]”.

**Use of skills outside of sport.** There was one sub-theme identified relative to the use of skills outside of sport: academic performance.

**Academic performance.** All five participants commented that the acquired skills could translate beyond sport. One participant expressed that they “feel much better prepared to take these deep breaths because even just thinking of [this major exam being] a month out gives me butterflies in my stomach so I think it’s going to be really helpful” (Mia). Another participant was able to utilize the skills attained during the actual course of the intervention: “I had an exam in the midst of this intervention and I found myself thinking about my breathing when I was feeling anxious. It helped for sure like just being able to calm my nerves a bit” (Brad). In this final quote, the participant highlighted that
this intervention is useful for everyday life: “If I am really nervous for a test my heart will be beating [fast], my hands will be sweating [and this] can calm me down. I would say it is helpful and like a life skill” (Lily). In sum, participants indicated that biofeedback has the potential to provide strategies to promote academic performance.

**Practical Limitations**

**Application of biofeedback.** There was one sub-theme identified with the application of biofeedback: application in sport.

**Application in sport.** Although this section seems to hold little importance due to the percentage of responses, it is essential to provide these details for any further research conducted in the field. In terms of sport, the participant articulated the following:

> I don’t know if it is something that a lot of people would be interested in enough to have a huge market for like I think once you learn about it, you need to practice it on your own like meet a couple times. I think you can apply the homework on your own and maybe check in, in a few months if you have recurring anxiety before a performance. (Hana)

The same participant went on to say:

> In swimming, it is hard in the pool because in the pool you can’t really think about this kind of stuff but like I said in pre-performance prep. I think biofeedback would help more with how people think like not necessarily in sport itself. I don’t think directly it would improve my swimming performance but maybe it could help; I guess I will figure it out in my results next week. (Hana)

It was evident that this participant felt as though the skills learned from the intervention could impact their pre-performance routine but not necessarily their sport performance.
Discussion

The purpose of this study was to qualitatively explore athletes’ perspectives of the use of biofeedback. The skills acquired from biofeedback training not only led to perceptions of enhanced self-regulation ability, but perceptions of superior performance. Specifically, in the post-intervention interviews, athletes reported that biofeedback contributed to their pre-performance routines, their ability to cope with adversity, and their use of breathing techniques for optimal functioning. During the intervention, resonance frequency breathing (i.e., breathing at or near six breaths per minute) was the focus. A main component of biofeedback training is training respiration rate. Breathing at resonance frequency produces a smooth sinusoidal wave where heart rate and respiration rate begin to cohere (Paul & Garg, 2012). This type of training exercises a participant’s ability to control a variety of physiological mechanisms such as heart rate variability and skin conductance. Therefore, with the emphasis of the biofeedback training being on controlled, resonance frequency breathing, the acquired self-regulation strategy could enhance autonomic control of emotional regulation and provide the athlete with skills to control how he/she responds to the inherent stress, anxiety, and pressure of high performance sport (Blumenstein et al., 2002; Dupee et al., 2015; Paul & Garg, 2012; Sime, 2003).

The results of the present research indicate that athletes’ perceptions of their overall self-regulation ability improved through the use of biofeedback training, specifically through the use of breathing techniques. Although the results of this study are based on qualitative perspectives of biofeedback training post-intervention, perceptions of enhanced self-regulation skills are congruent with sport biofeedback research (Bar-Eli & Blumstein, 2004; Blumstein et al., 2002; Dupee et al., 2015). Specifically, researchers
have found that performance can be optimized through the improvement of athletes’ self-regulation skills. Thus, findings from the current study highlight the positive implications of biofeedback training in terms of self-regulation skills (e.g., pre-performance routines, coping with adversity, breathing techniques) lending qualitative support to the quantitative evidence in the sport and performance literature.

Athletes reflected on how biofeedback training could improve their academic performance. Post-intervention data indicated that learning how to breathe at or near resonance frequency could in turn help the participants manage the physiological symptoms of stress by providing a calming effect in terms of nervousness and anxiety. These findings are congruent with previous research conducted within the biofeedback and academic performance literature. A recent study by Aritzeta and colleagues (2017) utilized a heart rate variability biofeedback intervention with 152 university students over an eight-week program. It was found that in educational contexts, biofeedback training can contribute to physiological control of emotions, thereby reducing anxiety and improving academic performance (Aritzeta et al., 2017). Further literature explored the use of a respiration and heart rate biofeedback intervention with university students and concluded that biofeedback training can be an effective program in improving academic performance by decreasing emotional responses (e.g., stress and anxiety) to academic demands (Vitasari, Wahab, Othman, & Awang, 2009). As such, these findings imply that biofeedback training can help individuals become self-aware of their emotions and provide self-regulation strategies for dealing with said emotions. It is important to recognize that stress is inherent both in sport and academics. Therefore, developing techniques to cope with the emotions, stress, and adversity presented is advantageous for
performance purposes.

Although the findings from this research have important implications there are some limitations with the study. Given the small sample size ($N = 5$), the results must be interpreted with caution. Due to the limitations of the current technology (e.g., wires and electrodes that must be attached to the participant while connected to a large encoder), evaluating self-regulation during competitive events while measuring physiological activity/reactivity is near impossible, which reflects the practical limitation (i.e., application in sport) discussed in the results section. Further to this, in some sports (e.g., swimming) where the athlete has 30-seconds or less to compete their event, it makes it difficult to incorporate self-regulation. This is an important implication for service providers like sport psychologists and mental performance consultants as it was suggested that biofeedback is a more suitable tool for pre-performance preparation.

Larger scale studies including both male and female athletes should be conducted to determine if perspectives on the use of biofeedback are different between genders, which has yet to be determined. It would be interesting to quantitatively and qualitatively compare athletes’ physiological deviations to determine if perspectives matched physiological changes. Further, it would be beneficial to determine if perspectives on the tool differ between athletes who are involved in individual or team sports, as this has not been established in the biofeedback literature. With the exploratory nature of Phase 1 (i.e., five biofeedback training sessions), it would be advantageous for future research to compare results of physiological variables between groups completing varied intervention lengths. For example, participants could be assigned to one of three groups (e.g., five sessions, seven sessions, and ten sessions) to determine if results differ between
groups over time. Qualitatively this particular sample indicated that the intervention length was adequate in enhancing self-regulation ability, however, quantitative findings between groups over time would contribute valuable information to future researchers conducting biofeedback training interventions.

Despite the limitations inherent in the present study, the findings suggest that the participants deemed biofeedback to be a viable tool for enhancing their use of self-regulation both in sport and academics. Further, it emphasizes the positive perceptions that athletes have of biofeedback training and the positive effects they believe it can have on their overall performance. Although the sample size is small, findings from this study can provide mental performance consultants and sport psychologists with a better understanding on how biofeedback is perceived. Not only can this study appeal to sport psychologists and mental performance consultants, but also to a range of other informed deliverers including coaches, sports scientists, medics, performance directors and managers, and athletes themselves. Qualitative research seems to be a promising way to determine an individual’s response to biofeedback by providing conversational evidence about the usefulness of biofeedback training in terms of performance quality.
References


John Wiley.


Knight, C. J., & Holt, N. L. (2013). Factors that influence parents’ experiences at junior tennis tournaments and suggestions for improvement. *Sport, Exercise, and*


Steffen, P. R., Austin, T., & DeBarros, A. (2017). Treating chronic stress to address the growing problem of depression and anxiety: Biofeedback and mindfulness as simple, effective preventive measures. *Policy Insights from the Behavioral and Brain Sciences, 4*(1), 64–70.

biofeedback: A new training approach for operator’s performance enhancement.

*Journal of Industrial Engineering and Management, 3*(1), 176–198.


*Applied Psychophysiology and Biofeedback, 36*(1), 27–35.


Study 2

Sport Biofeedback: Effective but Under Utilized

In sport, mental performance consultants can provide athletes with an assortment of self-regulation techniques (e.g., imagery, cognitive restructuring, self-talk, biofeedback) intended for optimizing performance. By facilitating the learning of self-awareness through various self-regulation techniques, athletes can learn to manage levels of stress, anxiety, and arousal to achieve their performance potential (Bar-Eli & Blumenstein, 2004; Dupee, Werthner, & Forneris, 2015). With the application of mental skills training, MPCs must consider an athlete’s age and level of experience, as well as the physical, emotional, and environmental demands of their sport. Gaining perspective on these factors could help MPCs tailor their training programs to the needs of the athletes to whom they are providing services.

It is important to acknowledge the difference between a sport psychology consultant and a mental performance consultant (MPC). As outlined by the Canadian Sport Psychology Association (CSPA) and the Association for Applied Sport Psychology (AASP), the title “sport psychology consultant” or “sport psychologist” is for registered psychologists who offer clinical-based psychological services. In Canada, using this title without a psychology license violates licensing regulations mandated by a Province’s Health Professions Act (Canadian Sport Psychology Association, 2018). A MPC is usually accredited through an organization (e.g., CSPA, AASP) devoted to applied sport psychology.

\(^2\)A version of this study has been submitted to *Qualitative Research in Sport, Exercise and Health* and is currently under review.
psychology and has the necessary training and education to provide athletes with performance enhancing strategies. At a minimum, MPCs have a master’s degree in sport psychology or a related field and have extensive, hands on consulting experience. Therefore, there are two types of service providers available to athletes: clinical psychologists (i.e., sport psychology consultant) and mental performance consultants. For the purposes of this paper the term MPC will be used to describe the service providers in this study.

Among the various mental skills techniques that can be provided is biofeedback. Since the 1980’s, biofeedback has been found to be one of the most powerful means for facilitating the learning of self-regulation (Bar-Eli & Blumenstein, 2004; DeWitt, 1980; Dupee et al., 2015). Biofeedback is a technique that provides psychophysiological assessments in real-time to enhance awareness of thoughts and emotions (Blumenstein, Bar-Eli, & Tenenbaum, 2002; Jiménez Morgan & Molina Mora, 2017). The application of biofeedback in the sport context has been widely recognized as a technique for enhancing athletic performance (Dupee et al., 2015; Jiménez Morgan & Molina Mora, 2017). Researchers have utilized biofeedback as a tool to positively influence performance and cognitions by reducing anxiety intensity (Lagos et al., 2011), decreasing sympathetic arousal (Divsarnaz, Khalifeh, Divsarnaz, & Azimipoo, 2012), and enhancing self-regulation skills to enable an athlete to take control over negative thoughts and emotions (Divsarnaz et al., 2012; Dupee et al., 2015; Lagos et al., 2008; 2011; Paul & Garg, 2012).

Although the positive effects of biofeedback are recognized, researchers (e.g., Giblin, Tor, & Parrington, 2016) have outlined limitations to the use of biofeedback that
may prohibit some MPCs from using the tool. One major limitation is the biofeedback equipment. Researchers typically use equipment (e.g., Thought Technology biofeedback device) that has been shown to provide valid and reliable data as it extracts in-depth and meaningful information about a participant’s physiological functioning (Giblin et al., 2016). These types of devices can extract information about a subject’s heart rate, respiration rate, muscle tension, skin conductance, and temperature. However, there can be several issues MPCs face when using such equipment, including: ecological validity (i.e., use is often restricted to lab), high cost, specific knowledge and training requirements, duration of preparation and set-up, and the ease of which practitioners and athletes can comprehend the data (Giblin et al., 2016). With advancements in technology, there are a variety of consumer products (e.g., smartwatches, mobile application such as Headspace) that have become available to both MPCs and athletes. Although these consumer products are more cost effective and easily accessible, not all applications provide valid and reliable data. In addition, these options do not extract the same amount of information and data in terms of physiological functioning. With that in mind, interventions and feedback based on these consumer products must be used with caution.

Unfortunately, research considering the practical application of specific self-regulation techniques is extremely limited. The current sport and performance literature lacks conversational findings in terms of the preferred self-regulation skills of MPCs. This is especially true with biofeedback. The last studies to discuss the use of biofeedback with MPCs that the present authors are aware of were conducted in the 1980’s. Suinn (1985) conducted open-ended interviews with 11 mental performance specialists who worked with various elite athletes who participated in the 1984 Olympic
games. Biofeedback was considered to be one of the most influential and useful intervention techniques in promoting performance enhancement. Gould et al. (1989) administered questionnaires to 44 MPCs who were identified to have worked with athletes from more than 25 U.S. Olympic sports between 1984 and 1988. Of those 44 consultants, only 17 reported the use of biofeedback. Quantitatively, biofeedback was found to be one of the least used self-regulation techniques by consultants. Unfortunately, there were no additional findings reported and no information on the potential limitations or practical implications for why biofeedback was employed so infrequently.

Although sport researchers have found biofeedback to be a successful tool in optimizing performance (see Bar-Eli & Blumenstein, 2004; Bar-Eli et al., 2002; Dupee et al., 2015; Galloway, 2011; Perry, 2018), no research to date qualitatively explores MPCs experience, knowledge, perceptions, and practice of biofeedback. There has been a growing awareness of the benefits of qualitative research and the unique inquiry it contributes to the sport and performance literature (Strean, 1998; Smith & McGannon, 2018). Therefore, the purpose of this study was to qualitatively explore MPCs’ use of biofeedback, including their exposure, knowledge, and use of the tool, as well as the positive implications and practical limitations of its use.

**Method**

**Approach to Research**

This study sought to describe and understand the participants’ knowledge, experiences, and perspectives of biofeedback. Therefore, a qualitative descriptive research approach (Knight & Holt, 2013; Sandelowski, 2000; 2010) was taken due to the descriptive and exploratory nature of this study. This approach was used to gain new
insights of the experiences and perceptions of each participant, highlighting implications
and practical limitations. This approach is not underpinned by pre-existing philosophical
or theoretical foundations but rather lead by general tenets and naturalistic inquiry
(Sandelowski, 2000; 2010). Qualitative description is a valuable research approach in that
it provides answers to questions that have important implications for practitioners
(Sandelowski, 2000). Thus, understanding perspectives of biofeedback training from
service providers (i.e., mental performance consultants) who offer such services can
provide empirical and applied suggestions to the sport and performance literature.

**Participants**

MPCs were recruited based on the following criterion: a) held a Ph.D. and were
accredited through a sport psychology association (e.g., Canadian Sport Psychology
Associate [CSPA] or Association for Applied Sport Psychology [AASP]). It addition, it
was important to seek a balance between MPCs who use biofeedback and those who do
not to ensure findings portrayed perceptions of both groups. On the CSPA and AASP
website, consultant biographies are provided. Seven professional members listed their use
of biofeedback. Therefore, email addresses of potential participants were collected from
each website. They were then contacted via email by the primary investigator and
provided with a letter of information detailing the purpose of the study. Five consultants
who use biofeedback expressed interest in participating by providing their consent. After
interviews were conducted with the five-biofeedback users, an additional five MPCs who
do not use biofeedback were contacted. Each participant provided consent and interviews
were conducted. Thus, 10 experienced MPCs (eight female and two male; five
biofeedback users) participated in this study. Participants had, on average, 17 years of
experience working as a MPC with athletes ($SD = 6.72$ years, range 7-26 years). To achieve a diverse sample, participants from British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, and Maryland were purposefully sampled.

**Data Collection**

Ethical approval was attained from the primary investigator’s university prior to recruitment (see Appendix F). Once consent was obtained, individual interviews with the primary investigator were conducted via phone. A semi-structured interview script was developed by the primary investigator to warrant the same systematic and comprehensive inquiry with each individual (Patton, 2014; see Appendix B). The interview script was designed to understand consultants’ use and knowledge of biofeedback as well as their education, training, and perceptions of value in regards to athletic performance. In addition, questions were formulated to uncover positive implications and practical limitations of its use. The semi-structured nature of these interviews allowed for some flexibility facilitating relevant trajectories to arise. The primary investigator adopted a conversational interview method to allow for some autonomy and flexibility, enabling unconstrained dialogue (Patton, 2014), thus deepening the communication with each participant being interviewed. Interviews lasted between 15 and 33 minutes ($M = 23.03$, $SD = 6.56$). It is important to note that the shorter interview times pertain to consultants who do not actively use biofeedback.

Specifically, in each interview consultants were asked to discuss their familiarity with biofeedback, their education and training on the tool, and whether they have used biofeedback in their consulting practice. Further, questions were developed in relation to accessibility of the tool and educational training, as well as perceptions of value in terms
of athletic performance enhancement. Each interview was audio recorded and transcribed verbatim by the primary investigator, resulting in 47 pages of transcripts (11-point font, single-spaced).

**Data Analysis**

The objective of the analysis was to organize categories that emerged from the unstructured data to describe consultants’ experience, knowledge, perceptions, and practice of biofeedback. Inductive reasoning was used to guide the analysis, as the analysis was reflective of the content of the data and not a pre-existing theory (Braun, Clarke, & Rance, 2015). In keeping with a qualitative descriptive approach, a thematic analysis was conducted. Specifically, Braun and Clarke’s (2006) six-phase framework was followed. First, the primary investigator was fully immersed in the data by transcribing the audio recordings verbatim as well as reading and re-reading the transcripts to fully comprehend the content of interactions. After careful review of each transcript, preliminary codes were assigned to the data (i.e., phase two) in order to describe the various idiographic indications of each conversation’s context. Third, codes were compared and organized by relating clusters of data to each other based on common themes. The initial themes were then reviewed (i.e., phase four), refined, combined, and/or discarded to allow for further analysis to be conducted. The fifth phase consisted of producing clear definitions that captured the essence of the story to further enhance the identified themes and sub-themes. Overarching categories were then created to represent each theme and sub-theme. Lastly, the analysis was contextualized to relay the empirical evidence constructed from the data.

A critical friend familiar with qualitative research participated in phases three
through five to follow recommendations suggested by Smith and McGannon (2018). In addition, the critical friend helped to explore alternative perspectives of the data. This allowed for reflexivity as the experienced qualitative researcher and the primary investigator engaged in critical dialogue to challenge interpretations of the findings (Cowan & Taylor, 2016; Smith & McGannon, 2018). Following several discussions, some themes and sub-themes were altered and refined to better suit the purpose of the study.

Following this method, results were then sent to each participant for member reflection (Braun & Clarke, 2013; Tracy 2010; Smith & McGannon, 2018) as member checking has been deemed an “ineffective marker to judge the rigor or quality of qualitative research” (Smith & McGannon, 2018, p. 117). As member checking can create epistemological and ontological challenges, the aim of member reflection is to explore each participant’s interpretations of the findings to generate an intellectually enriched understanding of the data (Schinke, McGannon, & Smith, 2013; Smith & McGannon, 2018). This process helped to fill any gaps in the results by providing additional dialogue and insight, leading to deeper clarification of the data.

**Results**

Analysis led to the identification of two categories, four themes, and 10 sub-themes. The sub-themes are explored under each category and theme heading. Each sub-theme is accompanied by quotations to enhance the clarity of the data presented. Table 2 illustrates a breakdown of categories, themes, sub-themes, and the number of responses associated with each sub-theme. Pseudonyms have been used to maintain participants’ anonymity.
Table 2

<table>
<thead>
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<th>Categories, themes, sub-themes, and number of responses</th>
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<td>Categories</td>
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Biofeedback Training

**Exposure to biofeedback.** Participants discussed their exposure to biofeedback through two sub-themes: (1) formal instruction, and (2) self-taught.

**Formal instruction.** In terms of formal instruction, some participants mentioned that it was introduced to them through a demonstration, whether that was during their master’s degree or via a colleague, at a workshop during a conference, or briefly touched on during an academic lecture. Nia stated, “not until my master’s was it introduced and that would have been because my advisor had experience with it. It wasn’t introduced in any of my undergrad or master’s lectures; it was demonstrated to me by my master's advisor”. Similarly, another participant said, “I didn’t learn it because of a class. A [professor] did a demonstration [in my master's class] and then I went to follow her” (Sara). Laura said, “I actually learned about biofeedback through a colleague. I didn’t
come across it at all in my own graduate work”. She continued by saying “it wasn’t until I sort of reconnected with a colleague and when we were trying to think about different [research] projects where she mentioned this idea of biofeedback” (Laura). One participant reflected on how they first learned about biofeedback at a conference during their Ph.D.: “I am thinking it was through a workshop at a conference [in my Ph.D.] where I first learned about it” (Kayla). Interestingly, only one participant revealed that biofeedback was a topic reviewed during an academic lecture: “I was starting in applied sport psych and it was touched on in our anxiety and emotion control lectures but it wasn’t something that was actively promoted” (Sofia).

**Self-taught.** More than half of the MPCs explained that their knowledge of biofeedback was self-taught, which comprises the second sub-theme. One participant in particular spoke about how biofeedback is a technique that you have to seek out on your own. This is emphasized in the following quote:

> Since I had interest in it, I started doing research on it on my own time, even though my master’s work was in a different area. My Ph.D. is when I really started diving into biofeedback stuff. I have found from experience and talking with colleagues that biofeedback is a technique that you almost have to seek out on your own, which is exactly what I did. (Nia)

Sofia also said, “my training and then use of it with my clients has just been on my own like professional upkeep so professional development” (Sofia). In addition, another participant stated: “It is kind of a teach yourself [technique]” (Sara). Another participant explained that he “took some independent pursuits and did a small applied research project during the course [of my master's] and just kept taking the ball forward
incrementally from there” (Todd). Through the interviews, it was evident that most knowledge of biofeedback comes from independent interests and that education on the technique may be lacking in the academic setting.

**Application of Biofeedback**

**Positive implications.** During the interview, many positive implications of the use of biofeedback were conferred, which can be explored through the three sub-themes drawn from the data: performance enhancement, self-awareness, and buy-in factor.

**Performance enhancement.** The participants recognized biofeedback as being a performance enhancing tool, regardless of whether they actively use biofeedback or not. This is emphasized in the following quote: “I’ve seen performance enhancement happen [with biofeedback], I have seen it with athletes” (Laura). In addition, participants expressed how biofeedback contributes to self-management. Sofía said, “self-management is a critical piece of enabling optimal performance and biofeedback gives you some very concrete objective information about when your body is in a readiness state versus a disorganized, distracted state”. Another participant outlined, “it really is a performance enhancing technique. It provides athletes with so many tools in terms of self-management. Seeing how emotions, whether positive or negative, affect physiology is so valuable in terms of mind-body connection” (Nia). In terms of self-regulation, Kim stated: “I think in training, from a self-regulation, emotional control piece [it] is really, really valuable under pressure in competition [in terms of optimizing performance]”. Lastly, Todd said: “To objectively tap into pre-performance states or recovery states and ideally to the extent that we can during performance states, you learn to replicate that and to become practiced making consistency happen [contributing] to performance
Participants, whether they use biofeedback or not, recognize the positive implications biofeedback can have on athletic performance.

**Self-awareness.** The third sub-theme, self-awareness, was discussed by some of the participants. One participant expressed, “it brings a piece of self-awareness to the athlete in terms of psychophysiological activity. Something they can see on a screen and how their thoughts impact their physiological reactions. Awareness of that mind-body connection is crucial for success” (Nia). Relatedly, Laura talked about how “using biofeedback is a way, is one way, to help increase that self-awareness for athletes and understand how their bodies work, understand that they have more control than they think over the physiology that they have”. Sara also stated, “the biggest thing for me is the self-awareness it provides for the athletes being able to see what their body and their mind is doing”. She further elaborated by saying, “I think it opens doors that aren’t necessarily open when talking to an athlete so a deeper level of awareness that they can get to because they can see what’s going on” (Sara).

**Buy-in factor.** The second sub-theme to emerge from the data was the buy-in factor that biofeedback training can create. This is highlighted in the following quote:

> It is also the buy-in factor that can be missed in regular mental performance sessions. Again coming back to that self-awareness and feedback piece, being able to physically see what is going on in your mind and body and knowing the positive effect of getting your physiology under control can have. Seeing helps us believe in the process. (Bryn)

Similarly, Todd discussed how “[biofeedback] takes it from what could be like woo-woo
ideas that don't apply to all of a sudden you have buy-in because people see right away that [the] techniques are influencing their physiology”. Further, the same participant revealed that it has the potential to show athletes the influence they have over their psychophysiological response. The sentiment is captured in this quote:

It is funny because with the breathing thing like they come in and I get an eye roll and then you hook them up to heart rate variability biofeedback and they can see how their breath is influencing their heart rate and they're like, wow there is something to this and more often than not they can recognize at that point when they are in a good state versus a deregulated state and - and they start to recognize, huh I do have influence over this. (Todd)

Another participant mentioned that they “find it particularity useful in situations where people might be opposed to sport psychology or not willing to talk or don’t really believe in it” (Sara). Lastly, Sofia said, “if I can connect their body to something they are doing in their headspace, it gets them to buy-in to the headspace stuff”. She went on to say “being able to help them get a real sense of how they are controlling their bodies through their mind is really useful” (Sofia). It was very apparent that consultants who use biofeedback believe that the tool enriches the process of mental training.

**Practical limitations.** Three sub-themes relating to practical limitations of biofeedback developed including, high cost, time constraint, and limited education and training.

**High cost.** Most of the participants disclosed that the high cost of biofeedback is a critical limitation in terms of accessibility of the tool. One participant said, “the higher end equipment is a leap so that kind of investment prohibits MPC's from using it” (Todd).
Further, Nia went on to say, “it is very expensive and not affordable for a lot of MPC's who have their own individual practice, which is probably a key factor in why a lot of consultants don’t use it”. Comparably, Kayla conferred: “if an individual consultant you know is working on his or her own and not affiliated with an academic institution, it is very, very difficult to put out that money at the outset to purchase a piece of equipment”. She later stated, “there is no way an individual MPC could afford that $11,000 or so to get the equipment” (Kayla). Lastly, one participant was hopeful that the cost of the equipment would come down, enhancing accessibility to the tool: “What I am waiting for is when it gets cheaper and easier which it will of course in the next two years so be able to use it more often and effectively” (Julie).

**Time constraint.** A few of the participants conversed about the time constraint that biofeedback can create. Kayla said, “it is tough to have that consistency in terms of time to train the athlete on biofeedback”. In addition, Julie mentioned how “[there is a limitation] in the amount of time and effort and explanation and learning and that kind of piece that it really takes the athlete and me”. Lastly one participant stated: “Also too the training, getting the electrodes set up, it is a process and it can be time consuming so finding something that can be more accessible in terms of speed in getting someone set up” (Kim). Due to this time constraint, two of the participants who recognized this limitation do not use biofeedback during consultations anymore.

**Limited education and training.** The third sub-theme, limited education and training, was recognized by most of the participants. This limitation acts as a major barrier to the accessibility, ease, and use of the tool. One participant acknowledged that the “resources for learning are pretty scarce, particularly when it comes to athletes in
sport [so this] is another barrier for why MPC’s wouldn’t have access to the equipment but the training and knowledge too” (Sara). This participant continued by saying, “there are very few people who really know how to do it and a lot of people want to do it but there is a definite lack of knowledge, education, and training in the area” (Sara). Likewise Julie said, “you know more understanding, more applicability of really how to use it, when to use it, you know integration is required”. Another participant spoke about how their lack of education and training is one reason why they do not use the tool, which is seen in the following quote: “I don’t even know well I have an idea of how to use it but not in any sort of functional way, it would take me awhile to figure out its usefulness” (Kyle). Interestingly, one participant discussed “how biofeedback should be part of the sport psychology curriculum [as] it seems like a natural fit for them to go together” (Todd). Lastly, Bryn stated, “there is such limited training on it. Between the lack of education and resources available for students, academics, and professionals, it is no wonder that people are intimidated by it”. It was clear that the limited education and training available is a major limiting factor in terms of the application of biofeedback.

**Equipment options.** There were two sub-themes identified in relation to equipment options: increasing accessibility and no validity of other equipment options.

**Increasing accessibility.** A couple of participants considered how mobile applications could increase accessibility to biofeedback training. “There are a lot of other apps, other techniques, other things that are just as simple at providing the athlete with the information they can use” (Julie). Additionally, Laura expressed that “[there are] more practical devices that you can find now that do not necessarily hook you up to a computer but sort of a quick way of accessing just how your body is doing”. She further
elaborated on how “some of those less expensive options might be good for people to know about” (Laura).

**No validity of other equipment options.** In contrast, three of the consultants who actively use biofeedback discussed how there is no validity of the additional equipment options in terms of research. As stated by Kim, “you know there are all these little devices but they still cost money and how valid and reliable are apps, what is really valid? There is so much out there, which is concerning. [Is it] doing what it’s supposed to?” Adding to this point, Nia said, “I think there are a lot of great apps that can do some physiological training but how valid and reliable and how accurate those measures are, I really don’t know and there’s no research to support it”. Lastly, another participant emphasized that “there are some cheaper alternatives like [mobile] apps and devices but I don’t know how valid these alternative options are” (Sara). With the advances in technology, there are some mobile applications and cheaper alternatives to the Thought Technology biofeedback system but it is evident that research supporting these tools is limited, decreasing the validity of these options.

**Discussion**

Very little research qualitatively examines the services that MPCs provide, the implications of those services, and the problems encountered in their ability to deliver such services. With technology becoming a widespread tool in monitoring athletes’ physical and mental states, some MPCs have integrated biofeedback training into their mental skills training programs and/or interventions with the desire to provide a competitive edge over the opposition (Giblin et al., 2016). Therefore, the purpose of the current study was to explore MPCs’ use of biofeedback, including their exposure,
knowledge, and use of the tool, as well as the implications and practical limitations of its use. It is important to recognize that participants in this study had a combined average of 17 years’ experience and included some of the leading MPCs across Canada and the United States. Thus, results portray their years of experience in providing competitive athletes with self-regulation strategies best suited for achieving optimal performance.

Consultants, whether they use biofeedback or not, described the positive implications (e.g., performance enhancement, self-awareness, buy-in factor) and the practical limitations (e.g., high cost, time constraint, limited education and training) of its use. Both elite and recreational athletes are in constant search of both physical and mental strategies to enhance their performance. In sport, negative performance outcomes can often be related to how thoughts, emotions, and physiology affect one’s ability to perform (Dupee et al., 2015). Being able to self-regulate, especially in high-pressure situations (e.g., expectations to win), allows an athlete to gain control over a range of physiological, psychological, attentional, and behavioural responses that could be detrimental to performance (Bell & Deater-Deckard, 2007). Consistent with the biofeedback research (Dupee et al., 2015; Perry, 2018), the MPCs in the current study believe that with biofeedback, athletes can become self-aware of their internal physiology and mental states, enabling them to learn, modify, and regulate psychophysiological activity for improving performance.

Although there is only a subset of biofeedback research that focuses on direct sport performance outcomes, perceptions of performance enhancement have been supported. Bar-Eli et al. (2002), leading researchers in biofeedback in sport, found that both technique and speed could be significantly improved in swimmers with biofeedback
training. Further research investigated the effects of biofeedback training on adolescent short track runners (Bar-Eli & Blumenstein, 2004). Results indicated that the biofeedback group exhibited greater improvements in their running speeds. Galloway (2011) evaluated the effectiveness of a biofeedback intervention on the accuracy of tennis serving. It was found that following the intervention tennis serving accuracy and consistency as well as participants’ mental skills adherence improved. Further, following a three-year mental skills training program that integrated biofeedback, Beauchamp et al. (2012) found that incorporating biofeedback training led to performance advantages and enhanced self-regulation skills. It is evident that research quantitatively supports biofeedback in terms of performance quality. Therefore, the nature of this study compliments the existing research in that it provides readers with a qualitative analysis on the implications and limitations of biofeedback, which is absent in the sport and performance literature.

Although biofeedback may serve many benefits in aiding an athlete to reach performance potential, the MPCs identified three limiting factors: high cost, time constraint, and limited education and training. Of these limitations, the high cost of owning and operating a valid and reliable device such as those developed by Thought Technology seemed to be a contributing factor as to why MPCs do not use and/or have the ability to offer such a technique. These types of devices cost a minimum of $10,000 to purchase. For some consultants in the present study, biofeedback was only accessible to them because of their affiliation with an academic institution and the available funding opportunities to incorporate it into their practice. In contrast, program funding, whether it be from an institution or sport organization, is not always available. Consistent with
Gould et al. (1989) investigation of consultants’ use of biofeedback 30 years ago, without funding the feasibility of including biofeedback into mental skills training programs and/or interventions is near impossible today.

In addition to cost, connecting an athlete to biofeedback and using specific training techniques can take upwards to an hour to complete. Biofeedback systems like those developed by Thought Technology require a great period of processing and analysis time in order to provide accurate feedback to an athlete (Giblin et al., 2016). During practice and/or competition, there is limited time to connect an athlete and provide meaningful information. For some consultants, this time constraint makes integrating biofeedback into their practice difficult. Consequently, there is a necessity to develop advanced tools that offer valid and reliable data to check an athlete’s psychological and physiological well-being in order to implement any changes to improve overall performance (Giblin et al., 2016). Another limitation of the use of biofeedback is the minimal education and training available outside of the clinical and medical realms. When participants reflected on their exposure to biofeedback, they indicated that their experience and knowledge of biofeedback was primarily self-taught, emphasizing the diminutive opportunities to learn, practice, and transfer the technique into practice. With research highlighting the positive implications of biofeedback in the sport and performance literature, it is surprising that it is not included in most kinesiology curriculums. It is especially pertinent in courses that focus on the cognitive, affective, and behavioural experiences and consequences of involvement in sport, exercise, and physical activity.

The use of technology in sport is not new and with the expanding number of new
tools, applications, and devices being developed, MPCs, sport scientists, coaches, and athletes are seeking access to these options (Jiménez Morgan & Molina Mora, 2017). An influx in equipment options such as commercial devices (e.g., Fitbit) and mobile applications (e.g., Headspace) have become available to consumers at a minimum cost. Some MPCs discussed their preference for these tools due to the simplicity, accessibility, and affordability of these options. Although these options provide service providers and athletes with the ability to use a less elaborate form of biofeedback, these products are not always the most appropriate option. Very limited research exists to support these consumer products, compromising the integrity of their use. In research investigating the impact of technology on elite sport performance, Giblin et al. (2016) discuss the use of ‘fad options’ and the effectiveness of new technology. When selecting the appropriate technology to support athletic performance and development, two factors need to be considered: (1) validity and reliability of the data, and (2) in-depth, meaningful data (Giblin et al., 2016). When using invalid and unreliable options, the feedback provided could result in unfavorable and detrimental effects on athletic performance. In addition, in-depth and meaningful information is required for MPCs, sport scientists, coaches and/or athletes to make informed decisions to implement the necessary changes to positively affect the performance of their athletes. Although there may be limitations to both high end (i.e., Thought Technology) and consumer products, it is important to consider the valid and reliable options first prior to using technology to aid in athletic performance.

Findings from the current study not only demonstrate perceptions of effectiveness but also provide current MPCs with valuable information about the use of biofeedback
when facilitating mental skills training programs and/or interventions. A major strength to the current study was the inclusion of 10 accredited, highly trained, and experienced MPCs. The qualitative nature of this study provides perspective on how MPCs perceive biofeedback as being a valuable strategy in achieving peak performance. Gaining their perspective on the implications and limitations of biofeedback training provides readers with credible information in relation to a self-management technique that providers may lack knowledge and education on. Further, conclusions from this research may lead more MPCs, sport psychologists, sport scientists, and coaches to combine biofeedback with the mental skills strategies they deliver.

When evaluating the usefulness of biofeedback in relation to sport performance, consultants, whether they use biofeedback or not, agreed that acquiring self-awareness and self-regulation skills is necessary to reach performance potential. Unfortunately, with the high cost, time constraint, and limited education and training, many consultants are unable to incorporate biofeedback into their practice. These limiting factors have contributed to the ever-evolving technological tools, devices, and applications available to a variety of consumers. Even though these products provide consumers with simple, accessible, and affordable alternatives, service providers, coaches, and athletes should exercise these options with caution. In summary, findings provide a unique inquiry to further support the use of biofeedback for athletic performance. With the inherent stress, anxiety, and pressure in sport, integrating biofeedback training to provide skills to control and modify physiological, psychological, attentional, and behavioural responses would be advantageous for athletes of all levels.
References


Study 3

Combining Biofeedback and Imagery: Visualizing the Outcome

Involvement in high performance sport (i.e., varsity sport) can often be associated with increased performance demands, and the athlete’s ability to cope with such demands can have a direct influence on sport performance (Woodman & Hardy, 2003). It is essential that high performance athletes have the self-regulation strategies to manage both the positive (e.g., success) and negative (e.g., pressure, anxiety) effects of sport. Biofeedback is a technique that provides psychophysiological assessments in real-time to provide an athlete with the necessary self-awareness and self-regulation skills to manage the physiological, psychological, attentional, and behavioural responses that could be detrimental to performance (Bar-Eli & Blumenstein, 2004; Blumenstein, Bar-Eli, & Tenenbaum, 2002; DeWitt, 1980; Dupee, Werthner, & Forneris, 2015; Jiménez Morgan & Molina Mora, 2017; Paul & Garg, 2012; Perry, 2018).

When applied, biofeedback training can teach an athlete how to voluntarily control anatomic responses such as electromyography, respiration rate, skin conductance, temperature, and heart rate. The intuitive feedback that biofeedback provides about physiological activity could have a direct impact on an athlete’s ability to recover from the inherent stress, anxiety, and/or pressure during competition (Blumenstein et al., 2002). With biofeedback, athletes can learn how to control and alter the physiological responses (e.g., respiration rate) that are best suited for optimal performance. The

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3A version of this study has been submitted to *The Journal of Applied Sport Psychology* and is currently under review.
various modalities of biofeedback can serve multiple purposes and researchers have used a combination of these modalities (e.g., Dupee et al., 2015) or a single modality (e.g., DeWitt, 1980) depending on the purpose of the intervention. For the current study, heart rate variability, respiration rate, and skin conductance were trained.

Heart rate variability measures changes in heart rate patterns and refers to the beat-to-beat changes in the electrocardiogram (Lagos et al., 2008). Changes in heart rate can be triggered by emotions, breathing patterns, and changes in physical behaviours (Lagos et al., 2008). High heart rate variability can be associated with faster reactions and a better ability to manage changes in internal and external stimuli. Conversely, low heart rate variability can be associated with slower reactions and a lessened ability to manage changes in internal and external stimuli. With biofeedback, an athlete has the capacity to learn strategies to increase heart rate variability, enhancing their ability to regulate emotions and perform at full potential (Lagos et al., 2008).

Respiration rate, the process of inhaling and exhaling, is a source of rhythmical stimulation and has a direct impact on heart rate. Breathing at a certain pace (i.e., six breaths per minute) can induce high-amplitude oscillations in heart rate, increasing an athlete’s heart rate variability. Research indicates that breathing at about six breaths per minute or a resonance frequency in heart rate close to 0.1 Hz can optimize performance (Dupee et al., 2015; Lehrer, Vaschillo, & Vaschillo, 2000; Meuret, Wilhelm, & Roth, 2001). Resonance frequency exists at a specific frequency for each individual and can be detected as the frequency at which maximum heart rate variability is produced (Lehrer et al., 2000). Thus, resonance frequency is generated by paced breathing and can be achieved by the breathing tools created within the biofeedback software. When an
individual breathes at their resonant frequency, their heart rate and breath rate will cohere, meaning as an individual inhales, their heart rate will increase and as they exhale, their heart rate will decrease (Lagos et al., 2008; Lehrer et al., 2000). As previously mentioned, reaching this coherence will increase heart rate variability, allowing an athlete to better manage emotions and changes to internal and external stimuli as well as facilitate faster reaction times (Lagos et al., 2008).

Lastly, skin conductance measures the skin’s ability to conduct electricity (Blumenstein, Bar-Eli, & Tenenbaum, 1997; 2002). Physiological activation caused by psychological stress states (i.e., increased anxiety) can have an immediate influence on skin conductance (Sime, 2003). As psychological stress states heighten, skin conductance can increase, which can negatively impact sport performance (Blumenstein et al., 2002; Dupee et al., 2015; Paul & Garg, 2012). For an athlete to reach maximal performance levels, they must be able to self-regulate and cope with various performance demands and outcomes (Dupee et al., 2015).

Therefore, pairing and training these three functions together with the use of biofeedback should help counteract the negative psychophysiological effects that athletes may experience and provide them with additional self-regulation strategies to improve performance. In addition, many sport biofeedback researchers couple respiration rate and heart rate variability training (see Dupee et al., 2015; Lagos et al., 2008; 2011; Paul & Garg, 2012), as respiration has a direct impact on heart rate through rhythmical stimulation. Skin conductance, which is the emotion detector, was incorporated as heightened emotional responses can directly impact levels of skin conductance. Incorporating measures of skin conductance can determine an individual’s emotional
response to the additional variables included in the current study.

Although there are a number of positive outcomes associated with biofeedback training, the equipment options are not always conducive to the sport environment. With the current valid and reliable technological devices (e.g., Biofeedback System manufactured by Thought Technology), evaluating psychophysiological responses during a competitive event is near impossible. This is due to the encoders, wires, sensors, and electrodes connected to the body (Collins & McPherson, 2006; Dupee et al., 2015). In an attempt to diminish this limiting factor, the Wingate five-step approach was developed (Blumenstein & Bar-Eli, 2005; Blumenstein et al., 2002). This approach provides structure and guidance in the application of biofeedback, incorporating psycho-regulative skills to enable an athlete to transfer the acquired self-management strategies outside of the lab setting. It is easily adaptable to be efficiently applied to various sport disciplines.

The first three stages of the Wingate approach are completed in a laboratory setting. First there is the introduction step, which combines mental training strategies such as relaxation with various biofeedback training modalities (i.e., electromyography, skin conductance, heart rate). For Step 1, 10-15 meetings are recommended, 2-3 times per week, lasting 55-60 minutes per session. Second is the identification step, where the most efficient biofeedback modalities for the athlete and their sport discipline are identified. For Step 2, 10-15 meetings are suggested. For the third step (simulation), athletes begin to mentally rehearse previous competitive situations while listening to audio/verbal stress factors under natural conditions. Fifteen meetings are recommended, 2-3 times per week, with each session lasting 50-60 minutes. The next two steps take place in the athlete’s sport environment. Step 4 is the transformation stage, where athletes
mentally prepare for their upcoming sport event with a portable biofeedback device. Ten to 15 meetings are suggested for the athlete to transfer the acquired skills from steps 1 through 3 into the sport environment. In Step 5 (realization), the athlete uses the mental techniques during competition with the integration of biofeedback where it fits (i.e., between events, during warm-up, etc.) (Blumenstein & Bar-Eli, 2005; Blumenstein et al., 1997; 2002; Blumenstein & Weinstein, 2011; Hall, Duncan, McKay, 2014). Researchers who have integrated the Wingate five-step approach into interventions (see Bar-Eli & Blumenstein, 2004; Bar-Eli, Dreshman, Blumenstein, & Weinstein, 2002; Galloway, 2011) have found a positive correlation between the approach and the intervention effects (i.e., performance enhancement).

With research showing the positive effects of biofeedback training on sport performance, it is interesting that more researchers have not measured the effects of combining an additional regulation strategy, such as imagery, with biofeedback. Researchers have investigated the effects of multi-modal mental skills interventions that utilize skills such as concentration, relaxation, imagery, and biofeedback (see Bar-Eli & Blumenstein, 2004; Bar-Eli et al., 2002; Galloway, 2011). However, there is a large gap in the sport and performance literature examining the effects of an imagery and biofeedback training intervention. This is especially notable given that in the Wingate approach, the third step (simulation) involves athletes mentally rehearsing previous competitive situations while listening to audio/verbal stress factors under natural conditions.

In the sport and performance literature, imagery is a well-researched topic with previous research demonstrating the positive effects it can have on an athlete’s sport
performance (Morris, Spittle, & Watt, 2005). Imagery can be described as “an experience generated from memorial information, involving quasi-sensorial, quasi perceptual, and quasi-affective characteristics, that is under the volitional control of the imager, and which may occur in the absence of real stimulus antecedents normally associated with the actual experience” (Morris et al., 2005, p. 19). Imagery is a multisensory construct where an athlete can incorporate all relevant modalities (i.e., kinesthetic, visual, auditory, tactile, olfactory, and gustatory) when practicing the skill. Imagery that encompasses all of the senses can lead to a more effective imagery experience (Moran, 2013; Vealey & Greenleaf, 2010).

Much of the imagery research has stemmed from Paivio’s (1985) framework, which suggests imagery has both cognitive and motivational functions. These functions operate at both a specific and general level. Based on Paivio’s analytic framework, Hall et al. (1998) identified five different functions of imagery: (1) cognitive specific (e.g., images of sport specific skills), (2) cognitive general (e.g., images of sport specific strategies and/or routines), (3) motivational specific (e.g., images related to an individual’s goals), (4) motivational general-arousal (e.g., images related to regulating arousal, stress, and anxiety), and (5) motivational general-mastery (e.g., images of being self-confident, focused, and mentally tough). Although athletes report using all of these functions, researchers have focused primarily on cognitive specific and motivational general-mastery functions as these functions are typically employed most frequently (Cumming & Hall, 2002; Hall, Mack, Paivio, & Hausenblas, 1998; Munroe-Chandler, Hall, Fishburne, Murphy, & Hall, 2012; Vadocz, Hall, & Moritz, 1997).

For the purposes of the current research, cognitive specific, motivational general-
arousal, and motivational general-mastery were emphasized. Cognitive specific imagery interventions have demonstrated a positive effect on sport performance (Munroe-Chandler et al., 2002). In addition, motivational general-arousal interventions have indicated that this function of imagery is effective in controlling emotions, as well as creating more facilitative interpretations of symptoms associated with competitive anxiety (see Jones, Mace, Bray, MacRae, & Stockbridge, 2002; Mellalieu, Hanton, & Thomas, 2009). Similarly, motivational general-mastery imagery interventions have shown that athletes have the ability to enhance levels of self-confidence and self-efficacy (e.g., Callow, Hardy, & Hall, 2001; O, Munroe-Chandler, Hall, & Hall, 2014).

Researchers indicate the positive effects that both biofeedback training and imagery interventions can have on sport performance. More specifically, the applied sport psychology literature suggests that combining relaxation techniques and imagery can be effective in enhancing performance (Paul & Garg, 2012). However, little research investigates biofeedback training in combination with imagery and whether this type of intervention can generate more control over the physiological and psychological stress states within sport performance (Paul & Garg, 2012). Further, if biofeedback training is disrupted with imagery training or a rest period, it is undetermined if athletes will reach resonance frequency and gain physiological control as quickly as those who have continuous biofeedback training.

Therefore, the purpose of this study was to examine the practice effect of biofeedback in high performance varsity athletes. More specifically, this research was guided by the following questions: (1) Are athletes who practice biofeedback continuously able to self-regulate by reaching resonance frequency and gaining
physiological control quicker than if practice time integrates imagery training? (2) If biofeedback training is interspersed with imagery training or a rest period, can athletes still reach resonance frequency and gain physiological control as quickly? (3) Do athletes believe that employing imagery can simulate a sport experience, contributing to the effectiveness of the intervention? (4) Do athletes think that five, 10-15 minute biofeedback training sessions is an adequate amount of time to gain physiological control?

Method

Participants

Twenty-seven high performance varsity athletes (7 male, 20 female) representing a post-secondary school in Southwestern Ontario, Canada agreed to participate ($M_{age} = 21.04, SD = 2.85$). Athletes ranged from having one to seven years’ experience at the varsity level and spent an average of 10 hours per week training. The sports represented include: rowing ($N = 13$), rugby ($N = 7$), swimming ($N = 4$), cheerleading ($N = 1$), basketball ($N = 1$), and dance ($N = 1$).

Measures

Physiological data were recorded using the Biograph Procomp Infiniti™ T7500M Biofeedback System manufactured by Thought Technology (Montreal, Quebec, Canada). This device is a valid research grade device that acquires 256 samples per second. For the purposes of this research, respiration rate, heart rate variability, and skin conductance were measured. Research suggests that training these variables can teach athletes to regulate competitive anxiety, increase self-confidence, cope with emotions, optimize self-regulation ability, and enhance performance (Blumenstein et al., 2002; Dupee et al.,
2015; Lagos et al., 2008; Lehrer et al., 2000; Meuret et al., 2001; Paul & Garg, 2012; Sime, 2003). To measure respiration rate, a strain-gauged belt was placed around the mid-section of the abdomen. Heart rate variability was measured through an indirect measure of heart rate. A blood volume pulse detection sensor was placed around the participant’s thumb and heart rate variability was computed using the formula HR Max – HR Min (i.e., the mean difference between heart rate maximum and heart rate minimum during each breath). Based on previous sport biofeedback research (Dupee et al., 2015), heart rate variability was measures using this formula. Lastly, skin conductance was measured by connecting two separate sensors to the index and ring finger. Once connected to the encoder, participants were able to monitor the three physiological variables through real-time, visual feedback on a computer screen. All three measures were recorded into a computer and analyzed by the aforementioned specialized biofeedback software program (i.e., Biograph Procomp Infiniti™ T7500M Thought Tehcnology Ltd., Canada).

Protocol

Ethics approval for this study was obtained from the university’s human research ethics board (see Appendix F). Written informed consent was obtained from each athlete prior to the start of the intervention. Participants were randomly assigned to one of three equal groups (i.e., 9 athletes per group): (1) biofeedback group (2 male, 7 female), (2) imagery group (2 male, 7 female), and (3) comparison group (3 male, 6 female).

**Group 1: Biofeedback group.** Participants in the biofeedback group completed five biofeedback training sessions, with each session lasting 15 minutes. The rationale for this experimental design (i.e., five training sessions) was based on previous pilot research
where athletes perceived five training sessions to be an adequate amount of time to learn
and attain the self-regulation strategies intended for optimal performance. This specific
population of high performance athletes was able to apply the skills and techniques
quickly. Therefore, based on the pilot research, a five-session biofeedback intervention
seemed appropriate with the exploratory nature of this study. The primary investigator
created a biofeedback training screen to measure breathing patterns, resonance frequency,
heart rate, and skin conductance. Particularly, participants were able to view their
respiration rate, beat-to-beat heart rate, and skin conductance (measured in micro
Siemens) on the screen. The primary investigator explained what each measure was to the
participant. The same screen was used for each training session. Participants were
connected to the aforementioned sensors and respiration strap prior to the start of each
session. During the first session, the protocol designed to increase heart rate variability
with biofeedback by Lehrer, Vaschillo, and Vaschillo (2000) was implemented. Each
participant was asked to breathe at variable respiration rates (e.g., 7.5, 7, 6.5, 6, 5.5
breaths/minute) while following a pacing stimulus (e.g., a line that moved up and down,
instructing the participant when to inhale and exhale) for two minutes. Resonance
frequency can be detected at the frequency at which maximum heart rate variability is
produced, which was detected through the biofeedback device. The resonance frequency
for most biofeedback group participants was close to 0.1 Hz, or about six breaths per
minute. The paced stimulus was set for each participant (e.g., 6 breaths/minute) and
participants were instructed for natural and shallow abdominal breathing in accordance to
his or her resonance frequency. The idea of balloon imagery (i.e., trying to fill the balloon
with each inhale, and deflate the balloon with each exhale) was introduced to participants
to facilitate abdominal breathing (Khazan, 2013). It is important for athletes to learn diaphragmatic breathing and to minimize thoracic movement to maintain control over physiological functions. The primary investigator continued to guide athletes by reminding them about using their belly to breathe while attempting to produce large, rolling peaks on the screen. For sessions two through five, participants closed their eyes for the last three minutes of biofeedback training to practice breathing at resonance frequency without the pacer stimulus. The feedback was provided to the participant in the form of respiration rate, beat-to-beat heart rate, and skin conductance rate over the span of 30 seconds on the screen. At the end of each 15-minute session, the biofeedback training screen was paused to allow participants to review their final physiological measures after opening their eyes. Physiological measures (i.e., respiration rate, heart rate variability, skin conductance) were recorded during each 15-minute session. This protocol was adhered to for all five intervention training sessions.

**Group 2: Imagery group.** Participants in the imagery group completed five training sessions, with each session lasting 15 minutes. However, participants in the imagery group followed a time sensitive protocol. For the first five minutes, participants practiced biofeedback. This was then followed by a five-minute imagery script. To finish, participants resumed biofeedback training for the remaining five minutes. The same training screen used for Group 1 was used for Group 2 for the duration of the intervention. Participants were connected to the aforementioned sensors and respiration strap prior to the start of each session. For session one, the same protocol to determine resonance frequency (Lehrer et al., 2000) was followed and participants in the imagery group received the exact same training and instruction (i.e., the idea of balloon imagery
to facilitate abdominal breathing) during each biofeedback training bout as the biofeedback group. The resonance frequency for most imagery group participants was close to 0.1 Hz, or about six breaths per minute. During the five-minute imagery script, participants were instructed to close their eyes and image the script that was read to them by the primary investigator. The same imagery script was read each training session. For sessions two through five, participants closed their eyes for the last three minutes of biofeedback training to practice breathing at resonance frequency without the pacer stimulus. The feedback was provided to the participant in the form of respiration rate, beat-to-beat heart rate, and skin conductance rate over the span of 30 seconds on the screen. At the end of each 15-minute session, the biofeedback training screen was paused to allow participants to review their final physiological measures after opening their eyes. Physiological measures (i.e., respiration rate, heart rate variability, skin conductance) were recorded during each 15-minute session. This protocol was adhered to for all five intervention training sessions.

**Group 3: Comparison group.** Participants in the comparison group completed five training sessions, with each session lasting 15 minutes. Similar to the imagery group, participants in the comparison group practiced biofeedback for the first five minutes. This was then followed by a five-minute rest period where participants were instructed to rotate their chair to ensure their attention was not directed at the biofeedback screen. All participants chose to use their mobile device for each rest period. To finish, participants resumed biofeedback training for the remaining five minutes. The same training screen used in Group 1 and Group 2, was used for Group 3 for the duration of the intervention. Participants were connected to the aforementioned sensors and respiration strap prior to
the start of each session. The same protocol to determine resonance frequency (Lehrer et al., 2000) was followed and participants received the exact same training and instruction (i.e., the idea of balloon imagery to facilitate abdominal breathing) during each biofeedback training bout as the biofeedback group. The resonance frequency for most comparison group participants was close to 0.1 Hz, or about six breaths per minute. For sessions two through five, participants closed their eyes for the last three minutes of biofeedback training to practice breathing at resonance frequency without the pacer stimulus. The feedback was provided to the participant in the form of respiration rate, beat-to-beat heart rate, and skin conductance rate over the span of 30 seconds on the screen. At the end of each 15-minute session, the biofeedback training screen was paused to allow participants to review their final physiological measures after opening their eyes. Physiological measures (i.e., respiration rate, heart rate variability, skin conductance) were recorded during each 15-minute session. This protocol was adhered to for all five intervention training sessions.

Imagery script. The imagery script (see Appendix C) was developed by the primary investigator and was created around cognitive specific (e.g., imaging sport specific skills), motivational general-arousal (e.g., regulating emotions using imagery), and motivational general-mastery (e.g., imagery to build self-confidence, focus) situations in accordance to Paivio’s (1985) model. Imagery scripts with response propositions (e.g., imagine being in control and confident during a difficult sport situation) are more likely to produce vivid images (Lang, Kozak, Miller, Levin, & McLean, 1980). Therefore, with athletes being recruited from a variety of sports, the script was general and focused on being in control and confident during performance
mistakes and outcomes to ensure that it was meaningful for each athlete. The imagery script was created using previous imagery scripts (e.g., Callow et al., 2001; Cumming & Ste-Marie, 2001; Vealey & Greenleaf, 2010) as a foundation and was adapted from work done by Leslie-Toogood, Hammond, and Gregg (n.d.) on developing a suitable imagery script.

**Post-manipulation check**

Following the intervention, each participant completed a post-manipulation check questionnaire (see Appendix D) developed by the primary investigator. The questionnaire varied by group and each consisted of six items. The questionnaire for the biofeedback group examined the effectiveness of the intervention (e.g., “the biofeedback intervention was effective, the length of the intervention was appropriate”) as well as the impact it may have elicited on sport performance (e.g., “this training will have a positive impact on my sport performance”). The questionnaire for the imagery group focused on the athlete’s ability to image (e.g., “I was able to image during the imagery script”), the effectiveness of combining imagery and biofeedback (e.g., “I found the combination of imagery and biofeedback to be effective”), if the length of the intervention was appropriate, and the impact it may have elicited on sport performance. The comparison group had a similar questionnaire to the biofeedback group with exception to training time and whether participants found 10 minutes of biofeedback to be sufficient (e.g., “10 minutes of biofeedback was an adequate amount of time each session”). Each item was rated on a five-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). Lastly, at the end of the questionnaire, participants were asked to provide additional comments and feedback on the intervention.
Data Analysis

Physiological measures. Physiological data was extracted from the specialized biofeedback software program, which were then statistically analyzed using the Statistical Package for Social Sciences (SPSS)/25.0 (Copyright © SPSS Inc.). For examining changes in the dependent variables between groups, a 3 (Group: biofeedback, imagery, comparison) x 3 (Time: first five minutes, second five minutes, third five minutes) x 5 (Session: 1, 2, 3, 4, 5) repeated measures ANOVA was applied to analyze differences between groups over times and sessions. Statistical significance was accepted at \( p \leq 0.05 \).

Post-manipulation check. To analyze post-manipulation check questionnaires, participant responses were inputted in SPSS to reveal descriptive statistics in the form of means, standard deviations, and range of response. The post-manipulation check provided space for athletes to disclose any additional comments or feedback on the training. Athletes provided rich content and therefore a qualitative analysis was necessary. An inductive thematic analysis was conducted to identify categories, themes, and sub-themes. The data were divided into initial codes, which lead to the development of themes and sub-themes to represent athletes’ perceptions of the intervention. The primary investigator and a critical friend (Smith & McGannon, 2018), a Ph.D. student familiar with qualitative data, engaged in critical dialogue where interpretations of the findings were challenged. This promoted refinement of themes and categories, enhancing the rigor and quality of the data.
Results

Physiological Measures

Heart rate variability. The ANOVA revealed a significant main effect of Time, $F(6, 19) = 15.876, p = .000, \eta^2 = .834$, as well as a significant Group x Time interaction, $F(12, 40) = 3.139, p = .003, \eta^2 = .485$. Figure 1 depicts the estimated marginal means for heart rate variability across each group (i.e., biofeedback, imagery, comparison) over time. The biofeedback group presented a relatively stable trend across each time point. There is a slight increase at Time 3, indicating that as participants continued to breathe at their resonance frequency, they were able to expand the amplitude of their heart rate oscillations. Participants in the imagery and comparison groups had a decrease in heart rate variability during Time 2. Heart rate increases with each inhalation and decreases with each exhalation. Therefore, high amplitude heart rate oscillations were not being achieved, resulting in a decrease in variability.

Figure 1. Estimated margin means for heart rate variability for each group across time.
**Respiration rate.** The ANOVA revealed a significant main effect of Time, $F(6, 19) = 15.876$, $p = .000$, $\eta^2 = .834$, as well as a significant Group x Time interaction, $F(12, 40) = 3.139$, $p = .003$, $\eta^2 = .485$. As seen in Figure 2, the biofeedback group maintained a constant respiration rate across time. For each time point, the group followed a breathing pacer in accordance to their resonance frequency. This means that each participant in the biofeedback group had instruction to breath at the pace best suited for their heart rate oscillations. Participants in the imagery group had a slight increase in their respiration rate during Time 2 (i.e., while imaging). This was expected as participants were instructed to close their eyes and follow along with the imagery script as opposed to the pacer stimulus. Further, the comparison group had a significant increase in their respiration rate during Time 2, which was anticipated due to their attention being on their mobile device and away from the biofeedback screen. During Time 3, participants in the imagery and comparison groups were able to bring their respiration rate down to their determined breathing pace.

![Figure 2](image.png)

*Figure 2.* Estimated margin means for respiration rate for each group across time.
**Skin conductance.** The ANOVA revealed a significant main effect of Time, $F(6, 19) = 15.876, p = .000, \eta^2 = .834$, as well as a significant Group x Time interaction, $F(12, 40) = 3.139, p = .003, \eta^2 = .485$. When examining marginal means for skin conductance among each group (see Figure 3), it is evident that the biofeedback group was able to maintain a relatively stable emotional response during all time points. This can be attributed to paced and controlled breathing in response to rhythmical simulation of each participant’s resonant frequency, eliciting a relaxed physiological state and in turn emotional regulation. For the imagery group, it was expected that skin conductance levels would increase during the five-minute imagery script. With the script focusing on athletic performance mistakes and outcomes, the rise in skin conductance could be attributed to heightened emotional responses. Although participants in the imagery group were able to reach and maintain coherence during Time 3 (i.e., biofeedback training), skin conductance slightly climbed indicating that athletes may not have had the chance to regulate the emotions associated with their imaging. Interestingly, the comparison group’s skin conductance continued to increase throughout each time point. For Time 2, participants used their mobile devices during each session. However, for Time 3 (i.e., biofeedback training), skin conductance levels continued to rise even once coherence was met. As anxiety and arousal levels increase, skin conductance begins to follow this pattern through psychophysiological activation. Therefore, participants’ psychophysiological activation during their rest period may not have been regulated during Time 3.
Figure 3. Estimated margin means for skin conductance across each group.

**Post-Manipulation Check: Descriptive Statistics**

A post-manipulation check was administered to each participant and was specific to the group they were assigned to (see Appendix D). Means, standard deviations, and range of responses are presented in Table 3. An overall examination of participants' perceptions of the intervention indicated that participants were highly satisfied with its effectiveness. Further investigation into the biofeedback group showed the intervention to be effective, the length of the intervention appropriate, the training relatively easy, 15 minutes of training to be adequate, and the training to have a positive impact on sport performance. The imagery group indicated a relatively high imagery ability, the combination of imagery and biofeedback to be effective, the training relatively easy, the length of the intervention appropriate, and the training to have a positive impact on sport performance. Lastly, the comparison group showed the intervention to be effective, the length of the intervention appropriate, the training relatively easy, 10 minutes of training to be adequate, and the training to have a positive impact on sport performance.
Table 3

*Descriptive statistics: Post-manipulation check responses from participants*

<table>
<thead>
<tr>
<th>Item</th>
<th>Biofeedback Group (N = 9)</th>
<th>Imagery Group (N = 9)</th>
<th>Comparison Group (N = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The biofeedback intervention was effective.</td>
<td>4.89 ± 0.33</td>
<td>4.56 ± 0.73</td>
<td>4.67 ± 0.50</td>
</tr>
<tr>
<td>The length of the intervention was appropriate.</td>
<td>4.78 ± 0.44</td>
<td>4.78 ± 0.44</td>
<td>4.78 ± 0.44</td>
</tr>
<tr>
<td>The training was easy.</td>
<td>4.33 ± 0.71</td>
<td>4.11 ± 0.78</td>
<td>4.44 ± 0.53</td>
</tr>
<tr>
<td>15 minutes of biofeedback was an adequate amount of time each session.</td>
<td>4.67 ± 0.50</td>
<td>4.78 ± 0.44</td>
<td>4.44 ± 0.53</td>
</tr>
<tr>
<td>The training will have a positive impact on my sport performance.</td>
<td>4.78 ± 0.44</td>
<td>4.67 ± 0.71</td>
<td>4.22 ± 0.67</td>
</tr>
</tbody>
</table>

*Note. Each item was rated on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree)*

**Post-Manipulation Check: Qualitative Findings**

Analysis led to the identification of two categories, four themes, and 10 sub-themes. The sub-themes are explored under each category and theme heading. Each sub-theme is accompanied by quotations to enhance the clarity of the data presented. Table 4 illustrates a breakdown of categories, themes, sub-themes, and the number of responses associated with each sub-theme. Participant codes have been used to maintain participants’ anonymity.
Application of Biofeedback

**Positive implications.** Participants considered the positive implications of the intervention through three sub-themes, including: self-awareness, real-time feedback, and life skill.

**Self-awareness.** Participants in all three groups recognized the impact biofeedback training had on developing self-awareness. One participant expressed, “I had no idea what biofeedback was before this and now realize how valuable it is. I gained so much awareness about how to manage my physiology and can't wait to see the benefits in sport and daily life” (B9). Additionally, some athletes mentioned how gaining self-awareness provided strategies to calm the body and the mind. This sentiment is captured in the following quote: “I am happy to have gained this self-awareness and a skill to help me calm and control my body and mind” (C5). Relatedly, another participant said, “biofeedback is a good way to gain awareness of how quickly we have the ability to calm the body and mind” (C8). Lastly, some participants revealed the positive implications in terms of managing emotion. This is highlighted in the following quote: “A great
experience. A lot of self-awareness gained which can help manage emotions and regulate anxiety” (B4).

**Real-time feedback.** Some participants disclosed that the real-time feedback that biofeedback provides contributed to the positive implications of the intervention, which is articulated in the subsequent quote:

I found it was very useful to be able to see on the screen how my stress levels and heart rate were affected when imaging being in a sport situation [where] I didn't perform well. Getting the real-time feedback as an athlete was super helpful and allowed me during our 5 sessions to learn how to control my breath and heart rate and align them to work together. (I6)

Participants also noted that seeing the physiological changes on the computer screen in front of them made them realize how much control they have over their functioning. B4 stated, “I think it was interesting to see the changes on the screen and to get that live feedback while controlling your body and mind and actually seeing the impact and effects”. Comparably, another participant said, “it is interesting to see the effect that biofeedback has on your body and to see the changes in front of you on the screen” (C3). During the intervention, participants continued to mention that “physically seeing” the implications biofeedback training had on their physiological functioning made the process “easier to buy-in to” (C5).

**Life skill.** It became apparent that participants felt as though the skills acquired through biofeedback training could transfer to other areas of their life. In general, some participants documented its applicability to everyday life but also the positive implications it could have outside of sport. One participant mentioned, “[I] really enjoyed
it and I have already seen positive impacts on both my training and everyday life” (I4).

Similarly, another participant said, “the biofeedback is helpful in other areas of life so it was a great experience overall” (I2). Lastly, B6 revealed, “biofeedback is very applicable for not only sport but everyday life” (B6). More specifically, one participant in particular who struggles with asthmatic lungs said: “mentioning breathing patterns with asthmatic lungs was specific to me and very helpful in day-to-day life” (C9). The strategies attained through biofeedback training support self-regulation beyond the sport setting, which was emphasized by participants from each group following the intervention.

Role of imagery. Most of the participants in the imagery group discussed how the integration of imagery during biofeedback training helped to transfer the training and acquired skills to their sport. The role of imagery can be explored through the sub-theme drawn from the data: simulate sport experience.

Simulate sport experience. Most of the participants in the imagery group felt as though imagery contributed to the intervention’s effectiveness. One participant said, “the imagery helped to simulate real sport experiences, which contributed to the effectiveness” (I8). In addition it was stated, “the imagery scripts were good and helped to engage in outside sport experience while doing the biofeedback training” (I2). Another participant added, “I can transfer imagery and visualization of skills to the field while visualizing myself completing skills or games during the biofeedback process” (I4). Further, one participant mentioned how “reflecting on past experiences engaged the whole body with bits of adrenaline, nerves, excitement, and hope” (I9). She went on to say, “I was able to connect quickly during the imagery and use the biofeedback to simulate that sport experience” (I9). Lastly, it was noted that “adjusting the imagery script to be more
applicable to individual experience was effective” (I9) and that the “imagery scripts were effective for my sport and transferring the biofeedback skills to my sport” (I7). Without being prompted to comment on the integration of imagery during each biofeedback training session, participants recognized the value that imagery added to the intervention.

**Discussion**

The purpose of this study was to examine the practice effect of biofeedback in high performance varsity athletes and four questions were posed. More specifically, this research aimed to determine (a) whether athletes who practice biofeedback continuously are able to self-regulate by reaching resonance frequency and gaining physiological control quicker than if practice time integrates imagery training, and (b) if biofeedback training is interspersed with imagery training or a rest period, are athletes still able reach resonance frequency and gain physiological control as quickly. It also explored (c) athletes’ perception of the role of imagery in terms of intervention effectiveness. Further, (d) this study investigated if the number of sessions (i.e., 5 sessions) and the practice time (i.e., 10-15 minutes) of each session was an adequate amount of time to learn strategies to gain physiological control.

Each group (biofeedback, imagery, comparison) had identical biofeedback training and instruction. One biofeedback training screen was used across groups and measured respiration rate, heart rate, and skin conductance. Participants were trained to breathe at resonance frequency (i.e., approximately six breaths per minute), producing a smooth sinusoidal wave where heart rate and respiration rate begin to cohere during each inhale and exhale (Paul & Garg, 2012). Training and exercising this balance between heart rate and respiration rate exhibits the body’s own physiological control mechanisms
This then expands the amplitude of heart rate oscillations, increasing a participant’s heart rate variability. Once this autonomic control is achieved, a subject has the ability to regulate emotions and optimize performance (Dupee et al., 2015; Lagos et al., 2008; Lehrer et al., 2000; Meuret et al., 2001; Paul & Garg, 2012).

The first two questions were answered by the significant Group x Time interaction. With Figure 1, 2, and 3 representing the marginal means of heart rate variability, respiration rate, and skin conductance, respectively, it is evident that this significant interaction can be attributed to the procedure followed within each group. In the imagery and comparison group, coherence (i.e., smooth sinusoidal wave between heart rate and respiration) was reached at Time 1 and Time 3 as participants maintained resonance frequency. As seen in Figure 1, the marginal mean for heart rate variability depicts high amplitude oscillations in heart rate in Time 1 and Time 3. As soon as imagery and comparison group participants lost resonance frequency (i.e., Time 2), their physiological variables such as heart rate and skin conductance began to rise. Although skin conductance did not increase much, heart rate variability decreased. As heart rate variability decreases, the ability to regulate emotions when internal and external stimuli change reduces (Lagos et al., 2008). Based on previous research, it is apparent that during these rest states, an athlete’s ability to manage physiological, psychological, attentional, and behavioral fluctuations diminishes (Lagos et al., 2008; Paul & Garg, 2012; Perry, 2018).

Although the biofeedback group trained continuously and maintained relatively stable physiological responses during each intervention session, the imagery and comparison group were able to reach resonance frequency and control their physiological
responses during Time 3 (i.e., once biofeedback training resumed). In Figure 1 (i.e.,
margin means for heart rate variability), both the imagery and comparison groups were
able to increase their heart rate variability during Time 3. The marginal means for these
groups were in fact higher than the biofeedback group (about 3 beats for the comparison
group and 5 beats for the imagery group). Therefore, the time spent training with
biofeedback and the positive outcomes associated with reaching resonance frequency did
not differ if biofeedback training was continuous or interspersed.

To date, researchers have not examined the integration of imagery during
biofeedback training while measuring physiological variables and how those variables respond. Each imagery session utilized cognitive specific (e.g., images of sport specific
skills), motivational general-arousal (e.g., images related to regulating arousal, stress, and anxiety), and motivational general-mastery (e.g., images of being self-confident, focused, and mentally tough) imagery functions. With research highlighting the positive effects these functions can have on sport performance (see Munroe-Chandler et al., 2002; Jones et al., 2002; Mellalieu et al., 2009; Callow et al., 2001; O et al., 2014), the integration of imagery could generate cognitive (i.e., psychological) and somatic (i.e., physiological) self-regulation, enhancing the outcome of biofeedback training (Paul & Garg, 2012). In their qualitative responses, which addressed the third research question, participants in the imagery group suggested that imagery helped to simulate real sport experiences while maintaining a relaxed physiological state. Although imagery participants increased their respiration rate and decreased heart rate variability during each five-minute imagery script, they were able to quickly regain physiological control during Time 3 (see Figure 1 and 2).
The interaction of emotional responses to stress, anxiety, and/or pressure can have a debilitative effect on performance (Dupee et al., 2015; Paul & Garg, 2012). Similar to the practice of skills, technique and strategy, self-awareness and self-regulation can be trained and practiced (Dupee et al., 2015; Perry, 2018). During each intervention session, and as indicated on the post-manipulation check, biofeedback proved to be a valuable tool aiding in the development of self-awareness and how thoughts and emotions impact psychophysiological states. With the real-time feedback biofeedback provides, athletes were able to learn strategies to manage those states and respond accordingly. Therefore, participants disclosed that they felt better equipped to excel in their sport.

Further, perceptions of effectiveness were not just associated with the self-regulation and awareness gained but also the length of the intervention. Participants trained for 10 to 15 minutes depending on the group to which they were assigned. As noted on the post-manipulation check (see Table 3), which addresses the fourth question, participants found the training time was adequate and appropriate. When following the Wingate approach, a minimum of 45 sessions each lasting 55-60 minutes per session is recommended for athletes to learn, simulate, and transfer the skills from lab to the sport environment. The present study did not employ the Wingate approach, but participants felt that the length of the intervention was sufficient for acquiring self-awareness and self-regulation strategies. Overall, these results question whether the number and length of sessions proposed in the Wingate approach are actually necessary, at least for varsity level athletes. High performance athletes have demanding schedules. The length of the Wingate approach makes conducting large-scale studies and applied interventions very
challenging. Therefore, further investigation is warranted to determine if the Wingate approach can be streamlined (Galloway, 2012).

The role of imagery on skin conductance (i.e., the emotion detector) may need further investigation as well. As seen in Figure 3, skin conductance continued to rise during Time 2 (imagery script) and Time 3 (biofeedback training) for the imagery group. As emotions, such as anxiety, stress, and pressure increase, skin conductance begins to follow this pattern through psychophysiological activation (Sime, 2003). Even though participants reached resonance frequency and increased heart rate variability for Time 3 (see Figure 1 and 2), the emotions associated with each imagery session may have had a direct impact on the continued rise in skin conductance. The relationship between imagery and skin conductance has received very limited empirical investigation (e.g., Haney & Euse, 1976).

Future research in biofeedback could benefit from including post-intervention follow-ups (e.g., 1-month and 6-month post-intervention) to evaluate adherence and perceived effectiveness. In addition, it would be useful to conduct a biofeedback training intervention similar to the current study during the competitive season. This could evaluate an athlete’s ability to transfer the acquired skills from the lab to the sport setting without the inclusion of the Wingate approach. It could also be helpful to employ the same intervention using group-training sessions with participants involved in team sports. It may be easier for athletes to implement the acquired skills if they are learning the self-regulation skills as a group. This could contribute to team cohesion as well as performance enhancement across the team. Continued research examining the combination of imagery and biofeedback training effects on sport performance is
necessary as this combined intervention could generate the management of both cognitive (psychological) and somatic (physiological) responses, contributing to positive performance outcomes. Lastly, future research examining participants’ physiological variables over varied intervention lengths would be valuable (e.g., five sessions, seven sessions, and ten sessions) to determine if results differ between groups over time.

While findings from the current study have important implications there are a number of limitations. A better understanding of intervention effects could have been determined through a post-intervention interview rather than feedback provided on the post-manipulation check. This could have offered valuable suggestions for future interventions. The transfer effect from the laboratory setting to the sport environment is undetermined, which poses a major limitation to the study. As previously mentioned, conducting this intervention during competition season and/or the inclusion of a post-intervention follow-up could have averted this limitation. Lastly, running a biofeedback training intervention with high performance athletes can be difficult due to the length and time required. Even though the sample size \(N = 27\) was relatively large for a study of this nature, the results should be interpreted with caution until these results are replicated and extended.

In conclusion, it is apparent that athletes who take rest periods between biofeedback training can quickly regain resonance frequency and increase heart rate variability. Therefore, it may be worth interspersing biofeedback with additional self-regulation strategies, such as imagery, to enhance the quality of the session. Further, results indicate that the athletes perceived five training sessions at 10-15 minutes per session to be adequate in providing the self-awareness and self-regulation skills required
to optimize performance. These results imply that future research may include a streamlined version of the Wingate approach. In sum, when biofeedback training is interrupted with either an imagery script or a rest period, participants can still regain resonance frequency and physiological control as quickly as continuous biofeedback training. Sport psychologists and/or practitioners offering biofeedback may optimize delivery and sport performance outcomes by including imagery and pairing two mental strategies together to generate the management of both cognitive (psychological) and somatic (physiological) processes.
References


training and practice with mindfulness. Malden, MA: John Wiley & Sons, Ltd.


Summary, Strengths, Implications, Limitations, Future Directions

The purpose of this dissertation was to examine the use of biofeedback. Specifically, the studies that were conducted and included in this dissertation: a) explore athletes’ perceptions of biofeedback, b) assess mental performance consultants’ experience, knowledge, perceptions, and practice of biofeedback, and c) evaluate the practice effects of biofeedback with the integration of imagery in enhancing intervention effectiveness and outcomes related to self-regulation.

Study 1 aimed to explore athletes’ perceptions of biofeedback following a five-session biofeedback intervention, training respiration rate, heart rate variability, and skin conductance. Five varsity athletes participated in a post-intervention interview. An inductive thematic analysis uncovered three categories in the data: understanding of biofeedback (e.g., knowledge of tool), positive perspectives of the use of biofeedback (e.g., enhanced self-regulation skills, use of skills outside of sport), and practical limitations (e.g., application of biofeedback). The qualitative nature of this study provided a promising way to determine an athlete’s response to biofeedback by offering evidence to mental performance consultants, sport psychologists, coaches, and other athletes on biofeedback in terms of performance quality.

Following these findings, the goal of Study 2 was to examine mental performance consultants’ use of biofeedback and their perceptions of the tool for influencing athletic performance. Ten experienced consultants participated in interviews and an inductive thematic analysis uncovered two categories from the data: biofeedback training (e.g., exposure to biofeedback), and application of biofeedback (e.g., positive implications, practical limitations, and equipment options). Findings suggested that biofeedback can
provide athletes with the necessary self-awareness and self-regulation skills to reach performance potential, but that there are limiting factors (e.g., high cost, time constraint, limited education and training) to its use. Overall, these findings offer current mental performance consultants with information about the use of biofeedback when undertaking mental skills training programs and/or interventions.

The purpose of Study 3 was to investigate if varsity athletes \( (N = 27) \) who practice biofeedback continuously can self-regulate by reaching resonance frequency and gaining physiological control quicker than if practice time integrates imagery training. It also explored athletes’ perceptions of the role of imagery in terms of intervention effectiveness. It was also determined if the number of sessions (i.e., 5 sessions) and the practice time (i.e., 10-15 minutes) of each session was adequate for athletes to learn strategies to gain physiological control. A significant Time effect as well as a significant Group (biofeedback, imagery, comparison) x Time (first 5 minutes, second five minutes, third five minutes) interaction was found. Although the biofeedback group trained continuously and maintained relatively stable physiological responses during each intervention session, the imagery and comparison groups were able to reach resonance frequency and control their physiological responses once biofeedback training resumed. Thus, the time spent training with biofeedback and the positive outcomes associated with reaching resonance frequency did not matter if biofeedback training was continuous or interspersed. Qualitative analysis suggested that imagery could help to simulate real sport experiences while maintaining a relaxed physiological state, contributing to the effectiveness of biofeedback training. Further, findings indicated that biofeedback is a valuable tool in the development of self-awareness and self-regulation. Outcomes related
to this study provide insight to mental performance consultants and sport psychologists who offer biofeedback, helping to inform future research, mental training programs, and biofeedback interventions.

The findings of this research helped to fill some of the gaps in the sport biofeedback literature. The novel qualitative findings from Study 1 and 2 provided a unique inquiry to the sport and performance literature (Smith & McGannon, 2018; Strean, 1998). Although, quantitative findings support biofeedback in terms of performance enhancement, sport biofeedback researchers have neglected to discuss intervention outcomes with athlete participants. Study 1 helped to determine an individual’s response to biofeedback, providing a better understanding of how biofeedback is perceived by offering conversational evidence to the usefulness of biofeedback training in terms of performance quality.

Furthermore, Study 2 further supported the use of biofeedback for athletic performance. Participants had an average of 17 years of experience and included some of the leading mental performance consultants in the field, working with world ranking and Olympic athletes from a variety of sport domains. Results portrayed their years of experience in providing high performance athletes with self-regulation strategies best suited for achieving optimal performance. Very little research has considered the services that mental performance consultants deliver and the effects of those services. With technology becoming a widespread tool in monitoring an athlete’s psychophysiological state, there is a gap in the literature that evaluates consultants’ use of these technological devices, their perceptions of effectiveness, and the limitations of their use. Therefore, findings from Study 2 demonstrated perspectives on the implications and limitations of
biofeedback, giving readers reliable information that some consultants may lack knowledge and education about.

Study 3 informed researchers, consultants, and sport psychologists conducting interventions and including biofeedback training into their mental skills programs on ways to optimize the delivery of biofeedback. Including imagery with biofeedback training could generate the management of both cognitive (psychological) and somatic (physiological) processes, enhancing sport performance outcomes. Results also indicated that future research could include a streamlined version of the Wingate approach, as athletes were confident in their self-awareness and self-regulation skills following the intervention employed in the present study.

Although the present dissertation has important implications, it is not without limitations. For Study 1, the sample size \( N = 5 \) was relatively small. While large samples are not required for qualitative research (Smith & McGannon, 2018) and data saturation was met, the results must be interpreted with caution. Future research may benefit from larger scale studies including both male and female athletes from a variety of sports to determine if perspectives on the use of biofeedback are different between genders and sports. This could help to generalize the findings. The physiological variables that were trained (heart rate variability, respiration rate, and skin conductance) in Study 1 were not examined, as the aim of the study was to qualitatively explore perspectives post-intervention. However, if physiological variables are analyzed, they could support qualitative results.

Moreover, in Study 2, mental performance consultants highlighted the limitations of the biofeedback device. Some participants mentioned their use of consumer devices
(e.g., Headspace) because they are more cost efficient and easier to use. Research is necessary to evaluate the validity and reliability of such tools, helping to inform mental skills training programs and/or future interventions. This could allow more consultants, psychologists, and athletes to use a form of biofeedback that is easily accessible, affordable, and efficient.

Although Study 3 presented significant findings, the transfer effect from the laboratory setting to the sport environment is undetermined. Future research should consider employing biofeedback interventions during the competitive season and/or the inclusion of a post-intervention follow-up to overcome this limitation. This could evaluate an athlete’s ability to transfer the acquired skills from the lab to the sport setting without the inclusion of the Wingate approach. However, with research supporting the use of the Wingate approach (see Bar-Eli, 2002; Bar-Eli & Blumenstein, 2004; Blumenstein et al., 1997; 2002; Galloway, 2011), future research should seek to examine if the same intervention effects can result if the approach is shortened.

In Study 3, additional intervention effects and outcomes could have been determined through a post-intervention interview rather than feedback provided on a post-manipulation check for Study 3. This could have offered strategies for future interventions as well as perspectives on the use of biofeedback and the administration of the intervention. Future sport biofeedback research could benefit from post-intervention follow-ups to evaluate effectiveness and adherence. Continued research examining the combination of not just imagery and biofeedback training, but other self-regulation techniques (e.g., self-talk, cognitive restructuring) could contribute to positive performance outcomes.
The experimental designs (i.e., five training sessions) in both Study 1 and Study 3 were exploratory. The number of sessions and the length of each session were based on previous pilot research. Thus, future research examining participants’ physiological variables over varied intervention lengths would be valuable. For example, participants could be assigned to one of three groups (e.g., five sessions, seven sessions, and ten sessions) to determine if results differ between groups over time. Findings could contribute valuable information to future researchers conducting biofeedback training interventions and help determine if the Wingate approach is the most suitable approach for biofeedback delivery and sport performance outcomes.

Overall, this dissertation provided insight about the effects of biofeedback on athletic performance. Qualitatively, results confirmed the existing outcomes (e.g., performance enhancement, self-awareness, self-regulation) related to previous quantitative findings. This dissertation also indicated the need for future research investigating methods to transfer the acquired skills to the sport setting, the effectiveness of integrating additional self-regulation skills into biofeedback interventions, the role imagery can have on simulating real-sport experiences during biofeedback training, and if the Wingate approach can be streamlined for larger scale studies to be conducted.
References


APPENDIX A

Post-Intervention Interview Guide (Study 1)

Thank you for your participation. I am starting the audio recording now. Please note that you can skip any question you wish not to respond to.

1. How would you explain what you have learned through this training to someone who may not be familiar with biofeedback?

2. Describe ways in which this training will be helpful in regards to your sport performance?

3. What would you say to someone else who is considering training in this area?

4. What are some positive outcomes from the intervention?
   a. What specific self-regulation techniques have you learned?

5. Can you identify any negative outcomes and/or experiences from the intervention?

6. Overall, how do you think biofeedback training can enhance your sport performance?

7. How will this training be helpful in other areas of your life?

8. Any other thoughts or comments?
APPENDIX B

Mental Performance Consultant Interview Guide (Study 2)

Thank you for your participation. I am starting the audio recording now. Please note that you can skip any question you wish to.

1. How long have you been a mental performance consultant for?

2. What are the most prominent mental skills training techniques that you use during consultations with athletes?

3. Are you familiar with what biofeedback training is?

Before proceeding with the interview, the definition of biofeedback is as followed:

Biofeedback is the use of sophisticated equipment to note psychophysiological responses to stress through visual or auditory feedback. Through this technique, athletes learn to develop strategies to control bodily outputs including rate of respiration, heart rate, variability, sweat, temperature, and muscle tension. Research has shown that biofeedback can decrease competition anxiety, reduce muscle tension, provide an athlete with greater self-regulation, decrease the likelihood of an injury, and help facilitate relaxation.

3. Is biofeedback a technique that you may have learned about during your educational training?
   - If yes, was it through a lecture, demonstration, or a particular reading material?

4. Have you ever used biofeedback during your consultations?
   - If yes, do you think biofeedback is a useful technique to use in your practice with athletes?
   - If not, is there a particular reason why you do not use biofeedback as a mental skills technique?

5. Do you think access to equipment is a factor contributing to why some MPC’s do not incorporate biofeedback training into their mental skills training programs?

6. Do you think MPC’s require more knowledge and/or training on the use of biofeedback?
   - If so, would this increase the chance of MPC’s using it in their practice?

7. Do you see biofeedback as being a valuable tool in helping athletes reach optimal performance?
APPENDIX C

Imagery Script (Study 3)

Mental imagery involves imagining yourself performing an activity. This is a technique that has been found to have powerful effects on helping people change their behaviors, self-concepts, and other thoughts related to themselves. Imagery incorporates all the senses and allows you to not only see yourself engaging in a behavior, but also feel what it is like to do it. The most effective images can also include sounds, smells, or even tastes that are associated with the behavior.

It is important to pay attention to using proper technique. I want you to be in a comfortable sitting position. You can start by closing your eyes. Take three deep, slow breaths that fill your lungs and chest with air, breathe in... breathe in...breathe out... Good, your mind is relaxed, and ready to start our imagery session.

1. Recall a previous competition where you were in a difficult situation and performed poorly as a result…. Imagine yourself back in this situation, picture the competition venue you were at and the skill or play you needed to make…Experience the emotions you felt… were you angry, frustrated, upset, down on yourself? Now clear your mind and picture yourself back in this difficult situation…But now see yourself remaining confident and in control… see yourself respond positively… the past is in the past and it is time to move forward and have a great performance.

2. Imagine yourself feeling really great, performing really well during an important competition in your sport…However, you lose focus and begin to think ahead, becoming careless making a number of silly mistakes…You begin to feel tense and in a panic to turn it around…Imagine yourself refocusing and remaining confident... You re-focus on your process and fully commit to each skill or play you make... Now see yourself at the competition totally focused, having a great performance.

3. See yourself at an important competition; performing very well…As the competition progresses, you are in a great position to win… As you are performing, your movements are flowing, you feel totally focused and in your zone…Being in control during this situation increases your confidence…Picture yourself being self-confident, having great posture, your head held high, excited to be competing.

That is the conclusion of this imagery session. You may begin slowly activating your body and mind. At your own pace, take a nice relaxing deep breath in and when you are ready, go ahead and open your eyes.

Adapted from: Leslie-Toogood, A., Hammond, T., & Gregg, M. (n.d.). How to develop your own imagery scripts.
APPENDIX D

Post-Manipulation Checks (Study 3)

Biofeedback Group

On a scale of 1 to 5, please check the response that best represents your thoughts.

1. The biofeedback intervention was effective.
   
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2. The length of the intervention was appropriate.
   
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3. The training was easy.
   
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4. 15 minutes of biofeedback was an adequate amount of time each session.
   
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5. This training will have a positive impact on my sport performance.
   
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6. Are there any additional comments or feedback that you would like to make about the training?
**Post-Manipulation Check: Imagery Group**

On a scale of 1 to 5, please check the response that best represents your thoughts.

1. I was able to image during the imagery script.

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2. I found the combination of imagery and biofeedback to be effective.

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3. The training was easy.

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4. The length of the intervention was appropriate.

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5. This training will have a positive impact on my sport performance.

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6. Are there any additional comments or feedback that you would like to make about the training?
Post-Manipulation Check: Comparison Group

On a scale of 1 to 5, please check the response that best represents your thoughts.

1. The biofeedback intervention was effective.

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2. The length of the intervention was appropriate.

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4. 10 minutes of biofeedback was an adequate amount of time each session.

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6. Are there any addition comments or feedback that you would like to make about the training?
APPENDIX E

Letter of Information

(Study 1)

Project Title
A Voice Unheard: A Qualitative Exploration Of Varsity Athletes’ Perspective On The Use Of Biofeedback Post-Intervention

Document Title
Letter of Information

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

1. Invitation to Participate

You are being invited to participate in a study titled “A voice unheard: A qualitative exploration of varsity athletes’ perspective on the use of biofeedback post-intervention” because of your experience and involvement in high performance sport.

2. Why is this study being done?

Biofeedback is the use of sophisticated equipment to note psychophysiological responses to stress through visual or auditory feedback. Athletes in a variety of sports (e.g., swimming, basketball, golf) have experienced beneficial effects of biofeedback training on their sport performance, such as: decreased competition anxiety, reduced muscle tension, greater self-regulation, enhanced self-perception, decreased likelihood of an injury, and facilitated relaxation. To date, a large gap in the literature exists that pertains to athlete’s perception on the use of a biofeedback. Therefore, the purpose of the study is to determine athletes’ perspective on the use of biofeedback. Quantitatively research shows that athletes can experience psychological and physiological benefits from biofeedback. However there are no studies to date that qualitatively discuss athletes view on whether or not they find biofeedback to be a valuable tool in providing the necessary self-regulation techniques aimed at performance enhancement. As information is obtained and analyzed from qualitative interviews, new directions in conceptualizing outcomes and measures may emerge. Results will contribute to the advancement of knowledge by adding to the biofeedback literature. Research of this nature will provide a
better understanding on how biofeedback can positively impact sport participation and psychological well-being for athletes.

3. **How long will you be in this study?**

The intervention will consist of 5-30 minute sessions. Following the intervention, you will participate in the post-intervention interview, which will take approximately 30 minutes to complete. Therefore, participation in this study will take approximately 3 hours. The biofeedback intervention sessions as well as the post-intervention interview will be scheduled at your convenience.

4. **What are the study procedures?**

There will be 5 participants needed for this study, therefore the first 5 participants to contact the researcher for participation will move forward with the study. Following recruitment, you will participate in a biofeedback intervention with the co-investigator (Kendra Nelson Ferguson), entailing 5 biofeedback intervention sessions that aim to train respiration rate, heart rate variability, and skin conductance as these functions have been found to enhance athletic performance. Measuring the above parameters will involve connecting you to several sensors and electrodes that will pick up these responses. This process is non-invasive. Sensors are placed on the surface of the skin. To measure respiration rate, a sensor will be connected around your waist. To measure heart rate variability, a sensor will be attached to your non-dominant thumb. To measure skin conductance, one sensor will be attached to your index finger and one sensor will be attached to your ring finger. You will be sitting during this process. Essentially, you will practice abdominal breathing (i.e., balance between their inhalation and exhalation) in conjunction with the biofeedback breathing modalities and guidance from Kendra, the co-investigator, for 30 minutes per session. Following the intervention, you will complete a post-intervention interview with the co-investigator to determine your perspective on the use of biofeedback. Further, the interview will focus on the positive or negative outcomes and/or experiences of the intervention and whether or not you view biofeedback as being a viable tool for athletic performance enhancement. Interviews will be audio recorded and transcribed by the co-investigator. Further, interviews as well as all 5 biofeedback intervention sessions will be located in the Sport Psychology Lab at Western University. In addition, your individual results will not be disclosed to you personally. We hope to find some significant results to contribute to peer-reviewed sources and once that is done, a summary of the studies results will be sent to you via email.

**PLEASE NOTE:** Participants will be excluded from the study if they are: pregnant, aged under 18 or over 25 years, do not speak English, and are not a current full-time varsity athlete at Western University.

5. **What are the risks and harms of participating in this study?**

You could feel psychological or mental fatigue during biofeedback sessions when you must concentrate for each session. With all research, there is always the risk of privacy
breach but as outlined in section 8, we will do our best to keep materials and data confidential. Further, your participation as well as data and results will not be shared with coaches and data will not be used in team selection or other team related decisions. It is not anticipated nor have any adverse effects happened from a study of this nature, but if you are harmed as a direct result of taking part in this study, all necessary medical treatment will be made available to you at no cost. You do not waive any legal rights by signing the consent form.

6. What are the benefits of participating in this study?

Potential benefits you may or may not receive for participating in this study include: management of pre-competitive anxiety, enhanced self-regulation techniques, and improved facilitation of relaxation. It should be noted that you may receive no benefit and that the same benefits may occur practicing the techniques used in the study outside of the study context.

7. Can participants choose to leave the study?

You can leave the study at any time. If you decide to withdraw from the study, you have the right to request withdrawal of information collected about you. If you wish to have your information removed please let the researchers know. This includes any audio recordings or data collected during the intervention. There are no limitations on the withdrawal. Please contact Kendra Nelson Ferguson or Dr. Craig Hall via email to withdraw from the study at anytime.

8. How will participants’ information be kept confidential?

All data collected will remain confidential and accessible only to the investigators of the study. Audio recordings will be kept on a password-protected computer that can only be accessed by the investigators and will be deleted following transcription. Kendra Nelson Ferguson, co-investigator, will be transcribing all interviews personally. During interview transcription, names will be blacked out and not collected with the data. You will be assigned a participant number to track your data across the study. If the results of the study are published, only the participant number, sport, and gender will be used. While we do our best to protect your information, there is no guarantee that we will be able to do so. If data is collected during the project that is required to report to the law, we have a duty to report. Your data will be stored on a password-protected computer that can only be accessed by the investigators and will be destroyed after seven years (as per UWO policy). Signed Letters of Information and Consent will be kept in a locked file box in the co-investigators office. In addition, representatives of The University of Western Ontario Health Science Research Ethics Board may require access to your study-related records to monitor the conduct of the research. Your participation as well as data and results will not be shared with coaches and data will not be used in team selection or other team related decisions.
9. Are participants compensated to be in this study?

All participants will be entered into a draw for a $25.00 SportChek gift card once the study is complete. You must participate in all phases of the study to be eligible to enter the draw. Once the study is complete, names will be written on a piece of paper, folder up and put into a box. The co-investigator will first be blindfolded and then will select one piece of paper from the box. Once the winner has been selected, they will be contacted via email and the principal investigator will arrange a time that works best for the winner to deliver the gift card.

10. What are the rights of participants?

Your participation in this study is voluntary. You may decide not to participate. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you choose not to participate or to leave the study at any time, it will have no effect on your status as an athlete or position on a team. We will give you new information that is learned during the study that might affect your decision to stay in the study. You do not waive your legal right by signing this consent form.

11. Whom do participants contact for questions?

If you have questions about this research study please contact Kendra Nelson Ferguson or Craig Hall. If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Research Ethics.

Thank you!

Investigators:

Craig Hall, Ph.D.  Kendra Nelson Ferguson, MA
Professor, School of Kinesiology  Ph.D. Candidate, School of Kinesiology
Western University  Western University

This letter is yours to keep for future reference.
Written Consent
(Study 1)

Project Title
A Voice Unheard: A Qualitative Exploration Of Varsity Athletes’ Perspective On The Use Of Biofeedback Post-Intervention

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant (Print): _______________________________________________
Participant (Sign): _______________________________________________
Participant (Date): _______________________________________________

Person Obtaining Informed Consent (please print): ____________________
Signature: ______________________________________________________
Date: __________________________________________________________

Thank you.
Letter of Information

(Study 2)

Project Title
Sport Biofeedback: Effective but Under Utilized

Document Title
Letter of Information

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

12. Invitation to Participate

You are being invited to participate in a study titled “Sport Biofeedback: Effective but Under Utilized” because of your experience as a Mental Performance Consultant.

13. Why is this study being done?

Biofeedback is the use of sophisticated equipment to note psychophysiological responses to stress through visual or auditory feedback. Athletes in a variety of sports (e.g., swimming, basketball, golf) have experienced beneficial effects of biofeedback training on their sport performance, such as: decreased competition anxiety, reduced muscle tension, greater self-regulation, enhanced self-perception, decreased likelihood of an injury, and facilitated relaxation. Although research has uncovered numerous benefits to using biofeedback to enhance athletic performance very few Mental Performance Consultants (MPC) use it in their practice. To date, there is no research on reasons why this may be. Therefore, the purpose of this study is to explore reasons why some MPC’s use biofeedback training during consults with athletes while others do not.

14. How long will you be in this study?

The interview will last approximately 45 minutes and will be scheduled at your convenience.

15. What are the study procedures?

There will be seven participants required for this study. Therefore the first seven participants to contact the researcher for participation will move forward with the study.
Following recruitment, you will complete an interview with the co-investigator (Kendra Nelson Ferguson). The interview will take approximately 45 minutes and will allow the researcher to gain knowledge on the reasons why you may or may not use biofeedback training in your practice as a Mental Performance Consultant. **Interviews will be audio recorded and transcribed by the co-investigator. Further, interviews will be conducted by phone. With qualitative data, direct quotes will be used to emphasize any themes that may come from the data. Therefore, direct quotes will be published under pseudonyms.** We hope to find some significant results to contribute to peer-reviewed sources and once that is done, a summary of the studies results will be sent to you via email.

**PLEASE NOTE:** Participants will be excluded if they do not hold a Ph.D., have not worked as a MPC for a minimum of two years, do not speak English, and are not able to meet by phone.

**If you choose to participate, you will be responsible for printing off a copy of the consent form to sign. You will then be required to send a photocopy of the form back to the co-investigator. From there, the co-investigator will sign the form and send the completed form back to you for your records. If you do not have access to a photocopier, there is an App you can download, Genius Scan, which will allow you to send a copy back to the co-investigator via email.**

**16. What are the risks and harms of participating in this study?**

There are no known or anticipated risks or discomforts associated with participating in this study. With all research, there is always the risk of privacy breach but as outlined in section 8, we will do our best to keep materials and data confidential. It is not anticipated nor have any adverse effects happened from a study of this nature, but in the event that a study related illness, injury or adverse effect occur, the primary investigator and/or the co-investigator will be responsible for seeking help and/or care for such an event.

**17. What are the benefits of participating in this study?**

Participants will not benefit as a direct result of participation any more than non-participants.

**18. Can participants choose to leave the study?**

You can leave the study at any time. If you decide to withdraw from the study, you have the right to request withdrawal of information collected about you. If you wish to have your information removed please let the researchers know. This includes any audio recordings or data collected during the intervention. There are no limitations on the withdrawal. Please contact Kendra Nelson Ferguson or Dr. Craig Hall via email to withdraw from the study at anytime.

**19. How will participants’ information be kept confidential?**

All data collected will remain confidential and accessible only to the investigators of the
study. Audio recordings will be kept on a password-protected computer that can only be accessed by the investigators and will be deleted following transcription. Kendra Nelson Ferguson, co-investigator, will be transcribing all interviews personally. However both the primary investigator and co-investigator will have access to the transcripts. During interview transcription, names will be blacked out and not collected with the data. You will be assigned a participant number to track your data across the study. If the results of the study are published, pseudonyms will be assigned and your gender will be disclosed. While we do our best to protect your information, there is no guarantee that we will be able to do so. If data is collected during the project that is required to report to the law, we have a duty to report. Your data will be stored on a password-protected computer that can only be accessed by the investigators and will be destroyed after seven years (as per UWO policy). Signed Consent Forms will be kept on a password-protected computer that can only be accessed by the investigators. In addition, representatives of The University of Western Ontario Health Science Research Ethics Board may require access to your study-related records to monitor the conduct of the research.

20. Are participants compensated to be in this study?

You will not be compensated for your participation.

21. What are the rights of participants?

Your participation in this study is voluntary. You may decide not to participate. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you choose not to participate or to leave the study at any time. We will give you new information that is learned during the study that might affect your decision to stay in the study. You do not waive your legal right by signing this consent form.

22. Whom do participants contact for questions?

If you have questions about this research study please contact Kendra Nelson Ferguson or Craig Hall. If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Research Ethics.

Thank you!

Investigators:

Craig Hall, Ph.D.  
Professor, School of Kinesiology  
Western University

Kendra Nelson Ferguson, MA  
Ph.D. Candidate, School of Kinesiology  
Western University

This letter is yours to keep for future reference.
Written Consent

(Study 2)

Project Title
Sport Biofeedback: Effective but Under Utilized

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant (Print): ____________________________________________

Participant (Sign): ____________________________________________

Participant (Date): ____________________________________________

Person Obtaining Informed Consent (please print): ________________

Signature: ____________________________________________

Date: ____________________________________________

Thank you.
Letter of Information

(Study 3)

Project Title
Combining Biofeedback and Imagery: Visualizing the Outcome

Document Title
Letter of Information

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

23. Invitation to Participate
You are being invited to participate in a study titled “Biofeedback training: Improving the quality of the session the most efficient way” because of your experience and involvement in high performance sport.

24. Why is this study being done?
Biofeedback is the use of sophisticated equipment to note psychophysiological responses to stress through visual or auditory feedback. Athletes in a variety of sports (e.g., swimming, basketball, golf) have experienced beneficial effects of biofeedback training on their sport performance, such as: decreased competition anxiety, reduced muscle tension, greater self-regulation, enhanced self-perception, decreased likelihood of an injury, and facilitated relaxation. Little research exists investigating the difference between participants who engage in biofeedback training on its own in comparison to biofeedback combined with imagery techniques. Therefore, the purpose of this study is twofold: (a) to determine if biofeedback training on its own has the greatest impact on an athletes’ ability to gain and maintain physiological control, and (b) to determine if the quality of biofeedback training is enhanced with the use of imagery. Results will contribute to the advancement of knowledge by adding to the biofeedback literature. Research of this nature will provide a better understanding on ways to improve biofeedback training in terms of athletic performance.

**This is a student research project.**
25. How long will you be in this study?

There will be 5 meeting times and each meeting will take a maximum of 20 minutes to complete. Therefore, total participation time for this study will take approximately one hour and 40 minutes. Biofeedback sessions will be scheduled at your convenience.

26. What are the study procedures?

There will be 30 participants needed for this study, therefore the first 30 participants to contact the researcher for participation will move forward with the study. Following recruitment, you will be assigned to 1 of 3 groups. The biofeedback group will practice biofeedback for a total of 15 minutes each meeting. The imagery group will practice biofeedback for a total of 10 minutes and imagery for a total of 5 minutes each meeting. The comparison group will practice biofeedback for a total of 10 minutes and then be asked to relax for 5 minutes each meeting. Within each 5-minute interval, the biofeedback software will collect means and standard deviations of each physiological measurement to determine if there are any differences between the three training groups. During biofeedback training, we will train respiration rate, heart rate variability, and skin conductance as these functions have been found to enhance athletic performance. Measuring the above parameters will involve connecting you to several sensors and electrodes that will pick up these responses. This process is non-invasive. Sensors are placed on the surface of the skin. To measure respiration rate, a sensor will be connected around your waste. To measure heart rate variability, a sensor will be attached to your non-dominant thumb. To measure skin conductance, one sensor will be attached to your index finger and one sensor will be attached to your ring finger. You will be sitting during this process. Essentially, you will practice abdominal breathing (i.e., balance between their inhalation and exhalation) in conjunction with the biofeedback breathing modalities and guidance from Kendra, the co-investigator, for 10-15 minutes per session, depending on the group you are assigned to. For the imagery group, you will be read an imagery script after 5 minutes of biofeedback training and then will resume biofeedback training for the remaining 5 minutes. For the comparison group, you will relax after 5 minutes of biofeedback training and then will resume biofeedback training for the remaining 5 minutes. All 5 sessions will be located in the Exercise and Health Psychology Lab. After the fifth session, you will complete a short 5-question survey examining your thoughts on the intervention. **PLEASE NOTE:** Participants will be excluded from the study if they are pregnant, under the age of 18, do not speak English, and are not a current athlete at Western University. In addition, a participant may be withdrawn from the study if they do not show up to two consecutive, scheduled biofeedback sessions.

27. What are the risks and harms of participating in this study?

You could feel psychological or mental fatigue during the biofeedback sessions. With all research, there is always the risk of a privacy breach but as outlined in section 8, we will do our best to keep materials and data confidential. Further, your participation as well as data and results will not be shared with coaches and data will not be used in team selection or other team related decisions. It is not anticipated nor have any adverse effects
happened from a study of this nature. However, if you are harmed as a direct result of
taking part in this study, all necessary medical treatment will be made available to you at
no cost. You do not waive any legal rights by signing the consent form.

28. **What are the benefits of participating in this study?**

Potential benefits you may or may not receive for participating in this study include:
management of pre-competitive anxiety, enhanced self-regulation techniques, and
improved facilitation of relaxation. It should be noted that you may receive no benefit
and that the same benefits may occur practicing the techniques used in the study outside
of the study context.

29. **Can participants choose to leave the study?**

You can leave the study at any time. If you decide to withdraw from the study, you have
the right to withdrawal information collected about you. This includes any data collected
during the biofeedback training. There are no limitations on the withdrawal, meaning you
can withdrawal your data at any time prior to publication of the study results. If you wish
to withdrawal from the study, you can do so via email, phone/text, or in person with
Kendra Nelson Ferguson or Dr. Craig Hall. In addition, a participant may be withdrawn
from the study if they do not show up to two consecutive, scheduled biofeedback
sessions.

30. **How will participants’ information be kept confidential?**

All data collected will remain confidential and accessible only to the investigators of the
study. You will be assigned a participant number to track your data across the study. If
the results of the study are published, only the participant number, sport, and gender will
be used. While we do our best to protect your information, there is no guarantee that we
will be able to do so. If data is collected during the project that is required to report to the
law, we have a duty to report. Your data will be stored on a password-protected laptop
that can only be accessed by the investigators. The laptop is password protected and has
Wi-Fi Protected Access (WPA). The laptop is also encrypted with firevault, which
provides full disk encryption. Once data is collected and analyzed, it will be removed
from the laptop and will remain stored by the PI at the institution on the secure University
drive. It will be destroyed after seven years (as per UWO policy). Signed Letters of
Information and Consent will be kept in a locked file box in the PI’s office (AHB
3R02A). In addition, representatives of The University of Western Ontario Health
Science Research Ethics Board may require access to your study-related records to
monitor the conduct of the research. Your participation as well as data and results will not
be shared with coaches and data will not be used in team selection or other team related
decisions.

31. **Are participants compensated to be in this study?**

You will not be compensated for your participation.
32. What are the rights of participants?

Your participation in this study is voluntary. You may decide not to participate. Even if you consent to participate you have the right to not answer individual questions or to withdraw from the study at any time. If you choose not to participate or to leave the study at any time, it will have no effect on your status as an athlete or position on a team. We will give you new information that is learned during the study that might affect your decision to stay in the study. You do not waive your legal right by signing this consent form.

33. Whom do participants contact for questions?

If you have questions about this research study please contact Kendra Nelson Ferguson or Craig Hall. If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Research Ethics.

Thank you!

Investigators:

Craig Hall, Ph.D.                        Kendra Nelson Ferguson, MA
Professor, School of Kinesiology       Ph.D. Candidate, School of Kinesiology
Western University                      Western University

This letter is yours to keep for future reference.
Written Consent

(Study 3)

Project Title
Combining Biofeedback and Imagery: Visualizing the Outcome

Principal Investigator
Dr. Craig Hall, Ph.D., Western University

Co-Investigator
Kendra Nelson Ferguson, Ph.D. Candidate, Western University

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant (Print): _______________________________________________

Participant (Sign): _______________________________________________

Participant (Date): _______________________________________________

Person Obtaining Informed Consent (please print): _____________________

Signature: _______________________________________________________

Date: ___________________________________________________________

Thank you.
APPENDIX F

Research Ethics Board Approval Notices

Study 1

Western Research

Date: 10 April 2018
To Dr. Craig Hall
Project ID: 111241

Study Title: Gaining Perspective on the use of Biofeedback
Application Type: HSREB Initial Application
Review Type: Full Board
Meeting Date: 20/Mar/2018 13:30
Date Approval Issued: 10/Apr/2018 14:29
REB Approval Expiry Date: 10/Apr/2019

Dear Dr. Craig Hall,

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREIM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

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<th>Document Type</th>
<th>Document Date</th>
<th>Document Version</th>
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<td>03/Apr/2018</td>
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<td>Written Consent/Assent</td>
<td>09/Apr/2018</td>
<td>4</td>
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<td>26/Mar/2018</td>
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<td>Pre-Intervention Interview Questionnaire</td>
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<td>26/Mar/2018</td>
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No deviations from, or changes to, the protocol or WREIM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the TriCouncil Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB00000946.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Nicola Geoghegan-Morphet, Ethics Officer or behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Dear Dr. Craig Hall,

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above-mentioned study as described in the WREM application form, as of the HSREB Initial Approval Determined above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

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No deviations from or changes to the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazards to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Nicola Ginghman-Morphet, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
Study 3

Dear Dr. Craig Hall,

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the above mentioned study as described in the WREM application form, as of the HSREB Initial Approval Date noted above. This research study is to be conducted by the investigator noted above. All other required institutional approvals must also be obtained prior to the conduct of the study.

Documents Approved:

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<td>Post-Medication Checks</td>
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No deviations from, or changes to, the protocol or WREM application should be initiated without prior written approval of an appropriate amendment from Western HSREB, except when necessary to eliminate immediate hazards to study participants or when the change(s) involves only administrative or logistical aspects of the trial.

REB members involved in the research project do not participate in the review, discussion or decision.

The Western University HSREB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonisation Good Clinical Practice CONSORTIUM Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is registered with the U.S. Department of Health & Human Services under the FDA registration number IRB 00000948.

Please do not hesitate to contact us if you have any questions.

Sincerely,

Karen Gopal, Ethics Officer on behalf of Dr. Joseph Gilbert, HSREB Chair

Note: This correspondence includes an electronic signature (validation and approval via an online system that is compliant with all regulations).
CURRICULUM VITAE FOR KENDRA NELSON FERGUSON
School of Kinesiology
Western University
London, Ontario, Canada

POST-SECONDARY EDUCATION

Sept. 2015 - present
Ph.D. Candidate in Psychological Basis of Kinesiology, School of Kinesiology, Western University, London, ON, Canada

June 2015
Master of Arts in Kinesiology and Recreation Management: Sport Psychology, University of Manitoba, Winnipeg, MB, Canada

June 2013
Bachelor of Arts in Kinesiology and Applied Health (4-Year), University of Winnipeg, Winnipeg, MB, Canada

AWARDS & HONOURS

2017-2018
Ontario Graduate Scholarship, Western University, $15,000.

2015-2016
Ontario Graduate Scholarship, Western University, $15,000.

2014-2015
University of Manitoba Educational Grant, University of Manitoba, $8,000

2013-2014
University of Manitoba Educational Grant, University of Manitoba, $8,000

2008-2012
Suncor University Scholarship, University of Winnipeg, $2000/year = $8000

PUBLICATIONS

Journal Articles


Book Chapters

Published Abstracts


Publications in Progress


**REFEREED CONFERENCE PRESENTATIONS**

Nelson Ferguson, K., & Paradis, J. *How do surgical residents approach their surgical training: Are elements of deliberate practice observed? Verbal presentation* at the 2019 annual meeting of the Canadian Society of Otolaryngology-Head & Neck Surgery, Edmonton, AB.

Nelson Ferguson, K., & Paradis, J. *How do surgical residents approach their surgical
training: Are elements of deliberate practice observed? **Verbal presentation** at the 2019 annual meeting of the Otolaryngology-Head & Neck Surgery Medical Research Symposium, London, ON.

**Nelson, K.**, & **Strachan, L.** *A retrospective exploration of sibling relationships in elite youth sport: Perceptions of the parental role*. **Verbal presentation** at the 2016 annual meeting of the North American Society for Psychology of Sport and Physical Activity, Montreal, QC.

**Nelson, K.**, **Hall, C.**, **Gregg, M.**, **Law, B.**, & **Pope, P.** *Sport psychology for coaches: Appraising what information coaches want*. **Poster presentation** at the 2016 annual meeting of the Kinesiology Graduate Student Association Symposium, London, ON.

**Nelson, K.**, & **Strachan, L.** *Friend, foe, or both? A retrospective exploration of sibling influences in elite youth sport*. **Verbal presentation** at the 2015 annual meeting of the Canadian Society for Psychomotor Learning and Sport Psychology, Edmonton, AB.

Johnson, J., Holman, M., Chin, J., Allan, E. J., Madden, M., **Nelson, K.**, Signer, M., & Krahn, A. *The landscape of varsity hazing in Canada: Preliminary results from a 3-year SSHRC funded study of the culture of hazing in Canadian interuniversity sport*. **Poster presentation** at the 2015 annual meeting of the Health, Leisure & Human Performance Research Institute, Winnipeg, MB.

Kamal, A., Strachan, L., Leslie-Toogood, A., **Nelson, K.**, Penelton, S., & Kristjanson, K. *Examining psychological literacy through the Long Term Athlete Development model (LTAD): Preliminary findings on parental roles and influence*. **Verbal presentation** at the 2015 annual meeting of the North American Society for Psychology of Sport and Physical Activity, Minneapolis, MN.

Johnson, J., **Nelson, K.**, Signer, M.A., Holman, M., Chin, J., & Madden, M. *Examining the Canadian Interuniversity Sport culture: A national study of gender, race, sexuality and violence in sport hazing (SSHRC)*. **Verbal presentation** at the 2014 annual meeting of the Health, Leisure & Human Performance Research Institute, Winnipeg, MB.

**RESEARCH EXPERIENCE**

2017- present  
**Graduate Research Assistant:** How do surgical residents approach their surgical training: Are elements of deliberate practice observed? Victoria Hospital/Western University, funded by the AMOSO opportunity funds.

2015-2017  
**Graduate Research Assistant**, www.sportpsychologyforcoaches.ca  
University of Winnipeg/Western University, funded by University of
Graduate Research Assistant: Examining the Canadian Interuniversity Sport culture: A national study of gender, race, sexuality and violence in sport hazing, University of Manitoba, funded by a SSHRC Standard Research Grant.

2014-2015

Graduate Research Assistant: Biofeedback training and its effect on sport performance with high performance athletes, University of Manitoba, funded by the Canadian Sport Centre Manitoba.

2014-2015

Graduate Research Assistant: Relax and refocus: Is biofeedback the key? University of Winnipeg, funded by Manitoba Health Research Council Establishment Grant.

2013-2014

Graduate Research Assistant: Psychological Literacy through the Long Term Athlete Development Model (LTAD), University of Manitoba, funded by Diving Plongeon Canada, Canadian Sport Centre of Manitoba, and Sport Manitoba.

2013-2014

Graduate Research Assistant: Biofeedback and Team Canada Volleyball, University of Manitoba, funded by the Canadian Sport Centre of Manitoba.

TEACHING EXPERIENCE

2019

Graduate Teaching Assistant, KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2018

Graduate Teaching Assistant, KIN 3476: Exercise and Health Behaviour Change. School of Kinesiology, Western University.

2017

Graduate Teaching Assistant, KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2016

Graduate Teaching Assistant, KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2014

Graduate Seminar Leader, PERS 2100: Introduction to Professional Practice. Faculty of Kinesiology and Recreation Management, University of Manitoba.

2014

Graduate Teaching Assistant, KIN 2540: Psychology of Sport and Physical Activity. Faculty of Kinesiology and Recreation Management,
University of Manitoba.

2014  
*Graduate Teaching Assistant*, PERS 1200: Physical Activity, Health and Wellness. Faculty of Kinesiology and Recreation Management, University of Manitoba.

2014  
*Graduate Teaching Assistant*, PERS 3100: Inclusive Physical Activity and Leisure. Faculty of Kinesiology and Recreation Management, University of Manitoba.

2013  
*Graduate Teaching Assistant*, PERS 2100: Introduction to Professional Practice. Faculty of Kinesiology and Recreation Management, University of Manitoba.

2013  
*Graduate Teaching Assistant*, KIN 2100: Leadership in Sport, Department of Kinesiology and Applied Health, University of Winnipeg.

**INVITED LECTURES**

2019  
*Exploring Perspectives of Biofeedback*. Guest Lecture for KIN 9230: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2019  
*Putting Knowledge to Practice: Biofeedback Demonstration*. Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2019  
*Psychological Intervention Assignment*. Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2018  
*Putting Knowledge to Practice: Biofeedback Demonstration*. Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2018  
*Biofeedback in the Exercise Domain*. Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2018  
*Biofeedback and Sport*. Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2018  
*Knowledge to Practice: Biofeedback Demonstration*. Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.
Rehabilitation. School of Kinesiology, Western University.

2018  
*Biofeedback and Sport: Exploring Interventions.* Guest Lecture for KIN 9230: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2017  
*Using Biofeedback for Exercise: Demonstrating its Effectiveness.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2017  
*Biofeedback in the Exercise Domain.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2017  
*Demonstration of Biofeedback: Examining the Stress Test.* Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2017  
*Biofeedback in Exercise, Sport, and Injury Rehabilitation.* Guest Lecture for KIN 3474: Psychological Interventions in Sport, Exercise and Injury Rehabilitation. School of Kinesiology, Western University.

2016  
*The Relationship Between Narcissism, Exercise Motives, and Behavioural Regulation: Study Results.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2016  
*APA Formatting.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2016  
*How to Write a Research Paper.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2016  
*The Relationship Between Narcissism, Exercise Motives, and Behavioural Regulation.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

2016  
*The Relationship Between Narcissism, Exercise Motives, and Behavioural Regulation.* Guest Lecture for KIN 2276: Introduction to Exercise Psychology. School of Kinesiology, Western University.

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**INVITED WORKSHOPS**

2018  
*Dealing with Pressure, Mistakes, and Success.* Workshop offered to elite dancers from Danceology. Lucknow, ON.
2017  *Mental Preparation.* Workshop offered to elite dancers from Danceology. Lucknow, ON.


2015  *Mental Strategies to Enhance Self-Awareness and Self-Regulation.* Workshop offered to elite rowers from Row to Podium, Rowing Canada. Welland, ON.

2015  *High Performance Sport: Managing Stress, Anxiety, and Pressure.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2015  *Mental Strategies for Basketball.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2015  *Mental Skills Training Workshop For Hockey.* Workshop offered to Junior Bison 16U Club Hockey, University of Manitoba. Winnipeg, MB.

2015  *Mental Skills Training Workshop For Volleyball.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2015  *Mental Preparation for Water Polo Athletes.* Workshop offered to the Manitoba Water Polo Provincial Team, Sport Manitoba. Winnipeg, MB.

2015  *Mental Toughness and Preparation.* Workshop offered to Junior Bison Club Volleyball (14U), University of Manitoba. Winnipeg, MB.

2015  *Breaking Through Barriers: Strategies to Enhance Preparation and Performance.* Workshop offered to Manitoba Ringette Association (Canada Winter Games Team), Sport Manitoba. Winnipeg, MB.

2015  *Breaking Through Barriers: Strategies to Enhance Preparation and Performance.* Workshop offered to Manitoba Table Tennis Association (Canada Winter Games Team), Sport Manitoba. Winnipeg, MB.

2015  *Breaking Through Barriers: Strategies to Enhance Preparation and Performance.* Workshop offered to Manitoba Ringette Association (Canada Winter Games Team), Sport Manitoba. Winnipeg, MB.

2015  *Mental Preparation for Water Polo Athletes.* Workshop offered to the Manitoba Water Polo Provincial Team, Sport Manitoba. Winnipeg, MB.
2014  *Mental Strategies to Enhance Self-Awareness and Self-Regulation.* Workshop offered to the Manitoba Water Polo Provincial Team, Sport Manitoba. Winnipeg, MB.

2014  *Breaking Through Barriers: Strategies to Enhance Preparation and Performance.* Workshop offered to Curl Manitoba (Canada Winter Games Team), Sport Manitoba. Winnipeg, MB.

2014  *Mental Preparation.* Workshop offered to club ringette players (Club U16AA, Magic). Manitou, MB.

2014  *Mental Strategies to Enhance Self-Awareness and Self-Regulation for Snowboarding.* Workshop offered to Snowboard Association of Manitoba (Canada Winter Games Team), Sport Manitoba. Winnipeg, MB.

2014  *Mental Skills Training Workshop For Volleyball.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2014  *Mental Skills Training Workshop For Soccer.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2014  *A 3-Day Workshop: Developing Mental Strategies for Performance Enhancement.* Workshop offered to Athletics Manitoba track team at the Canada West Challenge, Athletics Manitoba. Saskatoon, SK.

2014  *Mental Skills Training Workshop For Basketball.* Workshop offered at the Junior Bison High Performance Sport Camps, University of Manitoba. Winnipeg, MB.

2014  *Mental Skills Training Workshop For Volleyball.* Workshop offered to the Junior Wesmen volleyball team, University of Manitoba. Winnipeg, MB.

**SCHOLARLY ACTIVITIES**

2013-2015  *Graduate Student Association Committee,* Faculty of Kinesiology and Recreation Management, University of Manitoba

2013-2015  *Faculty Council Committee,* Faculty of Kinesiology and Recreation Management, University of Manitoba
RELATED EXPERIENCE


