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Exploring a Bio/Neurofeedback Training Intervention to Enhance Psychological Skills & Performance in Sport

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THESIS

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ABSTRACT

The purpose of the present study was to explore whether BNFK, which trains self-awareness and self-regulation of physiological and mental-emotional states, can enhance an athlete's psychological skills, specifically their ability to focus, relax and regulate their arousal and anxiety levels, and ultimately, enhance their sport performance. This research utilized a multiple-case study design. Six elite athletes, with a minimum of five years experience at the international or Olympic level, each received 30 hours of a BNFK training intervention. The effect of BNFK training was explored in three ways: (a) three phases of interviews were conducted with each athlete, prior to the BNFK training, between 20-30 hours of BNFK training, and at the end of the 2007-2008 competitive season; b) physiological and neurological quantitative data was collected which measured improvements specific to the BNFK training; and (c) performance results were noted at the completion of the 2007-2008 competitive season and compared to previous results.

The findings indicate that within the lab setting, the athletes developed i) greater self-awareness of how they hold tension and anxiety in the body and ii) self-regulation techniques to decrease that tension. As well, the athletes became more aware of their mental state, and through regulation of their level of anxiety and tension in the body, they enhanced their ability to focus. Although much improvement was seen, none of the athletes developed optimal self-regulation of all aspects measured. With respect to competition results, no definite improvement in performance was seen. The results of the study are further discussed in the context of the BNFK and sport psychology literature. Implications and future directions are also offered.

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CHAPTER 1: INTRODUCTION

Applied sport psychologists spend much of their time encouraging athletes to develop psychological skills that will enhance their performance. They work with athletes to develop specific skills such as focus, re-focus, imagery, relaxation, managing excessive anxiety, finding the right level of intensity, and developing pre-competition, competition, and post-competition plans (Jones, Hanton, & Connaughton, 2002, 2007; Hardy, Jones, & Gould, 1996; Orlick, 2008; Singer, Hausenblas, & Janelle, 2001; Vealey, 2007; Williams, 2006). These skills and strategies enable athletes to develop self-awareness and self-regulation of arousal (Crews, Lochbaum, & Karoly, 2001). The main purpose of all of these psychological skills or strategies is to enable an athlete to perform exceptionally well in the stressful environment of national, international and Olympic level competition. Specifically, research in sport psychology has noted that focus is a crucial skill in sport performance, and that focus is influenced by two other aspects, one's level or feeling of self-confidence, and the management of one's level of anxiety (Gould, Dieffenbach, & Moffett, 2002; Krane & Williams, 2006; Mellalieu, Hanton, & Fletcher, 2006; Ravizza, 2006; Singer et al., 2001).

To achieve appropriate arousal levels, Bio/Neurofeedback (BNFK) is often mentioned as a useful means for facilitating the learning of self-regulation by competitive athletes (Blumenstein, Bar Eli, & Tenenbaum, 2002; Collins & MacPherson, 2006; Ravizza, 2006; Zaichowsky & Baltzell, 2001). The relevance of BNFK interventions in athletic preparation is evident in the "psychophysiological principle" first presented by Green, Green, and Walters (1970). The main idea of psychophysiology is that every physiological change is accompanied by a parallel in the mental emotional state, and vice versa, every change in the mental emotional state is accompanied by an appropriate change in the physiological state. BNFK can be a powerful tool for physiological and psychological change, increasing individual awareness and control over the body and mind, reducing habitual stress, improving arousal regulation and enhancing focusing and relaxation skills. Schwartz and Andrasik (2003) state that BNFK can be used to enhance self-awareness, self-regulation, and athletic performance by providing athletes with information about what is going on inside their bodies and brains, making covert processes overt.

To date BNFK has predominantly been used in the medical field (Schwartz & Andrasik, 2003), although there is some research in the sport domain (Bar-Eli & Blumenstein, 2004; Davis & Sime, 2005; Edmonds, Mann, Tenenbaum, & Janelle, 2005; Gruzelier, Egner, & Vernon, 2006; Raymond, Sajid, Parkinson, & Gruzelier, 2005; Vernon, 2005). Within the sport performance enhancement literature, the Wingate Five-Step Approach (Blumenstein, Bar-Eli, and Tenenbaum, 1997) is a well documented training protocol specifically designed for the enhancement of athletic performance. A modified version of the Wingate protocol will be utilized in this research.

The present study primarily utilized a qualitative research approach. Six elite athletes, with a minimum of five years experience at the international or Olympic level, each received 30 hours of BNFK training. The purpose was to explore whether BNFK, which trains self-awareness and self-regulation of physiological and mental-emotional states, can enhance an athlete's psychological skills, specifically their ability to focus, relax and regulate their arousal and anxiety level, and ultimately, enhance their sport performance. The effect of BNFK training was explored in three ways: (a) three phases of interviews were conducted with each athlete, prior to the BNFK training, between 20-30 hours of BNFK training, and at the end of the 2007-2008 competitive season; b) physiological and neurological quantitative data was collected which measured improvements specific to the BNFK training; and (c) performance results were noted at the completion of the 2007-2008 competitive season and compared to previous results. The three phases of interviews with the athletes allowed us to achieve an in-depth understanding of the athletes' experiences with BNFK training, in reference to their use of psychological skills to regulate their arousal and anxiety level, their ability to focus and their ability to relax.

CHAPTER II: REVIEW OF LITERATURE

This chapter is divided into three sections: (a) a review of the research literature on key skills in the field of sport psychology, (b) a review of the literature on the concepts of biofeedback and neurofeedback, and (c) a review of the research literature on the use of bio/neurofeedback within sport.

Sport Psychology

The purpose of psychological skills training with athletes is to assist in achieving performance success and developing personal well-being (Vealey, 2007). There is a rapidly accumulating body of knowledge regarding the psychological skills used within the sport context (Anderson, 2000, 2005; Bull, Shambrook, James, & Brooks, 2005; Calmels, d'Arripe-Longueville, Fournier, & Soulard, 2003; Crocker, 2007; Frey, Laguna, & Ravizza, 2003; Gould, Dieffenbach et al., 2002; Hardy et al., 1996; Janelle, 1999; Jones et al, 2002, 2007; Krane & Williams, 2006; Murphy, 2005; Orlick, 2008; Scanlan, Stein, & Ravissa, 1989; Taylor & Wilson, 2005; Tenenbaum & Eklund, 2007; Vealy, 2007; Williams, 2006). Key psychological skills and characteristics have been identified from this research that help athletes consistently perform close to their optimal level.

Krane and Williams (2006), in an extensive review of literature, identified a number of psychological characteristics of highly successful athletes as well as the mental skills these athletes used to achieve an optimal psychological state. The psychological characteristics included self-regulation of arousal, high levels of self-confidence, an ability to effectively focus, an "in control but not forcing it attitude", positive imagery and self-talk, and high levels of determination and commitment. Skills used to achieve an optimal psychological state included imagery, goal setting, thought control strategies, arousal management, well-developed competition plans, well-developed coping strategies, and pre-competition mental preparation plans.

A study by Gould, Dieffenbach, et al. (2002), with Olympic champions, closely paralleled these findings. After administering a battery of psychological inventories the authors found that these athletes where characterized by: (a) the ability to cope with and control anxiety, (b) a high level of self-confidence, (c) mental toughness/resiliency, (d) sport intelligence, (e) the ability to focus and block out distractions, (f) competitiveness, (g) a hard work ethic, (h) the ability to set and achieve goals, (i) coachability, (j) high levels of dispositional hope, (k) optimism, and (l) adaptive perfectionism. Specifically, results from the Athletic Coping Skills Inventory–28 (ACSI-28) showed that these outstanding performers rated high on levels of self-confidence, freedom from worry, goal setting and mental preparation, and concentration/focus. Similarly, the Test of Performance Strategies (TOPS) results showed that these Olympians rated high on goal setting, activation, relaxation, emotional control, and automaticity/attention focus.

Mental toughness is a concept used within sport psychology to describe the qualities or characteristics required to succeed at the highest level of sport. Jones et al. (2002, 2007) argue that mental toughness is one of the most important psychological attributes in achieving performance excellence. The authors sought to define mental toughness and identify the attributes required to be a mentally tough performer. The definition of mental toughness reflects the desired end state of being mentally tough, while the attributes reflect the specific detail of how athletes achieve that state. Their definition emphasized a natural or developed psychological edge that enabled high performance athletes to cope effectively with the demands of training and competing. Specifically, the authors defined mentally tough athletes as more consistent and superior at remaining determined, focused, confident, and in control under pressure. The 12 attributes that emerged from the 2002 study with elite athletes at the international level were categorized as follows: self-belief, desire and motivation, focus (performance-related), focus (lifestyle-related), dealing with competitive related pressure (external) and anxiety (internal), and dealing with physical and emotional pain. In the 2007 study with elite athletes, who had been Olympic or world champions, 30 distinct attributes were found to cluster into 4 dimensions of mental toughness (a) attitude/mindset, (b) training, (c) competition, and (d) post-competition. The 13 attributes that clustered under the competition dimension were considered essential to mental toughness. These attributes could be further divided into six subcomponents: belief, staying focused, regulating performance, handling pressure, awareness and control of thoughts and feelings, and finally, controlling the environment.

Jones et al. (2007) stated that the only other research done that comprehensively addressed the mental characteristics of elite athletes was by Orlick and Partington (1988). Orlick and Partington (1988) compared highly successful performers (e.g., Olympic medalists) with performers who failed to achieve at the level expected of them. They found distinct differences in attentional focus, commitment to pursuing excellence, engaging in competition simulation and imagery training, and an ongoing post-competition evaluation plan. As well, Orlick and Partington (1988) stated that "Mental readying is derived from a number of learned mental skills that must be continually practiced and refined for an athlete to perform to potential and on a consistent basis" (p. 129). However, as Krane and Williams (2006) have noted, achieving one's own ideal internal psychological climate is not a simple task.

In considering the research in the field of sport psychology, the majority of researchers appear to be in agreement on the critical psychological components required for achieving athletic excellence. Therefore, the remaining part of this section will discuss several of these key psychological components in more detail. This will include exploring the concepts of focus, self-confidence, and management of anxiety through arousal/intensity regulation.

Focus

Attentional focus is the ability to selectively direct and sustain a focus of attention required for the successful execution of a specific activity (Vealey, 2007). The ability to direct and sustain a focus of attention is widely observed in and cited by athletes as a mental skill critical to performance (Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007; Gould, Dieffenbach, et al., 2002; Greenleaf, Gould, & Dieffenbach, 2001; Jones et al., 2002; Orlick & Partington, 1988; Stratton, Cusimano, Hartman, & DeBoom, 2005; Thelwell, Weston, & Greenlees, 2005; Werthner, 2002). Orlick (2008) suggests that athletes must learn to hold their best focus in the face of potential distractions, and to refocus effectively if that focused connection is broken. He argues that focus is a choice and that something becomes a distraction only if the athlete allows it to distract them. Other research has also substantiated that successful athletes focus more on task relevant thoughts, and are less likely to be distracted (Gould, Dieffenbach, et al., 2002; Greenleaf et al., 2001; Jones et al., 2002; Orlick & Partington, 1988).

Nideffer & Sagal (2006) discuss attention as requiring at least two different types of focus. The first type is width of attentional focus. Certain sports, such as basketball and hockey, require a broad focus of attention. Other sports, such as sprints, diving, and shooting, require a narrow focus of attention. The second type of focus relates to the direction of the athlete's attention. In some situations, attention must be directed internally to make adjustments to muscle tension, or to problem solve and strategize. At other times, attention must be focused externally, on the opponent, or on various plays on the field. In total, there are four different types of concentration when both width and direction of attention are considered. The four dimensions of attention identified are assess (broad/external), analyze (broad/internal), perform (narrow/external), and rehearse (narrow/internal).

Csikszentmihalyi (1990) has published extensively on the concept of flow, which he developed after interviewing many experts in various fields, including sport. "Flow is about focus. More than just focus, however, flow is a harmonious experience where mind and body are working together effortlessly, leaving the person feeling that something special has just occurred. So flow is about enjoyment" (Jackson & Csikszentmihalyi, 1999, p. 5). These authors also noted that focus is a state of consciousness where athletes are totally absorbed in their activity.

Self-Confidence

Self-confidence is the belief that one has the internal resources, and specific abilities, to achieve success (Vealey, 2007). Orlick (2008) states that being confident requires that we believe in ourselves and refuse to allow negative thoughts to dominate our awareness. He suggests that the essence of strengthening confidence is embracing a positive focus. In other research, international level elite athletes identified resilience, robust self-confidence, and the unshakable belief in one's ability to achieve, as several confidence-related skills that have been defined as mental toughness (Bull et al., 2005; Jones et al., 2002; Thelwell et al., 2005). Self-confidence consistently appears as a key skill possessed by successful elite athletes (Gould, Dieffenbach et al., 2002; Gould, Greenleaf, Chung, & Guinan, 2002; Kitsantas & Zimmerman, 2002), and fluctuations in confidence can account for differences in best and worst performances (Greenleaf et al., 2001).

Arousal and Anxiety Regulation

Arousal and anxiety regulation is another issue that sport psychologists address with athletes and coaches. Whether described by the inverted-U hypothesis (Yerkes & Dodson, 1908), Hanin's (1980) zone of optimal functioning, Apter's (1982) reversal theory, Burton's (1988) multidimensional anxiety theory, or Hardy's (1996) cusp catastrophe model, each theoretical perspective recognizes the need for athletes and performers to effectively deal with anxiety and arousal-producing stimuli in order to perform optimally. To complicate the situation, most individuals, when highly activated or aroused, narrow their attentional span and tend to focus on and process irrelevant internal and external information (Janelle, Singer, & Williams, 1999; Kahneman, 1973). A great deal of literature has been produced in the sport domain concerning the arousal-anxiety relationship (Hoar 2007; Janelle, 2002; Landers & Arent, 2006; Mellalieu et al., 2006; Williams & Harris, 2006). Ultimately, sport psychologists attempt to teach skills that will enable athletes to better control arousal and thereby more effectively focus and cope with anxiety (Landers & Arent, 2006).

One strategy for achieving the ideal level of arousal or intensity for a sport performance is the development of self-awareness and self-regulation (Crews et al., 2001; Janelle, 1999). Self-awareness is the ability to engage in introspection and retrospection to understand one's thoughts, feelings, and behaviors (Vealey, 2007). The ability to engage in honest self-appraisal to enhance self-awareness has been identified as an important mental skill by elite athletes (Bull et al., 2005; Calmels et al., 2003) and sport psychology consultants (Ravizza, 2006). Self-awareness, self-monitoring and self-evaluation are critical precursors to effective self-regulation and success in sport (Chen & Singer, 1992; Kirschenbaum & Wittrock, 1984). According to Schwartz and Andrasik (2003), self-regulation is an integral part of all mental intervention activities used to facilitate performance. Athletes who have developed self-awareness and self-regulation of arousal can get their mental, emotional, and physical states to more nearly approximate what they know leads to their best performance (Ravizza, 2006).

Most researchers in sport psychology agree that the concept of arousal, in relation to psychological skills training for performance enhancement, encompasses both a psychological and a physiological component (Blumenstein et al., 2002; Hoar, 2007; Landers & Arent, 2006; Mellalieu et al., 2006; Williams & Harris, 2006). Zaichkowsky and Baltzell (2001) make it clear that arousal is a multidimensional construct and that it is imperative to consider the physiological and psychological aspects. The combination, of these two aspects, has been discussed in the literature as the psychophysiology principle (Andreassi, 2007; Cacioppo & Tassinary, 1990).

Cacioppo & Tassinary (1990, p. ix) define psychophysiology as "the scientific study of cognitive, emotional and behavioral phenomena as related to and revealed through physiological principles and events". The main idea of psychophysiology is that every physiological change is accompanied by a parallel in the mental and/or emotional state. Green et al., (1970, p. 3) formulated this psychophysiological principle as follows: "Every change in the physiological state is accompanied by an appropriate change in the mental emotional state, conscious or unconscious, and conversely, every change in the mental emotional state, conscious or unconscious, is accompanied by an appropriate change in the physiological state." This statement refers to the underlying connection between the brain and body.

Bio/Neurofeedback

One of the most effective techniques for facilitating the learning of arousal and mental state regulation is bio/neurofeedback (BNFK) (Blumenstein et al., 2002; Collins & MacPherson, 2006; Zaichowsky & Baltzell, 2001). It is the process of learning, through self-observation and self-monitoring, to control physiological and neurological functions with the use of instrumentation. BNFK training requires attaching sensors to the body for the purpose of acquiring biological and neurological signals such as those produced by muscles, sweat glands, body temperature, respiration, and heart rhythm (i.e. biofeedback modalities) and brainwaves (i.e. neurofeedback modality). Biological and neurological signals are fed to the individual being trained with the goal of gaining mental control over subconscious biological and neurological processes. The trainee receives moment by moment information about changes from the sensors. Information may come in the form of auditory tones, digital or analog displays, or computer graphics. BNFK training is a self-regulation skill with individuals learning to regulate aspects of the central and autonomic nervous systems functions.

BNFK is based on the underlying principle that the nervous system is the command center of the body. The nervous system can be divided into two parts: the central nervous system (CNS) & the peripheral nervous system (PNS). Information travels within and among the two divisions via neural tissue. The CNS includes the brain and spinal cord. Neurofeedback (NFK) training, also known as EEG biofeedback, is focused on cerebral functions, and more specifically, the brain's electrical activity. The PNS has two divisions: somatic (i.e. voluntary) and autonomic (i.e. involuntary). Biofeedback (BFK) training targets the autonomic nervous system (ANS), which is further divided in two parts: the sympathetic, which activates the fight and flight response in the body (i.e. the stress response) and the parasympathetic which deactivates the fight and flight response in the body and allows the body to rest and regenerate (i.e. the relaxation response). Ultimately, the controlling source of all systems is universally central and under the control of the CNS.

Biofeedback

Biofeedback (BFK) training focuses on developing voluntary control of the ANS with the goals of developing conscious regulation of the arousal state and the ability to enter into the state of parasympathetic predominance, which in effect, will turn off the stress response. When one experiences anxiety or stress, the sympathetic nervous system becomes dominant. BFK training improves the balance between sympathetic and parasympathetic nervous system activity, often referred to as ANS balance. The stress of competition and the resulting anxiety are common antecedents of performance, and BFK is an objective way of assessing, as well as controlling these variables (Sime, 2003).

The most common types of BFK training are muscle or electromyograph (EMG), skin conductance/electro dermal activity, heart rate and heart rate variability, respiration rate and peripheral body temperature. During the training, individuals develop self-awareness and self-regulation of the various feedback modalities. Muscle feedback training enables the athlete to become aware of tension in the muscles and trains the muscles to relax and release tension. Skin conductance feedback training is used to decrease arousal when the athlete is feeling anxious, or to increase arousal or activation before a competition. Heart rate variability feedback training induces greater parasympathetic nervous system activity and a relaxation response. Respiration feedback training reduces sympathetic arousal which encourages regeneration, releases tension, and increases physical and mental relaxation. Peripheral temperature feedback training is used to initiate a relaxation response in order to combat competition anxiety and to enhance recovery after a competitive event. A more in-depth explanation of each type of feedback modality follows.

Muscle or Electromyograph (EMG) Feedback Training

The principle of muscle feedback training is to provide the athlete with enhanced information about his/her muscle tension in a particular area which will facilitate learning to control tension in the muscle. Relaxation of excessive and inappropriate tension is the usual goal. Sensors are attached to the skin on the muscle being targeted for change. Muscles may be targeted anywhere on the body, including the forehead, neck, shoulders, back, jaws, arm, and legs. Measurement of muscle activity preceding muscle contraction is called electromyography or EMG. EMG measures, in microvolts, the electrical energy discharged by the motor nerve endings signaling a muscle to contract (Blumenstein et al., 2002). These tiny electrical signals emitted by the muscles, proportional to the degree of contraction, are amplified and fed to a visual display or audio signal. The visual display may be digits, polygraph-style lines, or changes in colors or patterns. The audio tone may indicate changes in muscle tension by a rising or falling tone or by a change in the frequency of a beep.

One or more criteria are usually set as goals of BFK training. Forehead (frontalis) and upper shoulder (trapezius) muscle activity are valid indicators of general arousal and muscle tension (Zaichowsky & Fuchs, 1988). Muscle tension above 2 micro volts is considered not relaxed, between 1 and 2 micro volts is considered relaxed and below 1 microvolt is considered deeply relaxed (Blumenstein et al., 2002). Speed of recovery from contraction is another common criterion, as well as keeping muscle tension lower during movement.

Skin Conductance or Electrodermal Feedback Training

This modality, known as electrodermal activity (EDA), or the more classic term, galvanic skin response (GSR), is related to the electrical activity of the skin. Sweat contains salt that makes it electrically conductive. A skin conductance device applies a very small electrical pressure (voltage) to the skin, typically on the volar surface of the fingers, where there are many sweat glands, and measures the amount of electrical current that the skin will allow to pass. Electrodermal activity (EDA) has been recognized as distinctly sensitive to transitory emotional states and mental events, as well as being closely correlated with sympathetic nervous system activity (Blumenstein et al., 2002). Self-calming by physical or cognitive means tends to lower skin conductance, while negative emotions such as fear, worry or anger usually raise it. In learning to reliably regulate EDA, the athlete learns to resist distractions which disrupt attention and to maintain a state of mind which is neutral or pleasant. Zaichowsky and Fuchs (1988) recommend this training to athletes for anxiety reduction. EDA can also be used by the athlete to increase their arousal or activation level before a competition if they feel they are not activated enough. EDA is measured in micro-Siemans and is known to increase during stressful times and decrease during relaxation. Exact levels vary from 1 micro-Siemans for individuals with dry hands to 10 micro-Siemans for individuals with moist hands.

Heart Rate and Heart rate Variability Feedback Training

Using a photoplethysmyograph monitor on the non-dominant thumb gives an indirect measure of heart rate. Under stress the number of beats per minute (bpm), or heart rate, goes up and should lower after the task. Typically athletes show much lower than average heart rates but genetics and conditioning determine the baseline. Well trained athletes often have heart rates of 45-60 bpm while the average non-conditioned individual is between 72-80 bpm. Normally, there are increases of 10-20 bpm with activity and a return to baseline within a minute.

Heart rate variability (HRV) is a term that is predated by the term Respiratory Sinus Arrhythmia (RSA) and refers to the rise and fall of the heart rate synchronized with each breath (i.e. faster on inhalation, slower on exhalation). The magnitude of this systematic variability seems to reflect a healthy alternation between two autonomic influences on the heart beat, the sympathetic and the parasympathetic. Lack of this variation reflects an imbalance between the two aspects of the ANS, most likely deficient parasympathetic influence. By calming one's emotional state and by making the breathing slower and more regular, the HRV can be increased. This involves the athlete learning to regulate breathing rate and rhythm in order to induce greater parasympathetic nervous system activity and create a relaxation response.

The feedback for HRV involves monitoring heart rate, or heart rate plus respiration. Heart rate may be detected from a photoplethysmographic sensor on the finger or earlobe, or via electrocardiogram (EKG) monitors. Most commonly, a trace reflecting cyclic variations in heart rate is displayed on a video screen. The variability of heart rate is what is of interest. The athlete observes the trace, or a derived graphic display, and uses it as feedback for regulating the breath and/or emotional state. The heart beat variability is maximized at a particular resonant frequency, which is breathing rate per minute, and this rate, usually around six breaths per minute, can be determined for each individual by observation and experimentation.

Respiration Rate Feedback Training

Respiration pattern, which is depth and frequency of breathing, is highly sensitive to changes of both arousal level and emotional factors (Mador & Tobin, 1991; Pack & McCool, 1992). However, it has rarely been used in BFK studies in the realm of physical activity possibly due to methodological and technical difficulties (Blumenstein et al., 2002). Recently though, Davis and Sime (2005) identified a shallow breathing pattern in athletes as one of the physiological indicators of stress.

The rate of breathing is controlled by the partial pressure of carbon dioxide in the blood stream and can be decreased by blowing out all the carbon dioxide from the bottom of the lungs.

Doing this will lower the breathing rate to 5 to 8 breaths per minute. An ideal rate of breathing for most adults is 6 breaths per minute (Elliot & Edmonson, 2006; Thompson & Thompson, 2003). Effortless diaphragmatic breathing reduces sympathetic arousal which encourages regeneration, releases tension, and increases physical and mental relaxation.

The instrument used to determine respiration rate is a strain gauge around the abdomen below the ribcage. Smooth continuous expansion of the abdominal region with inhalation is a sign of effortless breathing. The surface EMG of the shoulders can help to pin point whether the individual is overusing shoulder muscles during inhalation and if the shoulder muscle tension is released during exhalation. Deregulation in breathing often happens during tasks and is usually indicated by one of three variations a) shallow breathing, with the shoulders doing most of the work rather than the abdominal region; b) breath holding during tasks; and/or c) increasing respiration rate (breaths per minute or brpm). All three of these variations are associated with poor performance in sport (Wilson, 2007).

Peripheral Body Temperature Feedback Training

Skin temperature changes of the fingers provide information about peripheral circulation. The cardiovascular mechanisms that regulate skin temperature in the hands are closely related to the activity of the sympathetic division of the autonomic nervous system. When this system is activated, the smooth muscles surrounding the blood vessels near the skin surface are likely to contract, resulting in vasoconstriction. This causes a decrease in the flow of blood in the area bringing about a drop in skin temperature. Low peripheral body temperature is a physiological sign of inner tension. Conversely, an increase in hand temperature is accompanied by vasodilation, which is relaxation of the smooth muscles surrounding the peripheral blood vessels in the hands, and results from relaxation of sympathetic activity.

A thermal sensor, called a themistor, is taped to the skin, usually on the palmar surface of one of the fingers. The temperature of the skin changes the resistance of the thermistor, thereby altering the electrical signal in proportion to the temperature. The signal is displayed visually through a tone that changes in response to changes in temperature. The values of peripheral skin temperature range from 18-21degrees Celsius (i.e. high sympathetic arousal) to 32-35 degrees Celcius (i.e. low sympathetic arousal) (Zaichowsky & Fuchs,1988). During activity the goal is to maintain peripheral body temperature at or above 32 degrees Celsius.

Temperature training is typically combined with other BFK modalities to train general relaxation. Peper and Schmid (1983) used temperature training with elite level gymnasts to initiate a relaxation response in order to combat competition anxiety and to enhance recovery after the event.

The time required to achieve improved self-regulation of the various BFK modalities varies based on the individual's physiology, and normally averages between four to ten sessions. Generalization to the everyday environment, away from the BFK monitor, certainly takes longer than within the BFK context. However, practicing the various BFK modalities provides a model for real-life self-regulation. The goal is to develop awareness of one's breathing, emotional state, muscle tension and peripheral body temperature, all of which interact and influence autonomic nervous system balance, and aid in both recovery and ability to focus.

Neurofeedback

Neurofeedback (NFK) training focuses on optimizing brain wave patterns in specific regions of the brain that influence an individual's emotional state and cognitive performance (Schwartz & Andrasik, 2003). During NFK training, the individual trains his own brain waves to function more efficiently. The brain frequencies that are in excess are reduced, and those with a deficit are increased (Gunkelman & Johnstone, 2005; Thompson & Thompson, 2003). This technique is used to help improve concentration, deal with distractions and negative thoughts, and help the brain to recharge itself (Sime, 2003). Vernon (2005), in a review of literature, documented associations between specific cortical states and optimal level of performance.

The underlying process in NFK involves training and learning self-regulation of brain activity. The brain waves reflect what a person is doing from moment to moment. NFK training enhances flexibility in order to access the appropriate state to get a particular job done. In essence, the overall goal of NFK is to improve mental flexibility so that a person can produce a mental state appropriate to the situational requirements (Schwartz & Andrasik, 2003). In training, the athlete learns to regulate her brain waves in order to produce a desired mental state. NFK training enables the athlete to become aware that attentional focus is a choice. One can choose to stay focused or not. With training, NFK helps the athlete feel more in control of their mental state (Sime, 2003).

The brain's electrical patterns are a form of behavior, modifiable through operant conditioning (Sterman, 2000). Gunkelman and Johnstone (2005) argue that the operant conditioning technique, on which NFK is based, is a method of intervention that can be used to teach a new response to situational stressors. As well, they suggest that negative experiences may change the body's chemistry, increasing the stress hormone released from the adrenal cortex of the kidneys. This chemical, cortisol, is a healthy response to stress, although with chronic or overly intense stressors, the coritsol will have detrimental effects on the brain, specifically attacking a temporal lobe structure, the hippocampus, which has immune receptors (Gunkelman & Johnstone, 2005). The ability to teach a new response to various situational stressors can enable an individual to create a much more favorable outcome.

NFK training changes the way the brain works, and once the skill is learned, it appears to show long-term change in the brain's function (Monastra, Monastra, & George, 2002). NFK training improves attentional and behavioral states but requires a number of training sessions before the effect is noted and becomes well learned (Luber, 1997; Lubar & Shouse, 1976). The NFK training technique uses quantitative electroencephalographic (QEEG) feedback. The amount of electrical activity at different brainwave frequencies (i.e. the EEG signal) is amplified from the minute voltages, quantified (QEEG), and then translated into information that the athlete can learn. The athlete's EEG is actually what they use to operate the displays and games on a computer screen. The feedback from the screen, which may be both visual and auditory, alerts the athlete to what her brain is doing—concentrating, daydreaming, ruminating—and she can then use this information to change her brain activity. Over a series of training sessions, the athlete learns to use the EEG to control the displays and games on the computer screen. Controlling the computer display teaches the athlete how to produce the brain waves that are associated with focusing, staying in the present moment, remaining calm, and quieting the mind. The researcher slowly adjusts the thresholds, shaping the behavior of the athlete's brain into a more optimal pattern. With practice, the athlete learns how to do this on her own, without the computer feedback.

Gunkelman and Johnstone (2005) argue that the exact mechanisms by which brain activity becomes enhanced with NFK training have not yet been established. They state that it is generally known that exercising nerve pathways facilitates their growth and development. As well, they suggest that NFK training focuses on the underlying process of growth-through-utilization. Analogous to exercise building muscle mass, the utilization of the brain builds the mass of the brain's dendritic connections. NFK training can be thought of as weight training for the brain to assist with better utilizing one's potential (Sime, 2003).

In a paper by Lubar (1997), it states that the mechanisms underlying the generation and origins of EEG have been poorly understood, but are now beginning to become more clarified. To help develop models of how NFK might operate in producing changes in EEG and behavior, he suggests combining the information gathered on the genesis of EEG and neocortical dynamics (Nunez, 1995), with the findings from NFK investigations. According to Lubar, the cortex operates in terms of resonant loops between neocortical columns of cells known as local, regional, and global resonances. These resonances determine the specific EEG frequencies and are often activated by groups of cells in the thalamus known as pacemakers. There are complex excitatory and inhibitory interactions within the cortex and between the cortex and the thalamus that allow for these loops to operate and provide the basis for learning. NFK is a technique for modifying the resonant loops, and hence, modify the neurophysiological and neurological basis for learning and for the management of attention.

NFK for optimal performance is a method for repeatedly exercising the pathways related to attention, focus, and quieting the mind to facilitate their growth and development (Thompson & Thompson, 2003). Most people cannot say what they do, but with training, eventually are able to recognize both the state of focus and when they drift off into daydreams, ruminating thoughts, or negative self-talk. Much of the learning in NFK seems to happen at an unconscious level. Whatever the mechanism, the net result is that the athlete can become better able to self-regulate his mental state, manage distractions, and sustain focus on the task at hand (Schwartz & Andrasik, 2003).

Bio/Neurofeedback Research in Sport

Historically, BNFK has been used extensively in the treatment of health related disorders such as hypertension, tension headaches, migraine headaches, anxiety disorders, Raynaud's disease, and insomnia (Collins, 1995). BNFK has been shown to successfully improve concentration, attention and focus in a wide variety of domains (Schwartz & Andrasik, 2003). For instance, Schwartz and Andrasik (2003) state that noticeable positive outcomes using BNFK were observed in the treatment of Attention-Deficit/Hyperactivity Disorder (ADHD), anxiety disorders, mood disorders, seizures disorders, and traumatic brain injury. Lubar and Shouse (1976) demonstrated that teaching ADHD children to decrease the slow brainwave activity and increase the fast brainwave activity, using BNFK, improved their behaviour. Based on the fact that BNFK has been proven to be a successful technique used for the treatment of these disorders, it becomes interesting to consider the technique within the sport domain.

In the sport setting, particularly with elite athletes, BNFK training is highly appropriate. The measurement of the autonomic and central nervous system responses by psychophysiological assessment is especially relevant because of the psychological and physiological stressors inherent in the competitive environment (Tenenbaum, Corbett, & Kitsantas, 2002). Furthermore, athletes are motivated to continuously evaluate their performance and thereby are accustomed to feedback (Blumenstein et al., 1997).

Hanin (2000) states that there is an advantage to training for emotional regulation before and during competition. It is important for an athlete to control, reduce, and regulate the negative effects that heightened arousal can have on performance (Deeny, Hillman, Janelle, & Hatfield, 2003). Regulating a range of optimal arousal in order to become a more efficient and consistent high-level performer is a difficult skill that is usually developed over time with much practice and training. Regardless, even the most skilled athletes are often vulnerable when the stress is high, much is at stake, and choking can occur (Baumeister, 1984).

Over time, successful athletes can learn to compare differing aspects and levels of emotions, affect, and anticipation related to various performance outcomes, which can then enable them to identify their optimal state for competition (Hanin, 2000). For example, some athletes need to be more relaxed, while others need to heighten their arousal level prior to competition (Blumenstein, Bar-Eli, & Tenenbaum, 1995). Physiological and mental-emotional regulation strategies learned through the use of BNFB interventions is arguably the most crucial performance enhancement technique to be considered for further research (Blumenstein et. al., 2002).

Research in sport psychology and BNFK is primarily concerned with issues related to affect, emotions, arousal and focus and their relationship to performance (Gould & Udry, 1994). Arousal regulation and focus are known to be crucial aspects to quality performance. The advantage of utilizing BNFK training as a means to prepare for competition is to facilitate cognitive and affective awareness which is likely to improve the probability of a successful performance (Edmonds et al., 2005).

Research has shown that psychological and physiological stress, experienced by athletes during training and competition, can be regulated by BNFK training (Blumenstein et. al, 2002). For instance, Zaichowsky (1983) revealed that a BFK training program that included EMG, GSR, and temperature was an effective strategy in assisting gymnasts to regulate their levels of stress and improve performance. Peper and Schmid (1983) conducted a 2-year BFK training program utilizing EMG, GSR, and temperature in conjunction with progressive relaxation, autogenic training, and imagery and the athletes reported that the program enhanced their athletic performance.

Blumenstein et al. (1995) applied measures of GSR, EMG, and HR, in combination with autogenic training and imagery, on the physiological indices of athletic performance. Psycho-regulative procedures of relaxation and excitation were provided in combination with BFK to examine their effect on the physiological and athletic performance variables in an experimental design. Performance was assessed by a 100-meter sprint. The findings revealed that BFK significantly augmented athletic performance when accompanied by autogenic training and imagery.

Kavussanu, Crews, and Gill (1998) examined the effects of single versus multiple measures of BNFK (i.e., EEG, EMG, and HR) and its relation to basketball free throw shooting performance. The authors were also interested in determining if perceived control and self-efficacy could mediate the relationship between BNFK and performance. Results indicated that self-efficacy was the only significant predictor of performance accounting for the largest amount of the variance (60%) in the pre- and post-performance conditions. The relationship between biofeedback and performance was not influenced by either perceived control or self-efficacy.

Bar-Eli, Dreshman, Blumenstein, and Weinstein (2002) examined the relationship between psychological training with BFK (EMG, GSR, HR) on the performance of young swimmers utilizing an adapted version of the Wingate Five-Step arousal regulation approach (Blumenstein et al., 1997). The participants were randomly assigned to two groups. The experimental group received regular training in addition to the three stages of the Wingate training program. The control group received regular training in addition to some relaxation activities. Participants were tested twice during a 14-week period. The results revealed, based on coaches' evaluations and the actual results from competition, that the experimental group showed a substantially greater increase in performance over the control group.

In a similar study, Bar-Eli and Blumenstein (2004) examined the relationship between mental training with BFK (HR, EMG, GSR) and swimmers' performance. The Wingate five-step approach was used as a mental preparation technique for enhancing performance among pre-elite swimmers. Participants were randomly assigned to one of two groups. The experimental group received regular training plus the Wingate 5-step training program. The control group received regular training plus relaxation activities. Participants were tested on running and swimming five times during a 10-week period. Results indicated that the experimental group improved its performance over time on both running and swimming. The control group remained relatively stable on both dependent measures. Other research using BNFK has demonstrated similar findings in shooting (Hatfield, Launders & Ray, 1987; Landers, 1985), archery (Ren, 1995), golf (Crews, 1990; Crews & Landers, 1993), long distance running (Caird, McKenzie, & Sleivert, 1999), handball (Costa, Bonaccorsi, & Scrimadi, 1984), karate (Collins, 1995), and judo (Blumenstein, 1999).

A limited amount of research in sport has been done using, solely, the NFK modality. In a review article, Petruzzello, Landers, and Salazar (1991) stated that it is possible there is an optimal range of alpha activity, such that activity levels outside of this range may result in less than optimal performance. Similarly, Landers, Petruzzello, et al. (1991) in a study on pre-elite archers, supported the notion that NFK training can be an effective means to positively affect the performance of pre-elite athletes. Davis & Sime (2005) stated that NFK, in conjunction with video and internal imagery, appears to have potential as a tool for training visual attention in athletes within a variety of externally paced sports.

An examination of the literature by Vernon (2005) revealed that NFK training has been utilized to enhance performance in three main areas: sport performance, cognitive performance, and artistic performance. Several studies have reported that NFK training does enhance performance, however, due to a range of methodological limitations and a general failure to elicit unambiguous changes in baseline electroencephalograph (EEG) activity, a clear association between BNFK training and enhanced performance has yet to be established.

Schwartz and Andrasik (2003) suggested that NFK may be a very effective way of helping athletes achieve and maintain an ideal image by helping them control intrusive negative thoughts. NFK has also been shown to improve attention (Sime, 2003). Using NFK enables the technician doing the training to actually separate levels of concentration and alertness, allowing them to target the specific needs of the athlete. As a general conclusion, it appears that NFK has the potential to enhance performance, but further research is required to determine the appropriate brainwave activity that will lead to optimal performance.

In reviewing the BNFK research in sport, it is apparent that many of the studies have used an insufficient number of training sessions. This perhaps stems from the misconception that BNFK is a treatment, like a drug, rather that a tool. BNFK, as a training technique, is a learning process through which the individual learns to recognize and self-regulate physiological and psychological responses. Within the literature, the Wingate five-step approach (Blumenstein et al., 1997) is the only well documented training protocol specifically designed for the enhancement of athletic performance. Acevedo and Ekkekakis (2006) suggest that the Wingate five-step approach is presently the best methodology as it matches the principles of the BNFK method with a clear systematic approach for effective use with performers.

The work of Blumstein et al. (1997) highlighted a five-stage training program designed specifically to enhance self-regulation capacity and facilitate athletic performance through BFK training. The first stage, Introduction, familiarizes the athlete with the training process and the equipment that will be used in learning various self-regulation techniques. The second stage, Identification, identifies the modalities the athlete needs to improve in order to achieve peak performance. In the third stage, Simulation, biofeedback training is conducted while simulated competitive stress is created. This process is known as generalization, whereby the athlete is encouraged to detach himself from becoming dependant on the equipment to help control his physiological responses. The fourth stage, Transformation, has the athlete practicing self-regulation skills in the field, as opposed to the first three stages which all occur in a laboratory. The final stage, Realization, has the athlete applying the training to the competitive environment, and learning to develop optimal regulation in competition. These five stages were originally conceptualized for BFK training, but they can also be applied to NFK training (Blumstein et al., 1997).

In summary, the literature review within sport, particularly the work of Blumenstein et al. (1997, 2002), provides a conceptual framework for the multidimensionality of self-regulation of arousal and psychological skills training with BNFK training. Blumenstein et al. (2002) stated that the goal of a BNFK training program in sport is to improve the athletes' levels of self-regulation, optimize competitive behavior, and enhance athletic performance. BFK training equips the athletes with skills to regulate their physiological arousal level at will and to regulate the stress response. NFK training provides tools for the athlete to help them regulate their cortical arousal to develop concentration and alertness as well as manage their emotions, fears, and distractions in order to more fully focus on the task at hand.

Overall, the aim of BNFK applications in sport is to create a self-regulating athlete who possesses self-awareness and well learned psychological skills in order to cope with the stress of competition and diverse life tensions (Blumenstein et al., 2002). Most coaches and athletes agree that mental control, mental toughness, and self-regulation, all of which can be learned through BNFK training, are necessary for successful performance (Blumenstein et al., 2002). Physiological and mental-emotional regulation strategies learned through the use of BNFB interventions is an important performance enhancement technique to be considered for further research (Blumenstein et. al., 2002).

CHAPTER III: METHODOLOGY

This chapter outlines the purpose of the present study, the methods that were used to implement a BNFK training intervention, the outline for the interviews conducted, and the process by which physiological and neurological data was gathered and analyzed.

Purpose

The purpose of the study was to explore whether BNFK, which trains self-awareness and self-regulation of physiological and mental-emotional states, can enhance an athlete's psychological skills, specifically their ability to focus, relax and regulate their arousal and anxiety level, and ultimately, enhance their sport performance. The remainder of this section outlines the specific elements of the research perspective that was used, including (a) the research design, (b) the participants, (c) the instrumentation, (d) the procedures, (e) the data analysis, and (f) the trustworthiness.

Research Design

The proposed study utilized a combination of qualitative and quantitative methodology. The qualitative methodology consisted of an exploration of the experiences of the athletes over the course of the BNFK training and the implementation of that learning throughout the competitive season. The quantitative methodology consisted of an analysis of the physiological and neurological changes noted in the athletes over the 30 hours of BNFK training. A case study approach was utilized.

Yin (2003) provides a definition of the case study design as a research strategy: "The essence of a case study, the central tendency among all types of case study is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (p. 12). "How" and "why" questions possess a more explanatory nature which is most useful for the case study approach. Through observation and dialogue, qualitative researchers seek to derive and describe findings that promote greater understanding of how and why people behave the way they do (Gay, 1996). The specific questions asked of the athletes were: How are you experiencing BNFK training? How, upon completion of the training, are you able to use this training in your daily training and during actual competition?

According to Creswell (1998), in case study methodology, theory may or may not shape the direction of a study. In the present study, the theory of BNFK training shaped the exploration of the experiences of the athletes who took part in the 30 hours of training. The focus for the present study was on 6 cases, which Yin refers to as a multiple case design, and Stake (1995) refers to as a collective case study. Such a design has several advantages and as Yin (2003) states, "the evidence from multiple cases is often considered more compelling" (p. 46).

To obtain an in-depth knowledge of the participants' experiences with the BNFK training and of the evolution of the physiological indicators and the brainwaves, the researcher was looking to understand each participant's experience from their perspective. Smith (1988) specifically suggested that the case study approach is one that "can provide important insights into processes underlying athletic behavior, and can promote the development of interventions that improve performance and enhance the psychological well-being of participants" (p. 2). Therefore, the case study design, which allows the researcher to observe each case as a whole and separate entity, without any influence from the other cases involved in the study, was the most appropriate design for the present study.

Participants

In qualitative research, purposeful sampling models may be used. The researcher seeks out groups, settings, and individuals where and for whom the processes being studied are most likely to occur (Denzin & Lincoln, 2005). This study involved 6 athletes who competed at the elite level of aerial freestyle skiing. This is a high risk sport and as a result is quite stressful, both in the training environment and during competition. All athletes had at least five years of experience at the international or Olympic level. The participants were part of an ongoing research project on psychological preparation for the 2010 Olympics.

Instrumentation

Interviews

Semistandardized interviews were used for the qualitative aspect of the proposed study. According to Berg (2004), semistandardized interviews use predetermined, or semistandardized, questions in order to focus on specific topics, which are the main issues or concerns to be understood. At the same time, this approach allowed the athletes the freedom to expand on any thoughts or comments they may have had, in addition to their answers to the specific questions. This facilitates elaboration on all the aspects of the meanings and ideas that they had in mind. The researcher was also free to probe beyond the predetermined questions. Questions in a semistandardized interview reflect the assumption that people have unique perspectives, and experience and understand the world in different ways (Berg, 2004).

Physiological and Neurological Data

The instruments used in gathering physiological and neurological data were manufactured by Thought Technology. The hardware device used was a Pro Comp Infinity encoder and the software was Biograph Infinity.

Biofeedback Instruments

BFK sensors were temporarily applied to the athlete's body to record data. Muscle tension was recorded by electromyography (EMG) sensors on the forehead and shoulders measuring electrical activity, in micro volts, of the frontalis and trapezius muscles. Heart rate, in beats per minute, was picked up by a sensor on the thumb of right hand. Heart rate variability (HRV) was determined using the electrocardiography sensors on the forearms. The electrodermal response (EDR) sensors on the 1st and 3rd finger of the right hand measured the conductivity and electrical resistance of the skin. Respiration rate per minute was measured by a strain gauge around the abdomen below the ribcage. Peripheral body temperature was determined from the themistor on the palmar surface of the 1st finger of left hand.

Neurofeedback (EEG) Instruments.

The electroencephalography (EEG), which measures the electrical activity of the brain, in micro volts, was used for NFK training. The standard 10-20 sensor placement protocol was used (Jasper, 1958). This included three electroencephalograph (EEG) sensors being placed on the head to record brain wave activity, which was a graphical representation of neuronal activities in the cerebrum. One active sensor was placed on the midline of the scalp, at CZ for sensory motor rhythm (SMR)/beta training (focus training) and at PZ for alpha training (relaxation training). The second active sensor, the reference, was clipped onto the right earlobe while the third sensor, a ground, was clipped onto the left earlobe.

Procedures

The research consisted of three phases. Each athlete underwent 30 hours of BNFK training. In addition, three interviews were held with each of the athletes, prior to beginning the training, between 20 and 30 hours of the BNFK training, and at the end of the 2007-2008 competitive season. An initial and final psychophysiology and EEG assessment was conducted with each athlete. The total time commitment for each athlete participating in the study was 35 hours.

Phase One: Information session, initial interviews with athletes and athlete psychophysiology and EEG assessment.

Before the BNFK training began with each athlete, the researcher conducted an information session for the athletes. The purpose was to discuss the techniques and the time frame required for training. After the information session, an initial semistandardized interview was conducted with each athlete to explore how they had, to date, used specific psychological skills such as stress and anxiety control, relaxation, and focus (Appendix A). The athletes were also asked to talk about their performance in competition from the previous season. Following the interview, neurological and physiological base line data was collected to establish the athlete's psychophysiology and EEG baseline (Appendix B).

Phase Two: BNFK Training

The first three steps of the Wingate Five-Step Approach to mental training were used in this study. Details of the Five-Step Approach have been extensively outlined by Blumenstein et al. (1997) and are described in Appendix C. In addition to the original protocol, NFK training (Appendix E) was included in this research. Blumenstein et al. (1997) states that originally the five stages where conceptualized for BFK training, but they can also be applied to NFK training. As such, although the stages are not exclusive, they provided a concrete guideline on how NFK training can be conducted. As well, Thompson and Thompson (2003) suggest that individuals benefit most when NFK and peripheral forms of BFK interventions are used together, as both BFK and NFK modalities are ultimately under the control of the central nervous system.

Balancing the ANS nervous system (i.e., regulating the stress response) through BFK training enhances the trainee's control over the brain during NFK training, enhancing his ability to develop focusing skills (Thompson & Thompson, 2003).

During each two hour training session, the athlete completed 30-60 minutes of BFK training and 30-60 minutes of NFK training. During BFK training the Wingate protocol was followed (Appendix C). During NFK training, optimal performance protocols (Appendix D), which integrate BFK self-regulation skills into the NFK training, were followed for SMR/beta and alpha training according to Thompson and Thompson (2003). In order to enhance learning with each task, the athlete was asked to articulate the strategy they used to better perform the task. After identifying how they were able to achieve success or improve, the athletes were encouraged to reflect on the strategy, to enhance the possibility that the learning could be incorporated outside the lab setting.

Phase Three: Athlete Psychophysiology and EEG Assessment and Athlete Interviews

In the third and final phase of the research, each athlete underwent a psychophysiology and EEG assessment (Appendix B) following the completion of the BNFK training. The purpose of administering the assessment at this time was to evaluate the extent to which the athlete learned to self-regulate their physiological and neurological responses. The researcher conducted a second interview with each athlete to explore their experiences between 25 and 30 hours of BNFK training. At the completion of the 2007-2008 competitive season, a final interview was conducted with each athlete. The interviews with the athletes focused on their utilization of BNFK skills during the competitive season. See Appendix E and F, respectively, for details regarding the interviews.

Data Analysis

Interviews

The data analysis process began by conducting semistandardized interviews (Berg, 2004). The information was coded into sections of meaningful units of data. This study involved both inductive and deductive methods for analyzing the data. It was deductive in the sense that the questions asked of the athletes were based on the BNFK training. It was inductive in the sense that the athletes, at the same time, had the opportunity to discuss aspects of the training and their lives as athletes, and this information was part of the data, enabling other themes to potentially emerge (Rubin & Rubin, 2005).

Physiological and Neurological Data

Physiological Data Analysis

Self-regulation of the stress response was evaluated during the relaxation/recovery phases of the initial and final psychophysiology stress profile assessment by examining the athlete's physiological indicators against the following criteria: muscle tension at or below 1.5 micro volts, peripheral body temperature above 32 degrees Celsius, and respiration rate at 6 breaths or less per minute. The amount of decrease in both electrodermal activity (in micro-Siemans) and heart rate (beats per minute) between the relaxation and stress phases of the assessment were noted. All measures were evaluated during both initial and final assessments.

Neurological Data Analysis

Evolution of the athletes' brainwaves were examined against set criteria to highlight any significant changes in the brainwaves. SMR/beta (focus) training criteria was: theta brainwaves at or below 10 micro volts, and low beta brainwaves higher that high beta brainwaves. Two ratios were examined. An attentional abilities ratio (i.e., [4-8 Hz]squared / [13-21Hz]squared) was used to establish the attentional ability of the athlete relative to a normative data base (Monastra, Lubar, et al. 1999). The ratio reflects the capacity of the brain to pay attention when needed. High ratios suggest an inability to attend, which is evident in an increased amplitude of theta waves. A busy brain ratio (i.e., 23-34 Hz /13-15 Hz) of above 1.5 indicates that the brain is active when it should be calm (Thompson & Thompson, 2006). Generally, athletes who report doing a lot of critical self-evaluation, rumination, or over-thinking in their sports, have a high busy brain ratio.

Alpha (relaxation) training criteria was: sustained alpha dominant frequency state for 10 minutes, enhancement of alpha brainwaves, and low beta brainwaves higher that high beta brainwaves. One ratio, alpha/theta (8-12 Hz/4-8 Hz), was examined. A value of 1.5 or above for the alpha/theta ratio indicates that the brain is in the state of rejuvenation.

Trustworthiness

In respect to the qualitative aspect of the present study, trustworthiness is established by considering credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). For example, the authors proposed techniques such as prolonged engagement in the field and triangulation of data to establish credibility. Stake (1995) emphasizes the importance, particularly in using a case study approach, of triangulation and member checking. For triangulation, the present study utilized (a) the different data sources of the quantitative changes in the BNFK training, (b) the athlete's perspectives prior to the training, between 20 and 30 hours of BNFK training, and post- season, and (c) the actual performance results. As well, for member checking the researcher provided the interview transcripts to the athletes for additional comments and any clarifications.

CHAPTER IV: RESULTS

The results are divided into two sections. The quantitative data, gathered during the BNFK assessments, is presented in the first section, organized by individual athlete. Qualitative data, which includes the athletes' responses to the interview questions, have been combined and presented according to major themes in the second section.

Bio/Neurofeedback Assessments

Athlete 1 (A1)

Biofeedback Assessments – Initial & Final

The initial biofeedback assessment revealed that A1 had two of the five modalities in the target criteria range (see Table 1). Respiration was 5 breaths/minute during the recovery phases and peripheral body temperature was 32-35 degrees Celsius throughout the assessment. Average resting muscle tension was 3.5 mV, which is higher than target criteria of 1.5 mV. This suggests that A1 holds tension in her muscles. Heart rate variability (HRV) during activity was 5 beats, which is considerably lower than the target of 10 beats. Low HRV is synonymous with high sympathetic nervous system activation. Electro dermal activity range was minimal, 0.4 uSiemens. This indicates limited arousal and emotional self-regulation ranges.

The final biofeedback assessment revealed that A1 met the target criteria in three of the five modalities with improvements seen in the other two modalities as well (see Table 1). Most notable is that there was a decrease in resting muscle tension below the target criteria of 1.5mV. The athlete learned to decrease resting muscle tension in the body. Specifically, A1 identified her jaw as the place she held the most tension. Some increase in the self-regulation range of electrodermal activity and HRV was seen. As well, respiration rate during tasks decreased indicating that A1 maintained a more relaxed state during activity.

Table 1
Athlete 1's Biofeedback Assessment Data – Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		5.0	13.2	5.0		5.0	10.5	5.0
Muscle Tension	recovery < 1.5 mV		3.0	4.5	3.5		1.3	2.0	1.5
HRV	task > 10 beats		5.5	5.0	4.9		6.0	7.6	5.9
Electrodermal Activity	decrease in recovery		3.8	4.1	3.7		0.6	1.8	1.0
Peripheral Temperature	32-35C		33.0	32.7	32.8		32.8	31.4	31.6

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. Data on focusing and anxiety management ability was gained from the initial NFK assessment (see Table 2). The theta/beta ratio was high (3.2) during tasks. For optimal focusing ability the theta/beta ratio should be at 2.0 or below, especially during tasks. Hi beta brainwaves and hi beta/SMR ratio were elevated, 6.0mV and 1.9 respectively. This suggests that much energy is expended in the worry/rumination state. Also, this effectively decreases her ability to stay focused on the task at hand.

The final NFK assessment (see Table 2) indicated a substantial decrease in theta/beta ratio and absolute value of theta during task, and some decrease in the absolute value of hi beta and the hi beta/SMR ratio. A decrease in the value of the theta/beta ratio indicates that this athlete did learn how to focus more effectively. Even though there was some decrease in hi beta (worry/rumination state), the target criteria was not reached.

Table 2
Athlete 1's Neurofeedback Focusing Assessment Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		2.6	3.2		1.9	2.2
Hi Beta/ SMR ratio	below 1.5		1.5	1.9		1.1	1.7
Theta (mV)	below 10		9.2	12.1		8.7	9.4
Alpha (mV)	stable		7.0	7.6		7.0	7.5
SMR (mV)	increase		3.6	3.1		3.7	3.2
Beta (mV)	beta>hi beta		3.6	3.8		4.5	4.2
Hi Beta (mV)	decrease		5.5	6.0		4.0	5.5

Relaxation – eyes closed. During the relaxation component of the initial NFK assessment (see Table 3), the alpha/theta ratio, indicating ability to put the mind into a rejuvenating state, was 1.3, just slightly lower than the target criteria of 1.5. The ability to maintain a relaxed mental state, as measured by alpha dominance, was of short duration (1:06 min/sec) and of low amplitude (9.45). High beta was greater in amplitude (5.2 mV) than beta (4.6 mV) indicating rumination and worry during eyes closed relaxation.

The final NFK relaxation assessment (see Table 3) depicted considerable improvement in the amplitude and duration of maintaining an alpha dominant state, which increased from 1 minute to 6 minutes. The alpha/theta ratio increased to 1.4, just short of the target criteria of 1.5. Hi beta decreased below beta, indicating a decrease in worry and rumination during eyes closed relaxation.

Table 3
Athlete 1's Neurofeedback Relaxation Data – Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		1.3		1.4
Alpha Dominance (time)	increase		1 min. 6 sec.		6 min. 34 sec.
Alpha (mV)	increase		9.4		12.1
Beta (mV)	beta>hi beta		4.6		5.0
Hi Beta (mV)	decrease		5.2		4.8

Summary

In summary, A1 showed improvements in her ability to self-regulate all of the aspects measured. However, there were several areas where she did not meet the target criteria set for optimal physiological and neurological functioning. In future training, she needs to continue to increase HRV to greater than 10 beats, continue to increase electrodermal self-regulation range (arousal and emotional regulation), decrease hi beta/SMR ratio below 1.5 at task, increase the alpha/theta ratio above1.5, and continue to increase the amplitude and duration of the alpha dominant state.

Performance Results/Measures

In World Cup competition this year A1 had 1 finish in the top 10 and 4 finishes in the top 15. In the previous year she had 3 top 10 finishes and 2 top 15 finishes. This athlete was working on a number of technical issues in this season which may have affected her competition results.

Athlete 2 (A2)

Biofeedback Assessments – Initial & Final

The initial biofeedback assessment indicated that A2 had three of the five modalities in the target criteria range (see Table 4). This athlete was in the ideal range for respiration rate, HRV and peripheral body temperature, indicating good control and regulation of these physiological systems. Respiration was approximately 5 breaths/minute during the baseline and recovery phases, HRV was at or above 10 beats at both rest and task, and peripheral body temperature was 33-34 degrees Celsius throughout the assessment. Average resting muscle tension during the recovery phase was 12.9 mV, which is extremely elevated compared to the target criteria of 1.5 mV. This suggests that A2 is a muscle responder, holding tension in the muscles of her body even at rest. Electrodermal activity range was minimal, 0.4 uSiemens. This indicates limited arousal and emotional self-regulation ranges.

During the final biofeedback assessment (see Table 4), A2 demonstrated a dramatic decrease in resting muscle tension; however it was still slightly above the target criteria of 1.5 mV. A small increase in the self-regulation range of electrodermal activity was seen, from 0.4 uSiemens to 1.2 uSiemens, suggesting an improvement in the ability to activate and deactivate the arousal level at will. Resting respiration rate and peripheral body temperature were maintained within the target range, 5-8 breaths/minute and 32-35 degrees Celsius, respectively. HRV, although it was in the target range initially, increased slightly during both rest and task. The higher the HRV, the lower sympathetic arousal is, and the more the body, specifically the cardiovascular and pulmonary systems, is working in coherence.

Table 4
Athlete 2's Biofeedback Assessment Data – Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		5	11	4.5		5	10	4.7
Muscle Tension	recovery < 1.5 mV		7.0	13.6	12.9		1.9	2.8	2.0
HRV	task > 10		10.0	12.0	10.4		12.5	11.6	11.4
Electrodermal Activity	decrease in recovery		1.8	2.4	2.1		0.5	1.7	0.7
Peripheral Temperature	32-35C		33.8	33.1	33.3		33.7	33.4	33.40

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. Initially, from a NFK perspective with the eyes open (see Table 5), both the focusing ability (theta/beta ratio) and anxiety management ability (hi beta/SMR ratio) were slightly higher than optimal levels. The theta/beta ratio was high both at rest and task. The actual value was 3.3 which is above the target criteria of 2.0. The hi beta/SMR ratio was 1.7, slightly above the 1.5 target value. The value of hi beta was considerably elevated above beta both during rest and tasks. Hi beta brainwaves are thought to correspond with negative self-talk and ruminating thoughts. If this state is dominant then the athlete is not present in the moment but attending to thoughts in her head.

The final NFK assessment, with eyes open, indicated that neurologically, this athlete's focusing and anxiety management abilities improved (see Table 5). This was indicated by the lowering of the theta/beta and hi beta/SMR ratios. There was a significant decrease in the theta/beta ratio, from 3.3 to 2.4 at rest and even lower, to 2.2, at task. This was due mostly to a substantial decrease in the theta brainwave. A decrease in the value of the theta/beta ratio indicates an improved ability to focus effectively. The hi beta/SMR ratio decreased to target (1.5) during tasks. There was some decrease in the absolute value of hi beta (worry and rumination brainwaves), however the target criteria was not reached.

Table 5
Athlete 2's Neurofeedback Focusing Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		3.3	3.3		2.4	2.2
Hi Beta/ SMR ratio	below 1.5		1.2	1.70		1.1	1.5
Theta (mV)	below 10		10.3	11.3		8.7	9.2
Alpha (mV)	stable		8.0	7.8		8.1	8.0
SMR (mV)	increase		4.0	3.3		3.5	3.4
Beta (mV)	beta>hi beta		3.1	3.4		3.6	4.1
Hi Beta (mV)	decrease		4.9	5.5		3.7	5.2

Relaxation – eyes closed. A2 demonstrated the ability to achieve and maintain deep relaxation during the eyes closed component of the initial NFK assessment (see Table 6). This was indicated by an alpha/theta ratio of 2.1, compared to the target of 1.5, and the high amplitude (19.58 mV) of the alpha dominant state.

During the final assessment, an increase in both the amplitude and duration of sustaining the alpha dominant state was seen (see Table 6). As well, the alpha/theta ratio increased from 2.1 to 2.3. These numbers indicate a further improvement in her already well developed ability to put her mind in deep relaxation.

Table 6
Athlete 2's Neurofeedback Relaxation Data –Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		2.1		2.3
Alpha Dominance (time)	increase		4 min. 37 sec.		10 min. 16 sec.
Alpha (mV)	increase		19.58		29.28
Beta (mV)	beta>hi beta		4..2		4.2
Hi Beta (mV)	decrease		4.9		4.3

Summary

In summarizing the data, A2 improved her ability to self-regulate in all aspects measured. However, she did not meet the target criteria set for optimal physiological and neurological functioning in all areas. In future training the goals should be to decrease resting muscle tension below 1.5 mV, continue to increase electrodermal self-regulation range (emotional/arousal regulation), and decrease the value of hi beta, the rumination, worry, and negative self-talk brainwaves, below beta.

Performance Results/Measures

In World Cup competition this year, A2 had 1 top 3 finish, 2 finishes in the top 10 and 1 finish in the top 15. This athlete was coming back from a year off due to a serious neck injury. Two years ago she had 4 top 10 finishes and 2 top 15 finishes.

Athlete 3 (A3)

Biofeedback Assessments – Initial & Final

The initial BFK assessment revealed a low peripheral body temperature and increased resting muscle tension indicating that this is the way this athlete holds tension physically in the body (see Table 7). As well, resting respiration rate was slightly high at 10-11 breaths per minute compared to the target criteria of 5-8 breaths per minute. HRV was below the target criteria of 10 beats.

Data gathered from the final BFK assessment (see Table 7) indicated that the areas which improved most were the ability to increase peripheral body temperature to between 32 and 35 degrees Celsius (decrease in activation level of the sympathetic nervous system, which is the stress response) and the ability to decrease resting muscle tension to the target criteria of 1.5mV. Resting respiration rate and HRV remained relatively unchanged. Since maximal HRV is achieved when one breathes at their resonant frequency, which for the average adult is approximately 6 breaths per minute, the results gathered were as expected.

Table 7
Athlete 3's Biofeedback Assessment Data – Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		11	13	10		11	12	9
Muscle Tension	recovery < 1.5 mV		7.2	12.5	9.4		1.5	3.4	1.5
HRV	task > 10		5.0	9.5	6.3		6.0	8.7	5.8
Electrodermal Activity	decrease in recovery		2.4	3.6	2.9		1.6	1.8	1.7
Peripheral Temperature	32-35C		29.7	29.4	29.9		35	32.1	34.7

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. Looking at the initial NFK data for A3 (see Table 8), the key issue needing to be addressed was a high theta/beta ratio (3.7-3.9). A theta/beta ratio below 2.0 correlates with the ability to maintain a strong focus in the present moment. A3's theta/beta ratio was elevated at both rest and task due mostly to the large value of the theta brainwaves. As well, during tasks the hi beta/SMR ratio and the value of hi beta were elevated.

During the final eyes open NFK assessment (see Table 8) a large decrease was seen in the theta/beta ratio indicating an improvement in the ability to sustain present moment focus. However, the ratio was still above the target criteria of 2.0. It was 0.9 above at rest and 0.7 above at task. This would indicate that A3 can still improve her focusing ability. The hi beta/SMR ratio decreased to the target criteria of 1.5 during tasks. The value of hi beta, rumination and worry state, decreased considerably during tasks.

Table 8
Athlete 3's Neurofeedback Focusing Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		3.9	3.7		2.9	2.7
High Beta/ SMR ratio	below 1.5		1.2	1.8		1.2	1.5
Theta (mV)	below 10		15.9	13.4		11.4	11.6
Alpha (mV)	stable		18.7	8.9		10.8	9.1
SMR (mV)	increase		3.3	3.1		3.4	3.2
Beta (mV)	beta>hi beta		4.1	3.6		4.0	4.2
Hi Beta (mV)	decrease		4.0	5.6		4.0	4.9

Relaxation – eyes closed. During the eyes closed relaxation component of the initial NFK assessment (see Table 9), the alpha/theta ratio, indicating ability to let go of thoughts and allow the mind to be calm and re-energize, was 1.2, just slightly lower than the target criteria of 1.5. The ability to maintain a relaxed mental state, as measured by alpha dominance, was of short duration (2:26 min/sec) but of relatively high amplitude (19.9 mV). This indicates the ability to produce the alpha state but a lesser ability to sustain it.

Most noteworthy during the final assessment (see Table 9) was the large increase in duration of time that the alpha dominant state could be maintained. The length of time increased from 2 minutes and 26 seconds to 7 minutes and 3 seconds. As well, there was a some increase in amplitude of alpha, from 19.9mV to 26.1 mV. Increased duration of the time the alpha dominant state is maintained, at this high amplitude of alpha, helps to put the body into deep relaxation and reduces the stress which has built up in the nervous system.

Table 9

Athlete 3's Neurofeedback Relaxation Data – Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		1.2		1.4
Alpha Dominance (time)	increase		2 min. 26 sec.		7 min. 3 sec.
Alpha (mV)	increase		19.9		26.1
Beta (mV)	beta>hi beta		8.6		6.9
Hi Beta (mV)	decrease		6.8		5.4

Summary

Overall, much improvement was seen in A3's ability to self-regulate. However, there were areas where she did not meet the target criteria set for optimal physiological and neurological functioning. Resting respiration rate should be lowered to between 5-8 breaths per minute which will also help to increase HRV to above 10 beats. From a neurological perspective, A3 should continue to decrease the theta/beta ratio below 2.0 to optimize focusing ability and decrease hi beta below beta to enhance her anxiety management skills.

Performance Results/Measures

In World Cup competition this year A3 had 1 finish in the top 5, 1 finish in the top 10 and 3 finishes in the top 20. In the previous year she had 1 finish in the top 5, 2 top 10 finishes and 2 top 15 finishes. This athlete was also working on correcting a number of technical issues this season, in preparation for 2009 and the Vancouver 2010 Olympic Games.

Athlete 4 (A4)

Biofeedback Assessments – Initial & Final

The initial BFK assessment (see Table 10) revealed that A4 had only one of the five modalities in the target criteria range. However, respiration rate and muscle tension were only minimally elevated about target levels. Peripheral body temperature was maintained at the high end of the target range. His temperature was above 35 degrees Celsius throughout the entire assessment. On the other hand HRV was extremely low, 2 beats compared to the target of 10 beats, and was most suppressed during rest and recovery. Low HRV is indicative of low parasympathetic nervous system activation and a lack of coherence between the cardiovascular and pulmonary systems. A large activation range, 3.2 uSiemens, was seen in electrodermal activity. This indicates a very responsive nervous system, meaning that the sympathetic branch of the nervous system is easily engaged. A large range is advantageous only if there is also the ability to self-regulate arousal and emotions, at will. This would be indicated by the ability to return to a baseline or resting level, at will, after activation. In A4's case, he has a baseline measure of 1.9 uSiemens, an activation level of 5.1 uSiemens, and a recovery or resting measure of 2.8 uSiemens. In an optimally function system, there is a return to baseline level as the athlete demonstrated the ability to decreases their arousal level and let go of any emotional engagement.

The final BFK assessment showed changes in the majority of the areas measured (see Table 10). A4 demonstrated an improved ability in decreasing sympathetic arousal, indicated by a lowered resting breathing rate, reduced muscle tension, and a slight increase in HRV. However, the HRV value attained did not reach the target criteria of 10 beats. Peripheral body temperature remained relatively stable within the optimal range. The ability to regulate electrodermal activity range, by returning to resting or baseline measures after a task, was unchanged. Optimal arousal and emotional regulation was not achieved.

Table 10
Athlete 4's Biofeedback Assessment Data – Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		9	13	9.4		6	10.5	6
Muscle Tension	recovery < 1.5 mV		1.8	2.4	1.9		1.6	1.9	1.7
HRV	task > 10		2	6.4	2.3		5	9	6
Electrodermal Activity	decrease in recovery		1.9	5.1	2.8		1.5	3.9	2.5
Peripheral Temperature	32-35C		35.6	35	35.4		35.7	35.5	35.8

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. The initial eyes open component of the NFK assessment revealed information on focusing and anxiety management skills (see Table 11). The two areas that were most elevated above target criteria were the theta/beta ratio and the level of high beta. The theta/beta ratio averaged 3.6 at baseline and 3.4 at tasks, well above the target criteria for optimal focusing of 2.0. Negative self-talk, worry and rumination, as measured by the hi beta brainwave, was at the level of 5.1 mV during tasks. Optimally, it should be below the level of beta brainwaves which during tasks were at 3.4 mV.

During the final, eyes open, NFK assessment (see Table 11) a large decrease was seen in the theta/beta ratio indicating an improvement in focusing ability. However, the ratio was still above the target criteria of 2.0. It was 0.5 above at rest and 0.9 above at task. This would indicate that A4 can still improve his focusing ability for optimal functioning. The value of hi beta decreased after the training but was still above target criteria during tasks.

Table 11
Athlete 4's Neurofeedback Focusing Assessment Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		3.6	3.4		2.5	2.9
High Beta/ SMR ratio	below 1.5		1.4	1.9		1.2	1.7
Theta (mV)	below 10		10.7	11.6		9.2	10.2
Alpha (mV)	stable		4.2	3.8		4.3	3.7
SMR (mV)	increase		2.9	2.7		3.0	2.8
Beta (mV)	beta>hi beta		3.0	3.4		3.7	3.5
Hi Beta (mV)	decrease		4.0	5.1		3.7	4.7

Relaxation – eyes closed. During the relaxation component of the initial NFK assessment (see Table 12), the alpha/theta ratio, indicating ability to let go of thoughts and allow the mind to be calm and re-energize, was 1.3, just slightly lower than the target criteria of 1.5. The ability to maintain a relaxed mental state, as measured by alpha dominance, was of short duration (1:20 min/sec) and of moderate amplitude (13.8). High beta was greater in amplitude (4.5 mV) than beta (3.7 mV) indicating negative self-talk and rumination during eyes closed relaxation.

The final NFK relaxation assessment (see Table 12) showed an improvement in the amplitude and duration of maintaining an alpha dominant state. The state was held for over 4 minutes at an amplitude of 22.1 mV. The alpha/theta ratio increased to the target of 1.5. Hi beta decreased below beta, indicating a decrease in negative self-talk and rumination during eyes closed relaxation.

Table 12
Athlete 4's Neurofeedback Relaxation Assessment Data – Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		1.3		1.5
Alpha Dominance (time)	increase		1 min. 20 sec.		4 min. 07 sec.
Alpha (mV)	increase		13.8		22.1
Beta (mV)	beta>hi beta		3.7		3.5
Hi Beta (mV)	decrease		4.5		3.2

Summary

In summary, A4 showed improvements in his ability to self-regulate all of the aspects measured. To reach the target criteria in the BFK modalities, A4 needs to continue to increase HRV to greater than 10, through breathing exercises at resonant frequency, and to decrease electrodermal activity to resting levels at will. Optimal neurological functioning can be achieved by continuing to lower the theta/beta ratio below 2, decreasing hi beta brainwaves (negative self-talk and rumination) at task and by increasing the length of time the alpha dominant state can be sustained.

Performance Results

In World Cup competition this year A4 had 2 top 3 finishes, 1 finish in the top 10 and 4 finishes in the top 15. This athlete was coming back from a year off due to a serious injury. Two years ago he had 3 finishes in the top 3 and 4 finishes in the top 10.

Athlete 5 (A5)

Biofeedback Assessments – Initial & Final

The initial biofeedback assessment (see Table 13) revealed that A5 had only the temperature modality within the target criteria range. However, muscle tension and HRV were only slightly short of the target criteria. Muscle tension was 2mV at rest, compared to the target of 1.5mV while HRV was at it's minimum at 8 beats, just short of the 10 beat target. Respiration rate was elevated to 11-12 breaths/minute during the rest and recovery phases. Electrodermal activity range was large, 3.9-5.8 uSiemens. This indicates a responsive nervous system but limited amount of self-regulation as during the recovery phase the electrodermal activity remained elevated at 5.1 uSiemens.

The final biofeedback assessment (see Table 13) showed that A5 met the target criteria in three of the five modalities with improvements coming very close to target in the other two modalities. Most notable was the decrease in respiration rate to 6-7 breaths/minute in rest and recovery. There was a decrease in resting muscle tension below the target criteria of 1.5mV. As well, there was a lower deactivation level of electrodermal activity.

Table 13
Athlete 5's Biofeedback Assessment Data – Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		12	12	11		6	10	7
Muscle Tension	recovery < 1.5 mV		2	2.6	2.1		1.4	1.9	1.5
HRV	task > 10		8	15.4	9.5		10	8.4	9.6
Electrodermal Activity	decrease in recovery		3.9	5.8	5.1		3	3.9	3.5
Peripheral Temperature	32-35C		35.3	35.0	35.1		35.2	35.1	35.2

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. Looking at the initial NFK data (see Table 14) the key issue identified was an excessively elevated hi beta/SMR ratio of 2.3, at task, due mostly to the large value, 7.8mV, of the hi beta brainwaves. This suggests that A5 spends a great deal of time in the worry and rumination state. On the other hand, the theta/beta ratio, which correlates to the ability to maintain a strong focus in the present moment, was within the ideal range.

The final NFK assessment (see Table 14) with eyes open showed a decrease in hi beta value at task, from 7.8 to 7.0, and subsequently a decrease in hi beta/SMR ratio, from 2.3 to 2.0. However, this ratio was still elevated considerably above the 1.5 target criteria.

Table 14
Athlete 5's Neurofeedback Focusing Assessment Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		1.7	1.8		1.6	1.7
High Beta/ SMR ratio	below 1.5		1.7	2.3		1.5	2.0
Theta (mV)	below 10		9.7	9.7		9.4	9.8
Alpha (mV)	stable		4.7	4.8		5.1	5.6
SMR (mV)	increase		3.3	3.4		3.3	3.5
Beta (mV)	beta>hi beta		5.6	5.4		5.7	5.8
Hi Beta (mV)	decrease		5.7	7.8		5.1	7.0

Relaxation – eyes closed. During the initial eyes closed NFK assessment (see Table 15), A5's alpha/theta ratio was within the target range. He produced moderate amplitude (13.4 mV) of alpha brainwaves. However, the alpha dominant state was only sustained for a short duration of time, 2 minutes and 10 seconds. Hi beta was also slightly higher than beta during this time.

The final eyes closed NFK assessment (see Table 15) showed an increase in the alpha/theta ratio and in both amplitude and duration of the alpha dominant state. As well, hi beta decreased below beta, which was the ideal level desired.

Table 15
Athlete 5's Neurofeedback Relaxation Assessment Data – Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		1.6		1.9
Alpha Dominance (time)	increase		2 min. 10 sec.		6 min. 11 sec.
Alpha (mV)	increase		13.4		17.9
Beta (mV)	beta>hi beta		5.7		6.3
Hi Beta (mV)	decrease		6.0		5.1

Summary

Overall, A5 needs to work on only a few areas to optimize his physiological and neurological functioning. Regulation of his arousal level, both activating to reach his optimal performance state and deactivating to his resting level, at will, should continue to be trained. A decrease in hi beta values at task will effectively decrease the hi beta/SMR ratio below the target of 1.5. As well, an increase in the duration of time the alpha dominant state is sustained will effectively decrease the amount of stress in the nervous system.

Performance Results

This athlete did not compete this season, due to an injury. The previous year he had 1 top 3 finish, 2 top 5 finishes, and 1 top 15 finish.

Athlete 6 (A6)

Biofeedback Assessments – Initial & Final

Most notable in the initial BFK assessment (see Table 16) was a high resting respiration rate of 14-15 breaths per minute and increased resting muscle tension. HRV was slightly below the target criteria of 10 beats. The electrodermal activity range was minimal but at a low level. Peripheral body temperature was maintained above 34 degrees Celsius throughout the assessment. This athlete holds tension in the body in the form of increased muscle tension (2-4 mV rather than 1.5mV) and higher than optimal respiration rate (12-14 breaths per minute rather than 5-8 breaths per minute).

The final BFK assessment (see Table 16) showed changes in four of the five areas measured. A6 demonstrated an improved ability to decrease sympathetic arousal, indicated by a lowered resting breathing rate, reduction in muscle tension, an increase in HRV and an increase of peripheral body temperature. However, resting respiration rate and muscle tension values attained did not reach target criteria. The ability to regulate electro dermal activity remained unchanged.

Table 16
Athlete 6's Biofeedback Assessment Data –Initial & Final

			Initial Assessment				Final Assessment		
Physiology	Criteria		Baseline	Task	Recovery		Baseline	Task	Recovery
Respiration Rate	recovery 6-8 br/min		15	12	14		10	10	11
Muscle Tension	recovery < 1.5 mV		2.5	6.5	4		1.9	3.1	2.1
HRV	task > 10		5	9.5	9.5		10.2	12.1	10.3
Electrodermal Activity	decrease in recovery		0.9	1.3	1.1		0.7	1.1	1
Peripheral Temperature	32-35C		34.6	34.7	34.6		35.6	35.5	35.6

Neurofeedback Assessments – Initial and Final

Focusing – eyes open. The initial eyes open component of the NFK assessment (see Table 17) revealed information on focusing and anxiety management skills. The ratios for both of these areas were above target criteria especially during task. The theta/beta ratio averaged 4.0 at baseline and 4.2 at tasks, well above the target criteria for optimal focusing of 2.0. Negative self-talk, worry and rumination, as measured by the hi beta brainwave, was at the level of 6.1 mV during tasks. Optimally, it should be below the level of beta brainwaves which during tasks were at 3.4 mV. As well, the hi beta/SMR ratio was 2.3 at tasks, well above the 1.5 target. These numbers suggest that A6 does not focus optimally perhaps due in part to the large magnitude of worry and rumination brainwaves he produces.

The final NFK assessment with eyes open (see Table 17), indicated that neurologically, this athlete's focusing and anxiety management abilities improved. This was indicated by the lowering of the theta/beta and hi beta/SMR ratios. There was a substantial decrease in the theta/beta ratio, from 4.0 to 2.7 at rest and 4.2 to 3.6 at tasks. This was due mostly to a decrease in the theta brainwaves. A decrease in the value of the theta/beta ratio indicates an improvement in the ability to focus effectively. The hi beta/SMR ratio decreased to target (1.5) at rest and slightly above target (1.9) during tasks. This was due to an increase in SMR, indicative of calmness in the body, as the hi beta brainwaves increased in the final assessment.

Table 17
Athlete 6's Neurofeedback Focusing Assessment Data – Initial & Final

			Initial Assessment			Final Assessment	
Brainwaves	Criteria		Baseline	Stress/Task		Baseline	Stress/Task
Theta/Beta ratio	below 2		4.0	4.2		2.7	3.6
High Beta/ SMR ratio	below 1.5		1.7	2.3		1.5	1.9
Theta (mV)	below 10		11.0	14.2		11.8	12.8
Alpha (mV)	stable		3.6	3.8		4.0	4.2
SMR (mV)	increase		3.0	3.2		3.1	3.4
Beta (mV)	beta>hi beta		2.7	3.4		2.9	3.6
Hi Beta (mV)	decrease		5.0	6.1		4.6	6.5

Relaxation – eyes closed. During the relaxation component of the initial NFK assessment (see Table 18), the alpha/theta ratio, the ability to put the body into a relaxed state, was 2.2, well above the target criteria of 1.5. The ability to maintain this state, as measured by alpha dominance, was of short duration (2:10 min/sec) and of moderate amplitude (13.8).

The final eyes closed NFK assessment showed an increase in both the amplitude and duration of sustaining the alpha dominant state was seen. The alpha/theta ratio remained unchanged at 2.2. A6's ability to sustain a deeply relaxed state improved.

Table 18
Athlete 6's Neurofeedback Relaxation Assessment Data – Initial & Final

Brainwaves	Criteria		Initial Assessment		Final Assessment
Alpha/Theta ratio	1.5 or above		2.2		2.2
Alpha Dominance (time)	increase		2 min. 10 sec.		6 min. 11 sec.
Alpha (mV)	increase		13.4		17.9
Beta (mV)	beta>hi beta		8		7.4
Hi Beta (mV)	decrease		6.1		7.1

Summary

Overall, some improvements were seen in A6's ability to self-regulate. However, several key areas still require training for optimal physiological and neurological functioning. Physiologically, the ability to decrease resting respiration rate to 5-8 breathes per minute is probably the most important modality still needing to be trained. Continuing to decrease the theta/beta ratio and the hi beta brainwaves, to target criteria, would enhance his focus and anxiety management skills.

Performance Results

This athlete did not compete this season, due to an injury. In the previous year, he had 3 top 3 finishes.

Interview Results

Three interviews with each athlete were conducted throughout the research study. The first interview, conducted prior to BNFK training, detailed the psychological skills each athlete used in training and competition. The second interview, conducted between 20-30 hours of the 30 hours of BNFK training, asked the athletes to talk about their experiences and self-awareness that was developed during the training. The third interview, conducted near the end of the 2007-2008 competitive season, allowed the athletes to share if and how they used these new skills in training and performances during the competitive season. All information collected will be presented in organized themes.

First Interview

Focus

In the initial interview, all of the athletes were clear about what their best focus was and what was required to perform their best during a competition. They spoke of the need to be "in the present moment" and not anywhere else, especially not "ahead of themselves" meaning thinking about the outcome instead of on the "doing" of the jump. One athlete said, "...the best thing is to think about what you have to do to jump well, be aware of the wind and the feel of the snow under your skis when the pressure is on". Another athlete talked about "staying calm by focusing on my breath and thinking power". Before I start my mind is absolutely clear of any emotion at all except focusing, I'm totally not seeing anything around me. I have to go for it on each jump. I mean there is no holding back. I have to fully commit to the jump. This enables me to feel very self confident and have a strong belief in myself". Another athlete talked about the focus she brings to the training situation. "I like to concentrate on my technique. I don't talk too much on the hill, I'm always thinking about the positions I need to be in the air and on the landing to execute a perfect jump. I'm always concentrating in training."

A number of athletes also talked about when they "lost their focus" or "got ahead of themselves." One athlete stated that "just thinking about the outcome is enough to break your concentration and make you perform below your ability." The same athlete talked about the difficulty of following up a good first jump with a good second jump during competition. He would have an exceptionally good first jump and then the next jump fail to finish in the top five. When asked what he thought was going on, he said, "...worrying about the outcome. The first jump I was feeling relaxed and confident, just concentrating on what I can do. The second jump, I wanted to win again and I tried to hard. I wanted the result too much. This clearly illustrates both the need to "stay in the present moment" and how incredibly difficult it is to do so. Being in the "present moment" is very much a conscious act on the part of the athlete.

Arousal and Anxiety

In the competitive environment, the level of arousal is very much related to the "present moment" focus that an athlete wants to maintain. All athletes identified arousal regulation as an area that could enhance their performance if they managed it well. In assessing a previous World Cup competition, one athlete felt that he didn't achieve the proper level of activation or arousal. "I think I was just flat. Right from the start I felt that I was off track." The athlete felt that what he had needed to do was "to become more pumped up, activated or aroused both mentally and physically." A second athlete said "…I always try to pump myself up. For me I try to increase my energy level and become more aggressive."

The majority of athletes, in the present study, felt that at times they were stressed or over-anxious due to the demands of competition. They talked about how this affected their ability to concentrate or focus, to pay attention to what was important and let everything else go, and to focus on positive self-talk. One athlete mentioned that when she was nervous and over aroused she was not able to perform her best. For the most part she felt it was difficult to stay calm and positive.

Arousal level is about the athletes struggling to find the right balance so they can sustain their optimal performance state in competition. It is a conscious task that each athlete is engaged in to find the "right" level for himself. This is especially relevant for these athletes as they compete in a high-risk sport.

Relaxation

Two different aspects of relaxation were mentioned as areas that the athletes felt could enhance their performance. Being able to relax and recover between jumps within a competition was identified by four of the athletes as being crucial to having a second successful jump. This included not only physical relaxation but also that their mind was able to have a break from focusing, and that they were spending time not concerned and thinking about the second jump. Being able to fully relax between competition days, especially if they were consecutive days, was also identified as being an area that could enhance performance.

A variety of techniques were mentioned by the athletes as ways they relaxed. Listening to music, watching a movie, spending time alone, and thinking about positive things were some of the relaxation techniques they used. When asked about their ability to relax, most felt they were pretty good at it, but all of them were open and interested in learning new or different ways to relax.

During the first interview, prior to the BNFK training, it was clear that the athletes cognitively knew what was required in order to maintain their optimal performance state in terms of focusing, relaxing and managing their anxiety level. The initial assessment revealed that the athletes, although they were cognitively aware of what their optimal performance state was, they did not always optimally manage their physical and neurological states during the stress tests in the assessment.

Second Interview

Experiences with BNFK training

All six of the participants reported feeling more relaxed, calmer, and less stressed following the BNFK training sessions. One of the athletes described it as "feeling slowed down and more in control". When asked how she felt about the slowing down, she reported, "...it isn't uncomfortable. It is unusual but positive...it is not the way I feel most of the time." One athlete mentioned feeling more tuned into and connected with her own emotions. A third athlete stated that during and after the training she was able to, simultaneously, remain aware of how she was feeling and what was happening in the environment. In the past, she had mostly paid attention to the demands of the outside world and at times would lose touch with how she was doing and what she needed.

At the same time, the athletes said that they had difficulty finding words to describe the changes they experienced. Sometimes they were unable to express exactly what changes they made in order to increase their focus or decrease their anxiety level. They often lacked the vocabulary because, in some cases, they did not have any previous experience of being consciously aware of how they switched mental or physical states. An example of this was when one of the athletes became somewhat frustrated with his lack of descriptors and wanting to share his experience accurately, he answered the researcher's query about a specific change with, "I'd like to answer yes, but I know you're going to ask me how I made the change, and I wouldn't know how to answer that."

Specifically, when asked about the relaxation or alpha training, one athlete stated that "at first I found it hard and also very odd to pay attention to my breathing and if thoughts came to let them go. Before long it became easier and I enjoyed giving my mind a break from thinking. By the end of the training I was able to maintain a calm relaxed state for much longer than at the beginning. It is something I can probably use when I become overwhelmed and stressed out both in training and competition".

The athletes where also asked, in the second interview, about the development of their level of self-awareness of their physical and neurological states. Many of them were able to relate interesting observations regarding what they had learned about themselves during the course of the training. One athlete, during his initial session, found it difficult to relate to the feedback he was seeing on the screen. It showed that the muscle tension in his shoulders was quite high and when asked to decrease it, he was unable to. He stated "What is on that screen has nothing to do with me….I am relaxed. This is what I always feel like." During a later training session, he asked if he could work a little longer on the muscle tension exercise because he thought he could relax his shoulder muscles if he had the feedback for a little longer. In that session he was able to reduce his muscle tension for the first time.

Another athlete stated that she had learned a lot about herself during the training. She discovered she held a lot of tension in her jaw muscles. As a result, several sessions were focused on decreasing the resting muscle tension in her jaw. In one training session, while engaged in a task that required her to move the ball to the other side of the balance beam, which required her to decrease her hi beta brainwaves (worry and rumination), she worked on consciously relaxing her jaw and face muscles. To her surprise the ball moved quite easily to the other side. She repeated the exercise successfully several times. Following that exercise, she stated that it felt like when she relaxed her jaw, she was able to let go of the worried thoughts in her mind and therefore focus more effectively. Unfortunately, this happened right near the end of the training but if future training takes place this is certainly an area that will be worked on for this athlete.

A third athlete was also able to decrease his hi beta brainwaves. During the initial assessment, the magnitude of hi beta brainwaves was identified as excessive. This level of brainwaves suggests that he spent a considerable amount of time in a state of rumination and worry. By the end of the training sessions he was able to decrease his hi beta brainwaves considerably and occasionally even bring it below beta, which was the target criteria. When asked how he was able to decrease it so much on the several occasions he did lower it below target, he stated that he had just cleared his mind. He offered, at that point in time, that he didn't know exactly how he cleared his mind but he was just somehow able to let go of all the thoughts and that it felt good. It will be important, in follow-up training, to ensure he understands how to regulate this at will.

A fourth athlete mentioned that while she had used the technique of focusing on her breathing for a number of years in competition, BNFK training helped her to better understand how such awareness of breathing affected her body and thoughts. As well, she became aware that she held a considerable amount of tension in her shoulder muscles and over the course of 30 hours of training learned to be aware of and relax those muscles.

In summary, the athletes reported that the BNFK training was a positive experience. Many felt an improved sense of awareness of both their physical and mental state and an awareness and improvement in their ability to shift or change their physical and mental state at will.

Third Interview

Use of BNFK Skills in Training, Performance & Life

The third set of interviews were conducted near the end of the 2007-2008 competitive season. In answer to how they might have used the BNFK training during the competitive season, one athlete indicated that he could give his mind a break if he practiced alpha training (no thoughts) as he went back up the hill on the ski lift. He mentioned that he often had a lot of negative thoughts and that he had difficulty stopping the negative thoughts and/or switching them to positive ones. After working on this skill in the lab, he tried it on the hill and reported that he was able to switch from negative to no thoughts relatively easily and gave his mind a break as he was going back up the hill. He stated that "no thoughts are certainly a lot better than negative thoughts". He felt that all of his negative thoughts wore him out at times, making him feel drained of energy. During this post-season interview, this athlete stated that he had continued to use this technique throughout the competitive season.

Another athlete mentioned that the breathing exercises, at the end of each training session, had helped improve her ability to relax. She stated that normally it was difficult for her to totally relax and that during her best performance of the year she was able to stay focused on her breathing both during the competition and between jumps. She said "It is amazing how much easier it is to stay calm and focused on your jump when you are aware of your breathing".

The best focus and best performances of another of the athletes was when she was paying attention to what was going on in her present environment. Internally, she remarked that she attended to her breathing, making sure it was slow and calm as well as keeping her muscles relaxed, especially her shoulders. Externally, she paid attention to her immediate environment and instructions from her coach and the support staff. She also added, "...what was most beneficial was when I paid attention to what was going on in each moment and didn't allow my thoughts to race around about past mistakes or future expectations".

An athlete, who didn't compete this year due to an injury, shared a story about using what he had learned from the training in another aspect of his life. He noticed that after playing video games that his hands and feet were very cold. He used the portable thermometer he had been given to check his hand temperature and found it to be 21 degrees Celsius. He said that he knew from the BNFK training, that with a temperature that low, his nervous system was quite stressed. After several minutes of breathing slowly, he had his hand temperature above 32 degrees Celsius. He stated that from the BNFK training he knew he could get his body to relax by breathing slowly and increasing his hand temperature. Although this was not a sport specific example, this athlete did increase his self-awareness of how his body manifests stress and demonstrated an ability to regulate it at will.

Summary of Findings

The present research set out to understand whether BNFK training could enhance psychological skills and athletic performance. Within the lab setting, the six athletes developed i) greater self-awareness of how they hold tension and anxiety in the body and ii) self-regulation techniques to decrease that tension. As well, they became more aware of their mental state, and through regulation of their level of anxiety and tension in the body, they enhanced their ability to focus. Specifically, they did this by shifting their mental state from one dominated by theta (daydreaming) or high beta (ruminating and worrying) to one within the alpha/SMR/beta range (wide to narrow present moment focus).

Overall, the findings indicated that all athletes, over the course of the 30 hours of training, developed self-awareness of the various mental and physiological states and improved the skill of shifting these states at will. Although much improvement was seen, none of the athletes developed optimal self-regulation of all aspects measured. Each of the 6 athletes will still need to work on sustaining their ideal focusing state and more quickly refocusing to that state when they get distracted. As well, it is crucial that they continue to develop the ability to put their mind into deep recovery (alpha). This will enable each of these athletes to release the stress that they build up in the nervous system, and to be able to fully focus when required.

The subjective interview data gathered in the current study helped the researcher to obtain insight into the athletes' experiences with BNFK training. Generally, the athletes reported that having the BNFK training helped them become more aware of how they managed stress and gave them new tools to use to cope with the pressure of elite level competition. This was achieved through enhancement in their abilities to regulate their arousal and anxiety, to stay focused on the task at hand and to relax when needed. However, the objective performance results data gathered from the athletes during the competitive season, gave no clear indication of enhanced performance.

CHAPTER V: DISCUSSION

The purpose of this study was to explore whether BNFK, which trains self-awareness and self-regulation of physiological and mental-emotional states, can enhance an athlete's psychological skills, specifically their ability to focus, relax and regulate their arousal and anxiety levels, and ultimately, enhance their sport performance. It was expected that after BNFK training in self-awareness and self-regulation, athletes would be able to flexibly shift their mental and physical states to focus, relax and manage their arousal level optimally, as required by the demands of the task. It was also hoped that mastery of self-regulation skills would result in enhanced sport performance.

The following discussion provides an opportunity to compare and discuss the athletes' experiences and data gathered during BNFK training, identified in the results section, with existing literature in sport psychology and BNFK.

Previous research has suggested that BNFK is a powerful tool for physiological and psychological change, increasing individual awareness and control over the body and mind, reducing habitual stress, improving arousal regulation and enhancing focusing and relaxation skills. Specifically, Schwartz and Andrasik (2003) stated that BNFK can be used to enhance self-awareness, self-regulation, and athletic performance by providing athletes with information about what is going on inside their bodies and brains, making covert processes overt. The present research lends support to the first two premises of Schwartz and Andrasik's statement. In this study, BNFK training did enhance self-awareness and self-regulation with the athletes as seen in the results of the initial and final assessments. All six athletes were able to improve their self-regulation abilities, although, all of the athletes still had areas that still needed improvement after the 30 hours of training were completed. Enhanced athletic performance was not seen, however this could be due to a number of factors. Two of the six athletes did not, in fact, compete in the season following the training, due to injuries, and two athletes, two years out from the Vancouver 2010 Olympic Winter Games, were emphasizing technical changes rather than results. The final two athletes certainly maintained their status on the World Cup circuit. Specifically, in terms of the BNFK training, none of the athletes achieved what was defined in the research as optimal physiological and neurological functioning. All six athletes had two or more areas where they could still enhance their self-regulation ability to meet the target criteria. With further training to develop ideal self-regulatory abilities in all areas, perhaps enhancement of athletic performance would be seen. In reflecting on actual performance results it is also important to consider is that there are many factors that influence performance. Optimal development of psychological skills, through BNFK training, is not the sole contributing determinate of the level of performance at any given moment.

Krane and Williams (2006) have stated that achieving one's own ideal psychological climate is not a simple task. For the athlete, the ideal psychological climate is their ideal performance state. The results of the present research suggest that the athletes can identify cognitively what their ideal performance state is but implementation of it under stressful situations poses more of a challenge. On the other hand, after the BNFK training intervention all athletes were closer to the optimal criteria for focusing, relaxing and arousal regulation.

Crews, Lochbaum, and Karoly, 2001, in the sport psychology literature, suggest that many athletes typically describe the three aspects of the ideal performance state as a narrow focus of attention, concentrated in the present moment on the task at hand, an appropriate level of arousal or intensity, and a sense of personal control. During the initial interviews with the athletes in this study, two of these three aspects were mentioned. The importance of present moment focus in order to be at their best was reiterated many times. All athletes identified arousal regulation as an area that could enhance their performance if they managed it optimally. As well, the 30 hours of training enabled the athletes to develop a stronger self-awareness of exactly how they manage their arousal regulation and their focus.

As well, Williams & Harris (2006) have suggested that less than optimal sport performance can often be attributed to fluctuations in the athlete's mental control due to anxiety. This includes a decrease in the ability to concentrate or focus, to process relevant cues and control distractions, and to focus on positive self-talk. The majority of athletes, in the present study, mentioned that when they were nervous and over aroused they were not able to perform their best.

Ravizza (2006) emphasized the importance of athletes being aware of the way they experience stress and the very individual nature of how stress is experienced. The present research confirmed that each individual experiences and manifests stress uniquely. No two athletes presented with the same physiological or neurological athlete profile during any of the assessments. Also of interest was that as the athletes became more aware of their own early signals of stress, such as increased muscle tension or respiration rate, they were able to use these signals as cues to relax or shift focus while doing tasks. As well, Ravizza (2006) has suggested that the key learning is when the athlete starts to understand their own patterns and begins to identify and manage them while performing. All six athletes actively participated in the BNFK training at roughly the same time but the learning involved in identifying and managing their own physical and neurological patterns happened on a very individual basis. For a number of the athletes, it was in the later stages of the BNFK training intervention that they started to identify the links between the physical and mental coping patterns that they had developed as ways of managing stress. With this knowledge they immediately began to consciously manage these patterns in a more optimal manner, enabling them to focus and relax more effectively. With more training, the athletes should be able to more fully develop this ability and continue to learn to transfer these skills to the performance domain.

In summary, it is felt that the feedback, both physiological and neurological, presented to the athletes during the training challenged the effectiveness of their current coping styles and increased their awareness of stressors and the effect of those stressors on both their performances and their lives. In general, this prepares the athletes to acknowledge and understand physiological feedback, and view BNFK training as a new coping skill to help them manage the stress and anxiety of competition and life.

Importance of Findings

Research in the field of BNFK provides credible information to athletes, as well as coaches, sport psychologists and other support staff working with the athletes. This research has the ability to enhance understanding of BNFK and provides insight into how athletes handle and manage stress from a physiological and neurological perspective.

Specifically, applied sport psychologists solicited to help athletes manage stress and anxiety could adopt the methodology used in this study or could use techniques and strategies identified in the study to help athletes become more self-aware and better self-regulate physiological and neurological responses.

This research also furthers our understanding of how athletes, competing at the elite level of sport, manage and function physiologically and neurologically. This information can be of benefit to other athletes as they strive to be the best they can be and achieve their best focusing state during competition and practice.

This study may serve to increase professional credibility as BNFK becomes more wide spread. The data from this study may also be offered to BNFK trainers and may ultimately shape protocol development. Information via scientific literature may promote inter-professional communication and understanding, which may ultimately allow it to reach more athletes and coaches.

From the perspective of the field of sport psychology, this research has advanced the understanding of the physiological and neurological components of psychological skills in the high performance athlete. It has looked at specific physiological and neurological components of psychological skills required to be fully focused and to perform well at the highest level of sport. We now better understand some of the commonalities and uniqueness of pursuing such a "life of excelling". The complexity and contradictions among and within the six athletes demonstrate clearly that there is not just 'one way' to excel or one 'type' of individual who manages to perform at the highest level.

Limitations

This research has several weaknesses and/or limitations.

Procedural Aspect of Study

The population of interest in this study was limited to elite level athletes, specifically national team skiers, all in their mid-twenties. The small sample size and limited diversity of the sample inherently limits generalizability to other populations. However, the focus of the study was on how BNFK training affects psychological skills and sport performance in the elite athlete, and this study provides a useful beginning for further research.

Trainer's Expertise

Another limitation of the study was the researcher's expertise. Although a great number of hours over the last two years have been devoted to improving and refining training skills, being able to optimally adjust training protocols and screens is something that is developed with experience. It is felt that as the trainer becomes more skilled at providing the BNFK training, more individualized athlete training protocols will be utilized making the experience for the athlete more beneficial.

Training Time Demands

Due to the time demands of the BNFK training intervention only a small number of athletes were included in the study. Between 25 and 35 hours of training are required for a training effect to be noted and become more persistent.

Equipment Limitations

The instruments used for the BNFK training are not wireless, restricting actual measurements being taken during athletic competition. This limits the researcher's ability to measure transference of the learned response to performance in training and competition.

Future Directions

It has been extremely enlightening to look in-depth at a number of individuals' physiological and neurological responses as they sought to develop their psychological skills and enhance their performance through self-awareness and self-regulation. While much has been learned based on the results and the observations of the athletes, it would be worthwhile to consider the following suggestions for future research.

It would be valuable to continue BNFK training with the six athletes in the present study to see if they continue to develop their self-awareness and self-regulation skills to meet the ideal criteria as set out in the research, and if this serves to enhance competitive results.

It is recommended that future research be set up to allow a flexible number of hours of BNFK training. Instead of a set number of hours, the athletes should be trained until the optimal criteria for each modality is met.

The research could be strengthened by including a control group. Pre and post measurements of a "comparable" group of athletes who did not receive BNFK training could be added to the research design.

Exploration must also continue to make BNFK less laboratory-based and more field-based. At this time much of the equipment includes wires connecting the sensors to the data collection device. Direct application and measurement in the field would be of benefit, allowing the athletes to more effectively integrate the self-awareness and self-regulation skills into training and competitive settings. The development of wireless equipment that includes all the modalities of interest will be necessary as BNFK research with athletes continues to grow.

A more extensive NFK assessment would be beneficial. This more extensive assessment would involve 19 sites on the scalp rather than the 2 sites utilized in the present research. This would allow specific areas of the brain to be studied in greater detail, which would provide a more in-depth picture of the functioning of the brain and an opportunity to determine the coherence of different parts as well as optimize its function. As well, this allows for greater specificity on target areas to train for each athlete.

When providing BNFK training, it is also important for trainers to use feedback that is meaningful and interesting to the athletes. Trainers must take into consideration that research based BNFK software often presents clinical visual feedback in line graphs and bar graphs. This type of feedback might appear medical in nature to athletes. Therefore, training success could be increased if visuals on the training screens were sport specific or at the very least pertaining to athletics and competition.

BNFK training is increasingly being used for both optimal performance and medical disorders with stress related components. Therefore, it is important for athletes and sport psychologists at the elite level to continue to explore ways that this tool can optimize the psychological aspect of performing to potential. It is felt that as the athlete more fully develops self-awareness and self-regulation of their physiological and neurological functions, through BNFK training, the psychological skills of focus, anxiety and arousal management, and relaxation, and ultimately sport performance can be enhanced.

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APPENDICES

Appendix A

Athlete - Initial Interview Guide

Opening Questions

*Tell me about your last few competitive seasons? Success, failures, injuries, etc…

Performance

*How would you describe your performance last season?

*Overall, how did you perform last season? Where did you finish last year in your competitions?

*Tell me about what psychological skills you are good at, and what you need to work on.

Focus

*Tell me about your best focus.

*What do you need to focus on to perform your best?

*How good do you feel you are at focusing this way consistently?

Stress

*Tell me about a situation where you were stressed, and perhaps didn't perform well. Describe what happened.

*How do you feel you cope with stressful situations in your sport? In general, what do you do and how does it usually work for you?

Relaxation

*Where or when do you need to be relaxed?

*What do you do to relax?

*How do you feel about your ability to relax?

Appendix B

Psychophysiology and EEG Assessment

i) Psychophysiology Stress Profile Assessment

A standardized 16 activity stress test is administered.

Stage	Activity	Time
1	Eyes-closed Baseline	0:20 sec.
2	Eyes-open Baseline	2:00 min.
3	Stroop Test	1:06 min./sec.
4	Recovery 1	1:05 min./sec.
5	Math	1:07 min/sec.
6	Recovery 2	1:05 min./sec.
7	Game	1:06 min/sec.
8	Recovery 3	1:06 min/sec.
9	Positive Image	1:06 min/sec.
10	Recovery 4	1:06 min/sec.
11	Mouse Walk	2:00 min./sec
12	Recovery 5	1:06 min./sec.
13	Anticipation	20 sec.
14	Brief Stressor	3 sec.
15	Recovery 6	1:06 min/sec.
16	Biofeedback	2:00 min

ii) EEG Baseline Assessment

A standardized 4 activity EEG baseline assessment is administered.

Stage	**Activity**	**Time**
1	Eyes Closed Relaxation	2 minutes
2	Eyes Open Relaxation	2 minutes
3	Eyes Open with Task*	2 minutes
4	Eyes Closed Relaxation	2 minutes

*task identifying numbers

Appendix C

Wingate Five-Step Approach to Mental Training

Blumenstein et al. (1997) has developed a five-stage training program designed specifically to enhance self-regulation capacity and facilitate performance through BFK training. The steps include: (1) Introduction (i.e., learning various self-regulation techniques), (2) Identification (i.e., identifying and strengthening the most efficient biofeedback response modality), (3) Simulation (i.e., biofeedback training with simulated competitive stress), (4) Transformation (i.e., transformation of self-regulatory skills from laboratory to field) (5) Realization (i.e., obtaining optimal regulation in competition).

Step 1: Introduction

The initial step of this approach takes place in the laboratory. This is where the athlete is introduced to the BFK system, software, and media that will be used in the process. The first step typically lasts up to 10 sessions. The athlete begins to learn how to control her psychophysiological responses by observing the patterns on the screen of the BFK equipment. The modalities used in this step depend on the overall goals of the researcher/practitioner. Typically, the athlete begins with the frontalis EMG feedback, with surface electrodes placed on the frontalis muscle in accordance with Kondo et al. (1977) and Blumenstein et al. (1995). Later in this step, and in all the following steps, the athlete also uses other BFK modalities, such as galvanic skin response (GSR) and heart rate (HR), respiration rate and peripheral body temperature. Throughout these sessions the athlete is also introduced to different techniques that allow her to regulate her psychophysiological state. Examples of some of the relaxation techniques used are Jacobson's progressive relaxation (1938) and Schultz's (1970) autogenic training. In addition, in this stage, the athlete also learns different excitation activities, which are accompanied by verbal cues, in line with Williams (2006) recommendations. Finally, after the athlete is familiar with the different techniques and BFK modalities, she undergoes several training activities (i.e., relaxation with breathing, followed by excitation with verbal cues). The goal of the introductory stage is to develop a stable process where the athlete relaxes for about 2-3 minutes, maintains a deep relaxation state for about 5-10 minutes, then rehearses excitation for about 2-3 minutes. This entire process is accompanied by BFK, which is providing auditory and visual feedback to the athlete.

To determine the effectiveness of the training, the athlete completes a self-regulation test (SRT) to examine her baseline self-regulation level, between each of the steps. Essentially, the SRT consists of 4 elements: rest, tension, warmth, and competition. The first three were derived and modified from the autogenic training technique suggested by Schultz (1970). The fourth state, competition, is included to orient the athlete to the competitive setting. After recording the athlete's psychophysiological baseline (HR, GSR, EMG), the athlete is asked to imagine herself in resting, tense, warm, and competitive states, consecutively. Toward the end of each of these imagery phases, lasting about two minutes each, the athletes' psychophysiological responses (HR, GSR, EMG) are recorded to indicate the type of alteration in each response modality, as well as its relative intensity. In order to establish the unique pattern that characterizes each athlete, the relationship between the direction and intensity of the various psychophysiological indices are followed.

Step 2: Identification

The second step is designed to identify and begin working with the athlete's most efficient response modality in BFK. It consists of specific personal psychophysiological characteristics, and the type of sport or task in which the athlete competes. This is based on the premise that individuals differ widely in the autonomic responses that reflect changes in arousal (Zaichkowsky & Baltzell, 2001). For example, an athlete's response to stress may be primarily reflected by GSR, whereas another athlete may show a strong response in their respiration rate. Ideally, and what is trained, is the athletes ability to harmonically use several modalities to reach an optimal level of self-regulation.

Step 3: Simulation

In the third phase, the athlete views competitive situations in which she competed while employing the excitation and relaxation techniques that were learned in the previous two stages. This phase is geared to the particular needs required for competition, as well as the participant's personal characteristics. For example, in combat sports (e.g., judo, fencing, taekwondo, wrestling, or boxing), there are several breaks between the rounds. During these breaks, it is advisable for the athlete to be engaged in some self-regulatory activity that is focused mainly on the transition from relaxation to excitation, in order to bring up the intensity for the next round. In contrast, following the entire match, a transition from excitation to relaxation is needed. The athlete practices the shifts from one state to another by observing 5-10 scenes, lasting about 10-30 seconds each. The main principle guiding this training is a gradual increase in simulated stress.

After completing step 3, the athlete is re-tested using the SRT procedure. However, in contrast to the previous steps, the SRT procedure is now accompanied by VCR presentations. The athlete's psychophysiological indices during the rest, tension, warmth, and competition phases are recorded in response to a videotaped presentation of the athlete in an important competition. This helps to identify the level of stability with which the athlete is able to regulate her arousal.

Step 4: Transformation

In this phase, Transformation, the athlete prepares for a specific upcoming competition. The self-regulatory techniques learned and rehearsed by the athlete in step 1-3 are transferred into actual training settings, in contrast to the laboratory setting. For example, after completing a physical warm-up, the athlete is instructed to conduct a 1-min mental relaxation exercise using central elements of autogenic training (usually through key words used as cues), while being attached to a portable biofeedback apparatus. Then for 2 minutes she generates vivid images of the next specific moves to be performed in the practice session such as performing a particular technical element, in order to reach the appropriate excitatory state needed for this particular move.

The main purpose of step 4 is to enable the athlete to enter real future competitions with an improved self-regulation ability. After completing step 4, the athlete undergoes the SRT accompanied by the VCR. This is done in order to access the athlete's stability and readiness in applying the entire technique for self-regulation purposes in real-life settings.

Step 5: Realization

In the fifth and final step, Realization, the athlete applies the previously acquired self-regulation techniques during competition. The application mirrors what is practiced in the training session in step 4. Ideally, the performer begins to utilize the techniques in competitions that have less perceived importance, and then gradually moves to the bigger competitions in order to become less crisis-vulnerable (Bar-Eli & Tenenbaum, 1989). The overall goal at this stage is to have the performer trained so she is self-sufficient and can independently monitor her psychophysiological states within the competition.

This five-step approach was successfully utilized with Israeli elite athletes competing in a variety of sports at the Olympic Games, European championships and World championships.

Appendix D

Information on Neurofeedback Training Protocols: Alpha & SMR/Beta

A number of NFK protocols exist that are based on specific outcomes (Thompson & Thompson, 2003). For the goal of enhancing optimal functioning both an eyes open SMR/beta protocol, which trains the skill of focus, and an eyes closed alpha protocol which trains relaxation skills, have been used to enhance performance (Davis & Sime, 2005; Gruzelier, Egner & Vernon, 2006; Raymond, Sajid, Parkinson & Gruzelier, 2005).

The goal of the above protocols is normalization of the brain EEG via operant procedures. The assumption is that normalization of brain waves alter and improve optimal functioning (Thompson & Thompson, 2003). To reach that goal, during the SMR/beta training, the athlete learns to increase SMR and low beta waves, and decrease theta and high beta waves, while during alpha training, athletes learn to increase alpha waves and decrease theta and high beta waves. In general, theta, delta and high beta waves do not allow the brain to function well when an individual needs to be alert and externally-focused. High beta also interferes with the athlete's ability to stay calm and relax when appropriate. For the management of stress, alpha training is utilized. The amplitude of the alpha waves are greatest towards the back of the head and people who feel anxious, stressed, and unable to relax show a decrease in alpha waves in that area (Thompson & Thompson, 2003). The overall goal of utilizing these two protocols is to enable the athlete to learn to increase or decrease the frequencies of certain brainwaves. A more in-depth explanation of brain waves relevant to this study is provided below. In effect, this training enhances self-regulatory skills, by developing a more flexible brain and allowing the athlete to more easily produce a desired state (Thompson & Thompson, 2003).

Neurofeedback - Description of Brainwaves

Delta. .05-3 Hz waves are called delta (.05-3 cycles or waves in one second). They are the slowest yet highest amplitude waves. Delta waves normally occur during sleep. These waves are dominant in normal infants in the waking state up to about six months of age. They may be seen in people with brain damage, and in some learning disabled children (Thompson & Thompson, 2003).

Theta. 3-7 Hz waves are called theta (3-7 cycles or waves in one second). They represent the day dreaming, "spacey" state of mind associated with mental inefficiency. At very slow levels, theta represents a relaxed state and the twilight zone between waking and sleep. When we are drowsy or inattentive to external things and our mind is wandering more, theta is dominant (Thompson & Thompson, 2003).

Alpha. 8-12 Hz waves are called alpha (8-12 cycles or waves in one second). They are associated with a state of relaxation, representing the brain shifting into an idling gear, relaxed, and a bit disengaged waiting to respond when needed. When our eyes are closed and picturing something peaceful, there begins to be a large increase in alpha waves. Alpha is especially predominate in the back third of the head. People who feel anxious and stressed may show a decrease in alpha waves (Thompson & Thompson, 2003).

SMR. 13-15 Hz waves are called Sensori-Motor Rhythm, which is shortened to SMR (13-15 cycles or waves in one second). These waves are called SMR only across the sensori-motor strip of the cortex. They are called beta when found elsewhere. "SMR appears to be associated with a calm mental state with increased reflecting-before-acting. It is thus important to train up (increase) SMR in those who have problems with hyperactivity and/or impulsivity" (Thompson & Thompson, 2003, p.39).

Beta. Waves above 12 Hz are called beta. These waves represent awake, alert, externally-focused, logical, problem solving, and attentive states. They may also indicate anxious and tense states.

Low Beta. 16-20 Hz waves are called low beta. It is referred to as "problem-solving beta" (Thompson & Thompson, 2003, p. 39).

19-21 or 20-23 Hz Beta. These waves are often dominant in anxious people. They may correlate with emotional intensity. "They may correlate with productive cognitive work, productive but too intense work, or unproductive intense or anxious thinking" (Thompson & Thompson, 2003, p.40).

High Beta. 22-36 Hz waves are called high beta. These waves are seen in worried and anxious people, who often feel stressed-out, hyper-vigilant, are ruminating excessively or have negative self-talk. (Thompson & Thompson, 2003).

Neurofeedback Training Protocol Used in this Study

During NFK training, excessive brain frequencies are reduced, and those with a deficit are increased (Thompson & Thompson, 2003). Thresholds are set so that athlete has an 80% success rate. Shaping of the desired behavior is accomplished by adjusting the thresholds. Since the goal for the training is to enhancing optimal functioning, the researcher will utilize both an eyes open SMR/beta protocol (focus training) and an eyes closed alpha protocol (relaxation training) for training the athletes.

i) Alpha Protocol (Relaxation Training)

For the purpose of the present study, the PZ location, in the parietal lobe, will be used as the location for the sensor, for alpha training (Jasper, 1958). The theta (emotion or tuning out), alpha (relaxation), and high beta (distractions) brainwaves will be measured. Brainwaves in the alpha frequency range (8-12 Hz) will be rewarded with an auditory sound. During alpha training athletes will be asked to close their eyes, relax and maintain focus in the present moment enhancing the amplitude of the alpha frequency. When thoughts come into the athlete's awareness they will be encouraged to let them go and stay focused in the present moment. Auditory feedback will be given when the amplitude of the alpha frequency is above a set threshold level (80% success). The threshold will be increased as the athlete learns to passively (eyes closed) stay focused in the present moment.

The goal at the end of the 25-30 hours of training is to have the alpha (relaxation) brainwave frequency dominant and as high as possible, theta (emotion) below 10 micro volts and high beta as low as possible (at least below 4).

ii) SMR/Beta Protocol (Focus Training)

The location of the sensor on the scalp for SMR/Beta training is CZ which is in the center of the scalp on the sensorimotor strip of the cortex (Jasper, 1958). Theta (emotion), low beta (concentration), and high beta (distractions) brainwaves will be measured for focus training. Brainwaves in the SMR (12-15 HZ) and low beta (15-18 Hz) frequency ranges will be rewarded while brainwaves in the theta (4-7 Hz) and high beta frequency range (22 -30) will be inhibited. Thresholds will be increased/decreased as the athlete learns to actively (eyes open) stay focused in the present moment reducing distractions and emotions. Both visual and auditory rewards will be given.

During focus training the athletes will be asked to observe feedback on the computer screen regarding their brainwave activity. Athletes will be encouraged to decrease theta (emotion) and high beta (negative self-talk) brainwaves using BFK techniques such as decreasing muscle tension, and increasing deep breathing, in order to increase their concentration (low beta). The goal for the training is to have theta (emotions) brainwaves at or below 10 micro volts, SMR and low beta (concentration) brainwaves higher than high beta (distractions) and high beta brainwaves as low as possible (near 3-4 micro volts).

Appendix E

Athlete - Training Follow-up Interview Guide

BNFK Training Experience

*Overall, what was your experience like with the BNFK training?

*What part did you like the most? What part did you like the least?

*Did you find any biofeedback modality/modalities useful for stress and anxiety regulation i.e. breathing training, temperature training, muscle relaxation training or skin conductance training?

*What was your experience with the neurofeedback relaxation training (a.k.a. eyes closed alpha training)?

*What was your experience with the neurofeedback focus training (eyes open)? Which screens were your most/least favorite?

Learning and Utilization

*Did you develop any self-awareness or learn anything new about yourself or your abilities during the training?

*Were you able to use any psychological skills/techniques learned from the bio/neurofeedback training in the sport context or in any other area of your life? If yes, give an example.

*Do you think using these skills affects your performance in training? If yes, how?
(i.e., controlling stress and anxiety, ability to focus and/or relax)

* In general, how do you feel about bio/neurofeedback training? Do you have any overall comments, suggestions, or feedback about the bio/neurofeedback training? (i.e., number of hours, modalities used, etc.)

Appendix F

Athlete - Final Interview Guide

Performance

* Tell me about your performances this season. How did things go for you? (i.e. results, improvements).

* Have you been using any psychological skills/techniques learned from the bio/neurofeedback training? If yes, give an example. If not, why not?

*Do you think using these skills have affected your performance in training and competition?

-If yes, how? (i.e., controlling stress and anxiety, and ability to focus)

* Have you reached your personal performance goals this season?

* Do you think the bio/neurofeedback training helped in reaching any of these goals?

-If yes, how? If no, why not?

*What were you doing in your best performances this year? And in disappointing performances?

* Have you been working with a sport psychologist or any other sport related professional since the training?

* Have you been using any psychological skills/techniques suggested by the sport psychologist? If so, which techniques and how often have you been using them?

* Do you have any sport or life specific situations where your mental skills helped your performance?

* Have there been any significant changes in your life since the training?

-Sport (e.g., change of coach, injury) – Work/School – Relationships

* In general, how do you feel about bio/neurofeedback training? Do you have any overall comments, suggestions, or feedback about the bio/neurofeedback training?