A Preliminary Study on the Relationship Between Athletes’ Ability to Self-Regulate and World Ranking

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This study was designed to explore the relationship between elite athletes’ self-regulation ability and their ranking at the world level using psychophysiological stress assessment profiling. Fifteen elite level athletes’ psychophysiological stress response patterns were recorded during a nine-stage stress assessment. Respiration rate, heart rate, heart rate variability, skin conductance, peripheral body temperature, and electromyograph (trapezius and frontalis) were monitored. There was a significant correlation between elite athletes’ overall self-regulation ability and their ranking at the world level, meaning that the better the overall self-regulation ability of the athlete, the better the world ranking. In addition, a multiple regression analysis indicated that self-regulation accounted for 76% of the variance in world ranking. Our results suggest the existence of a relationship between elite athletes’ overall self-regulation ability and their ranking at the world level. Therefore, the results of this study have important implications for training of optimal psychophysiological self-regulation in athletes.

Introduction

The ability to manage one’s level of stress and anxiety in the high-pressure situations of national championships, selections, world championships, and the Olympic Games is a key skill that athletes need to develop in order to excel at the highest levels of sport. This elite sport environment is stressful and many talented athletes struggle and sometimes fail to achieve their performance potential (P. Davis, Sime, & Robertson, 2007; Paul & Garg, 2012). Accordingly, much of the research and applied work in the field of sport psychology has been driven by an interest in exploring the gap between an athlete’s potential and his or her actual performance (Bortoli, Bertollo, Hanin, & Robazza, 2012; Bouchter, 2008; P. Davis et al., 2007; P. A. Davis & Sime, 2005; Gould & Maynard, 2009; Gould, Dieffenbach, & Moffett, 2002; Jones, Hanton, & Connaughton, 2007). One major factor that has been shown to influence successful performance under pressure is an athlete’s ability to manage him or herself physiologically (Babiloni et al., 2011; P. Davis et al., 2007; Lagos et al., 2008; Robazza, Pellizzari, & Hanin, 2004). While the key variables that cause stress in the competitive setting (e.g., expectations, self-presentation, opponents, fans, weather, mental errors) have been well documented (Didymus & Fletcher, 2014; Hanton, Fletcher, & Coughlan, 2005; C. M. Janelle, 2002; Kristiansen & Roberts, 2010; Mellalieu, Neil, Hanton, & Fletcher, 2009; Nicholls, Jones, Polman, Borkoles, 2009; G. Wilson & Pritchard, 2005), minimal research has reported on the psychophysiological stress response profile of elite athletes.

The concept of psychophysiological response to high-stress environments, as in elite sports, is not new. In fact, the stress response is an adaptive biological mechanism that has evolved over time to ensure survival of the human species (Karatsoreos & McEwen, 2011; McEwen, 1998). The term “stress” can be defined as a threat (real or implied) to the body’s ability to maintain homeostasis through the stability of physiological systems that maintain life (e.g., pH, body temperature, glucose levels, and oxygen tension; McEwen & Wingfield, 2003). Humans, upon sensing an impending threat to their safety, react by either fighting back or fleeing the stressful situation. This behavioral response to stress has been described as the “fight-or-flight” reaction of the sympathetic nervous system (Cannon, 1967; McEwen, 1998). Associated physiological reactions can include cool, moist palms, elevated HR, increased respiration rate, muscle tension, and reduced brain functioning (attention; e.g., Andreassi, 2007; Bundy, Lane, Murray, & Fisher, 2002; C. M. Janelle, 2002). A contemporary theory of stress, namely allostasis theory, can be used to better understand these psychophysiological mechanisms of stress (McGrady, 2007).

Allostasis theory (McEwen & Seeman, 1999; McEwen & Wingfield 2003; Schulklin, 2003; Sterling, 2012) defines allostasis as the optimal operation of regulatory systems.
linking the nervous system with the endocrine and immune systems. It is the body’s continuous adaptive attempt to maintain stability (homeostasis) through change (i.e., stress). When too much stress accumulates in the physiological system, it can manifest as less than optimal functioning of that system, referred to as “allostatic load” (McEwen & Wingfield, 2003). Allostatic load, according to McEwen and Stellar (1993), develops as a result of excessive “wear and tear” on the body due to chronic stress or poor recovery. As a result, the sympathetic nervous system loses its capacity to return to baseline. There is clear evidence from allostatic load studies that failure to regularly shut off the sympathetic nervous system (the stress response) can have serious consequences, such as lower baseline functioning, poorer cognitive performance, weaker physical performance, augmented risk of incident cardiovascular disease, and increased risk of all-cause mortality (Juster, McEwen, & Lupien, 2010; Seeman, McEwen, Rowe, & Singer, 2001; Seeman, Singer, Rowe, Horwitz, & McEwen, 1997).

Psychophysiological stress profiling is useful for identifying patterns of reactions to stressful circumstances and for identifying and analyzing any atypical responses that may occur outside of normal ranges (Gevirtz, 2007; Kanbara et al., 2004; V. E. Wilson & Somers, 2011). Psychophysiological stress profiles are conducted by utilizing various modalities—for example, respiration rate (RR), heart rate (HR), temperature (TEMP), skin conductance (SC), and electromyography (EMG)—to measure the body’s response to stressful events applied in the lab (Gevirtz, 2007; Kanbara et al., 2004). Measures are taken before and after stressors based on the concept of autonomic response specificity (Lacey, Bateman, & Van Lehn, 1953) that later became known as individual response specificity (Andreassi, 2007; Marwitz & Stemmler, 1998; Simon & Bueno, 2009). This concept states that the autonomic nervous systems’ response to stress has a stable and reproducible reaction profile, meaning that an individual will respond with the same physiological response (e.g., skin conductance response) under different stress conditions (e.g., whether the athlete is faced with stress in a competitive setting or in a practice setting).

Moreover, the field of sport psychophysiology has developed over the last two and a half decades. Research has evolved with multiple studies validating the physiological effects of psychological stress states in sports (Blumenstein, Bar-Eli, & Tenenbaum, 2002; Carlstedt, 2001; P. A. Davis & Sime, 2005; Edmonds, Tenenbaum, Mann, Johnson, & Kamata, 2008; Hatfield & Hillman, 2001; C. Janelle, 1999; Paul & Garg, 2012; Shaw, Zaichowsky, & Wilson, 2012). P. Davis et al. (2007) noted that the psychophysiological effects of stress on athletes can lead to deterioration in overall performance. For example, negative emotions can result in narrowed or inefficient attention states (C. M. Janelle, Singer, & Williams, 1999; G. Wilson & Prichard, 2005), impaired motor performance (Eysenck, Derakshan, Santos, & Calvo, 2007), and reduced peripheral blood flow to the fingers, affecting an athlete’s dexterity (P. Davis et al., 2007).

In an attempt to counteract these psychophysiological effects of stress, various research studies have explored the effect of biofeedback training interventions on performance. For example, Blumenstein et al. (2002) focused their research efforts on the improvement of athletes’ self-regulation skills, through biofeedback training, specifically EMG, HR, and SC, and psychological skills training to enhance athletic performance. Their research with adolescent swimmers and runners reported increases in performance in the intervention group (i.e., consistent decrease in running and swimming times) compared to the relatively stable performances of the control groups (Bar-Eli & Blumenstein, 2004a, 2004b; Bar-Eli, Dreshman, Blumenstein, & Weinstein, 2002).

Although numerous studies have demonstrated enhanced performance with biofeedback training (e.g., Beuchamp, Harvey, & Beuchamp, 2012; Blumenstein, Bar-Eli, & Tenenbaum, 1995; Caird, McKenzie, & Sleivert, 1999; Dupee & Werthner, 2011; Edmonds & Tenenbaum, 2012; Edmonds et al., 2008; Galloway, 2011; Kavussanu, Crews, & Gills, 1998; Lagos, 2011; Lagos et al., 2008; Landers et al., 1991; Paul & Garg, 2012; Peper & Schmid, 1983; Raymond, Sajid, Parkinson, & Gruzelier, 2005; Shaw et al., 2012; Werthner, Christie, & Dupree, 2013), few studies have addressed the psychophysiological stress profiles of athletes and whether better baseline self-regulation of psychophysiological measures indicate better performance. Thus the purpose of this paper is twofold: (a) to explore whether the ability to self-regulate from a psychophysiological perspective is related to world ranking in elite athletes, and (b) to examine if any of the specific individual psychophysiological measures (e.g., RR, HR, HRV, SC, TEMP, EMG-Trapezius [EMG-T], and EMG-Frontalis [EMG-F]) are significant in relationship to their world ranking.

**Methodology**

**Participants**

Fifteen elite level athletes underwent a psychophysiological stress profile assessment to identify their self-regulation ability. The seven female and eight male athletes ranged in age from 20–29 years old (M ± SD: 25.1 ± 2.7 years), had
all been competing at the international level for at least 6 years, and were from different disciplines in the sport of freestyle ski. Ethics approval for this study was obtained from the University of Ottawa’s Office of Research Ethics and Integrity and written informed consent was obtained from each athlete in line with the University’s ethical research guidelines.

**Procedure**

Each athlete completed an informed consent form and demographic questionnaire and was seated in a cushioned recliner facing a computer monitor. Psychophysiological data were recorded using the ProComp Infiniti™ version 3.1.5, (Thought Technology Ltd., Montreal, Quebec, Canada). This eight-channel research grade device acquires 256 samples/s. To record RR, a belt containing a strain gauge was secured around the abdomen below the ribcage. An indirect measure of HR was recorded using a photoplethysmograph sensor, which was secured to the volar surface of the distal phalange of the nondominant thumb. HRV was computed using the formula HR Max – HR Min (that is, the mean of the difference between maximal HR and minimal HR in each breath cycle). SC response (SCR) was recorded using the SC sensor. SC electrodes were secured on the volar surface of the proximal phalanges on the second and fourth fingers of the dominant hand. A thermal sensor was secured to the skin on the palmar surface, at the base of the second finger on the nondominant hand, to measure TEMP. Surface EMG (SEMG) was monitored using a Myoscan Pro sensor (Thought Technology Ltd., Quebec, Canada) with a bandpass filter set between 100 and 200 Hz. Three EMG electrodes were placed on the participant’s forehead to measure EMG-F and on the participant’s nondominant shoulder to measure EMG-T.

**Stress assessment.** Psychophysiological recordings began and the athlete was asked to relax and remain still while the clinician checked to make sure that each sensor was accurately recording data. The psychophysiological stress profile testing started with a baseline measurement and then subjected the athlete to different stressors while monitoring the psychophysiological parameters. After each stressor there was a recovery period. The goal was to identify the psychophysiological response patterns that occurred. A modified version of a structured stress assessment protocol for athletes was used (V. Wilson, 2006). The assessment was divided into nine sections, with the initial baseline 2 min in length and each successive section of 1 min in duration. The recorded psychophysiological data was reviewed for movement artifacts and only artifact-free segments of the data were analyzed.

**Measures**

**World ranking.** Each athlete’s world ranking was recorded at the time of the assessment. For the purpose of this article, higher world ranking refers to a top-ranked athlete, such as one who is first or second in the world in his or her event, and a lower world ranking refers to an athlete who might, for example, be ranked 24th in his or her event.

**Self-regulation ability.** Data gathered for each athlete on the seven criteria (RR, HR, HRV, SC, TEMP, EMG-T, and EMG-F) were categorized as either poor, moderate, or good self-regulation ability in reference to whether the athlete returned to baseline after each stressor (V. E. Wilson & Somers, 2011). A poor rating (1) was given if during the recovery phase, the athlete either stayed at the same activation level as during the stressor or went in the opposite direction expected (i.e., respiration rate increased or temperature decreased during recovery). A moderate rating (2) was assigned if the athlete recovered up to half way to baseline. A good rating (3) was given if recovery was either back to baseline or greater than half of the way back to baseline. An overall self-regulation ability score (minimum of 7 and maximum of 21) was computed for each athlete by summing his or her scores on the seven criteria. Each athlete was then assigned an overall self-regulation ability score.

**Data analysis.** The psychophysiological data and world rankings were statistically analyzed using SPSS 18.0 (IBM, Armonk, NY). First, a spearman Rho correlation was conducted to examine the association between overall self-regulation ability and world ranking. Second, a multiple regression was conducted to examine if any of the specific individual psychophysiological measures (e.g., RR, HR, HRV, SC, TEMP, EMG-T, and EMG-F) were significant in predicting world ranking. The athlete’s actual numerical world ranking and his or her overall self-regulation ability score were used in the data analysis.

**Results**

As depicted in Figure 1, the overall self-regulation ability was significantly associated with world ranking ($r_s = -0.848, p = .01$), meaning that the better the overall self-regulation ability of the athlete the better the world ranking.

The multiple regression analyses with all measures of self-regulation predicting world ranking indicated that all seven measures of self-regulation accounted for 76% of the variance in world ranking (adjusted $R^2 = .525$). Examination of the individual psychological measures of self-regulation, as shown in Table 1, indicated that only the EMG-T self-regulation score ($\beta = -.708, p = .012$) significantly...
contributed to the model and accounted for 58% of the variance of world ranking.

**Discussion**

The purpose of this paper was twofold: (a) to explore whether the ability to self-regulate from a psychophysiological perspective was related to world ranking in elite athletes, and (b) to examine if any of the specific individual psychophysiological measures (e.g., RR, HR, HRV, SC, TEMP, EMG-T, and EMG-F) are significant in relationship to their world ranking. Results from this research showed that overall self-regulation ability was significantly associated with world ranking. Taken together, all seven measures of self-regulation accounted for 76% of the variance in world ranking; however, only the EMG-T self-regulation score significantly contributed to the model. The results of this research lend support to McEwen’s allostatic load model (McEwen & Seeman, 1999; McEwen & Wingfield 2003). The athletes who were less effective at turning off the stress response and returning their physiological state to baseline after a stress load (poor self-regulators) had poorer world rankings. Conversely, those who were ranked higher in the world demonstrated the ability to recover after a stress load was applied.

The results of this study also indirectly support research in the field of sport psychology. For example, Bois, Sarrazin, Southon, and Boiche (2009), studying the emotional management skills of professional golfers, found three predictors of superior performance: (a) slightly elevated levels of cognitive anxiety that were perceived by the golfers as facilitating performance, (b) frequent use of relaxation strategies, and (c) use of emotional control strategies. In that study, the regression accounted for 59% of the variance of players’ ranking. Although cognitive anxiety was not a direct measure in this particular study, self-regulation was obtained through both relaxation and emotional regulation strategies. In addition, Krane and Williams’ (2006) review of the sport psychology literature found that arousal management techniques were key to attaining peak performance. Similarly, a study by Gould, Dieffenbach, and Moffett (2002) showed that Olympic champions rated high on activation, relaxation, and emotional control abilities.

The second objective of the study was to examine if any of the specific individual psychophysiological measures (e.g., RR, HR, HRV, SC, TEMP, EMG-T, and EMG-F) were significant in relationship to an athlete’s world ranking. Sime (2003) suggested classic symptoms of stress in competitive sport are demonstrated in muscle bracing and residual tension and that optimal control of muscle tension assists not only in enhanced skill execution but also in the conservation of energy. This concept was supported in the current study, which indicated that EMG-T was the one psychophysiological measure that was found to be significant in terms of overall world ranking and the ability to self-regulate.

Overall the results of this study are congruent with Blumenstein and colleagues’ research (Bar-Eli & Blumstein, 2004a, 2004b; Blumstein et al., 2002) that showed increases in athletic performance through the improvement of athletes’ self-regulation skills, specifically EMG, HR, and SC. Thus, it follows that there is a need for self-regulation training for elite athletes in order to help them foster optimal performance. Based on this research, it is recommended that athletes be assessed to determine their psychophysiological stress response profile and identify their patterns of reactions. Once this is complete, self-regulation training can then be undertaken for any identified atypical psychophysiological responses. It is important that sport psychologists assisting athletes in achieving optimal self-awareness and self-regulation of their psychophysiological state recognize that each athlete’s path will be idiosyncratic and that any self-regulation training or interventions are adapted to the individual athlete’s needs.

Although the findings from this research have important implications there are a number of limitations. One of the limitations is the sample size (N = 15). Given such a small number of subjects, the results must be interpreted with caution. As well, the subjects were restricted to one winter sport. Future research should seek to explore psychophysiological stress profiling with a greater number of athletes in a variety of sports to determine whether or not there is a specific profile or whether particular psychophysiological
measures predict self-regulation ability and optimal sport performance. A third limitation is the ecological validity of the study. Ecological validity is limited due to the inability to evaluate baseline self-regulation ability under real life competitive field settings (Collins & McPherson, 2006). Due to the limitations of the current technology (e.g., equipment portability, wires, and electrodes attached to the athlete that may impede movement), it is difficult to capture psychophysiological data within the actual sport environment. As such, future research should seek to create protocols that closely mimic performance conditions (P. A. Davis & Sime, 2005; Linden, Strack, & Sideroff, 2011).

In conclusion, although several studies in sport have demonstrated enhanced performance with biofeedback and neurofeedback training, few studies, to date, have addressed the psychophysiological stress profiles of elite athletes and whether better self-regulation ability correlates to better performance. The results of this study indicated that elite-level athletes with higher world ranking can be discriminated from lower world-ranking athletes on the basis of their ability to self-regulate and, in particular, the EMG-T. Therefore, it is recommended that coaches consider biofeedback training to enhance an athlete’s ability to become first more self-aware and second optimize the management of their stress response. Developing ways of helping athletes manage the stress inherent in competitive sport would be advantageous in narrowing the gap between potential and actual performance.

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References


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