

**AN INVESTIGATION OF
PSYCHOPHYSIOLOGICAL STRESS IN
COMPETITIVE GOLF**



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ABSTRACT

Psychophysiological stress responses to competition golf were examined in three groups of players, professional trainee (PRO), recreational (REC) and elite amateur (AMA). The PRO and REC golfers, comprising a high and moderate ability group respectively, were additionally studied during a practice golf round. Competition stress was determined by comparing psychophysiological responses during competition to those in practice. Relationships between psychophysiological stress parameters and performance were also examined. In a further study, the AMA group underwent an eight week aerobic training program and their psychophysiological responses in a second competition round were compared to their pre-training levels. In the three studies, non-invasive stress parameters comprising saliva cortisol, heart rate and competitive state anxiety (CSAI-2; Martens et al. 1990) were measured before, during and after the completion of 18 holes of golf play.

The results from this thesis demonstrated that for PRO golfers, cortisol, heart rate and state anxiety were elevated during competition compared to practice; however, performance was only weakly predicted by cortisol and cognitive state anxiety and not by any of the other measures. In comparison, the REC golfers exhibited higher state anxiety during competition compared to practice but cortisol and heart rate were unaffected. Performance could not be strongly and consistently predicted by the psychophysiological measures, and there was some indication that performance toward the conclusion of competition was a weak antecedent of state anxiety. There was no consistent correlations found between psychological and physiological measures of stress in either of these studies. The aerobic training program did not significantly affect psychophysiological responses to competition in the AMA golfers. A fourth study examined the effects of competition (PRO and REC

groups) on heart rate immediately before, during and immediately after putting. The PRO golfers exhibited cardiac deceleration just prior to striking the putt in competition but this was not evident in practice, nor did it occur for the REC or AMA golfers for either golf round. In conclusion, these studies demonstrated that psychophysiological stress is higher in competition compared to practice rounds of golf, but that psychophysiological stress responses may be manifested differently. These differences may be due to factors such as the competitive situation and/or the ability level of the golfers. Despite perturbations in psychophysiological state, there was no clear evidence for a cause-effect relationship between any single, or combination of, parameter(s) and golf performance. The findings of the PRO and REC studies were strengthened by the use of real competition rather than contrived competition, but it was not possible to arrange a similar competitive situation for the AMA group.

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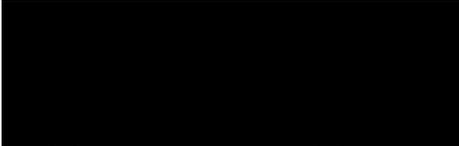
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DECLARATION

This dissertation reports original, previously unpublished work conducted in the Department of Physical Education and Recreation at Victoria University of Technology. The data was collected at golf courses located in the Melbourne metropolitan area, with laboratory testing being conducted in the Human Performance Laboratory, Victoria University. Cortisol radioimmunoassays were performed at the Western Hospital, Footscray. With the exception of data collection which required assistance, this dissertation is the result of the work performed solely by the author.


Jennifer. M/McKay ✓

PREFACE

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Chapter 1

INTRODUCTION

1.1 Stress in Sport

Stress has long been a topic of interest for scientific research because of its implications in physical health and mental well-being. Since the 1960's however, there has been a growing demand to understand the role of stress in sport; particularly the relationship between psychophysiological stress responses and performance in competition. Athletes, perhaps none moreso than elite golfers, stand to gain from a better understanding of the stress-performance relationship. Qualitative research has found that professional golfers frequently experience pressure and its physiological manifestations in tournaments, particularly when they are placed to do well (McCaffrey and Orlick, 1989). To date, the association between competition pressure and golf performance remains unclear. Heightened worry about performance is thought to disrupt the cognitive skills such as attention and concentration necessary for shot preparation (Crews, 1994; Molander and Backman, 1994), whilst increased muscle tension and limb tremor may affect the neuromuscular co-ordination and timing required for the fine motor skills, such as putting and chipping (Oxendine, 1970). Irrespective of the underlying mechanisms, poor performances by elite players may have a detrimental impact on their monetary earnings and golfing career. At the recreational level of the sport, which comprise the largest number of players, competition stress may detract from the enjoyment of the sport (Jones and Hardy, 1990), even leading some to avoid competition situations altogether. Despite the numerous anecdotal accounts relating competition stress to performance in golf, the psychophysiological changes consistent with competitive stress responses have yet to be

of competitive stress in golfers is particularly important in light of increasing evidence to suggest that stress is not always detrimental, and may in fact improve performance in some sportspeople (Jones, 1995).

Sport competition is commonly recognised as a stressor, whereby factors from the external environment elicit psychological and physiological changes to the internal milieu of the person as part of a stress response. Athletes typically experience feelings of nervousness and anxiety, accompanied by physiological responses such as sweating, racing heart rate and butterflies in the stomach. A key issue in sport science research has been to measure psychophysiological stress responses sensitively, and has therefore focused on valid and reliable tools used to measure stress, the timing of their application during sport contests, examining stress at the level of the individuals, and the ecological validity of the testing environment.

Stress research in sport has focused primarily on measuring emotional anxiety responses using sport-specific, multi-dimensional psychometric inventories such as the Competitive Sport Anxiety Inventory-2 (CSAI-2) (Martens et al., 1990). Anxiety-performance hypotheses predict the relationship between the cognitive worry (mental) and perceived physiological consequences of anxiety states and motor performance, based on high levels of anxiety being detrimental to performance. Support for the predicted anxiety-performance relationships in golfers remains equivocal. However golfers' state anxiety has generally been measured prior to and following competition events, and not during golf performances where cognitive anxiety is predicted to be especially manifest. More recently, the emphasis on understanding stress as a psychophysiological construct has led to the concomitant measures of physiological and psychological stress responses, rather than relying on self-report measures alone (Hatfield and Landers, 1983; Neiss, 1988). Especially in applied research settings, physiological measures are limited to those which

can be easily and accurately sampled, such as heart rate. However, heart rate reflects only general autonomic nervous system activity which may be one reason why the relationship between psychophysiological parameters and competitive performances has been equivocal. Refinement in biochemical methodology and technology has enabled a hormonal correlate (cortisol) of the hypothalamus-adrenal pituitary (HPA) axis to be accurately measured from saliva. The HPA axis responds sensitively to psychological stress, and salivary cortisol has been used to examine adrenocortical changes during competitive marathon running (Cook et al., 1987). Such responses to competition in low intensity sports such as golf have yet to be investigated. In addition to this, salivary cortisol offers the potential to examine the psychophysiological relationship from a different physiological perspective.

An important aspect of stress is the interaction between the sportsperson and their environment (Hatfield and Landers, 1983; Martens et al., 1990). Indeed, genuine as opposed to contrived laboratory competitions often evoke more potent and consistent stress responses in these individuals (McCann et al., 1992). In a recent review, Jones (1995) suggested that a future challenge for sport stress research is that field studies incorporate multimethod protocols, including physiological and self-report measures, to measure stress during genuine competition performances. However, the advantages in employing more sensitive measures in field environments must be weighed against the practical difficulties of obtaining measures during competition, and the difficulties imposed by extraneous environmental factors which cannot be strictly controlled in outdoor settings. Nonetheless, the complex nature of competitive golf play cannot realistically be simulated in laboratory environments. Field research therefore may contribute not only to a better understanding of competitive stress and golf performance, but may ultimately lead to the better management of stress by golfers.

Sport research has focused on the treatment and prevention of stress in athletes because certain psychophysiological states are proposed to be beneficial for performance. Aerobic fitness has been found to reduce psychophysiological responses to psychological stressors, however its ability to modify stress responses to competition in a low aerobically demanding sport, such as golf, remains unknown. This thesis is concerned with the measurement of competition stress in golfers, its influence on psychophysiological state and implications for golfers and their performance. There is a large body of anecdotal, even folkloric, evidence regarding stress in golf and its implications for performance, particularly competitive performance. However, the interrelationships between psychophysiological stress parameters and performance remain unclear, and provided the main rationale for the present studies. The second rationale was to design a series of field studies with high competitive validity in order that the effects of competition on stress and performance could be examined. A better understanding of stress in competitive golf, can ultimately assist golfers compete more effectively at all levels of the sport.

1.2 Purpose

The overall purpose of this research was to investigate stress in competition golf using non-invasive data collection protocols in a valid field setting, to determine whether elite and recreational golfers experience changes in psychophysiological state during competition compared to practice and whether this influences golf performance. In addition, the influence of enhanced aerobic capacity on psychophysiological responses in elite golfers was examined. Specifically, four studies were conducted using elite and non-elite male golfers with the following respective purposes.

(1) To examine psychophysiological stress responses in elite professional trainee (PRO) golfers (handicaps 5 and below) by examining changes in salivary cortisol, heart rate and

and again during a practice round. The relationships between psychophysiological stress parameters and golf performance were also examined.

(2) To examine whether recreational golfers (REC) (handicaps 9-26) experience psychophysiological stress to club level golf competition, by examining the above (1).

(3) To determine the influence of improved aerobic fitness on stress responses in golfers by comparing changes in salivary cortisol responses, heart rate and competitive state anxiety in elite amateur (AMA) golfers (handicap 5 and below) to 18 holes competition, before and after an 8 week aerobic fitness intervention.

(4) To examine heart rate patterns during putting for PRO, REC and AMA in competition, and additionally to examine in the PRO golfers the influences of competition on heart rates for different shot types (tee, fairway, approach and putting).

1.3 Organisation of the thesis

The current chapter (Chapter one) provides the motivation for the current research and an introduction to the problem. Chapter two provides a structured account of the current theory and measurement of stress in competition sport. The relevant literature is reviewed in three specific areas. Firstly, stress is reviewed according to psychophysiological definitions, including stress in competition golf. The second area reviews physiological and psychological stress parameters and their measurement, with the emphasis on those measured in the current thesis. Following this is an account of cortisol, heart rate and state anxiety responses to aerobic training. Chapter 3 describes the general methods used in data collection and testing procedures common to the three studies. These studies described in Chapter four, five and six comprise the core of the thesis. Chapter four and five describe studies measuring psychophysiological stress in elite trainee professional (PRO) and

recreational (REC) golfers respectively, by comparing stress responses in competition and practice. Also changes in psychophysiological measures and their relation to golf performance are described. Chapter six details an intervention study examining psychophysiological stress in male elite amateur (AMA) golfers to competition, before and after an 8 week aerobic training. The next chapter (Chapter 7) provides further analysis of heart rate data collected during golf play for PRO, AMA and REC golfers. In particular, heart rate patterns for putting in golf competition are compared between the three groups. Competition heart rates for various shot types in PRO golfers are also compared for competition and practice situations. Chapter eight provides a general discussion together with conclusions from the research, based on research findings from Chapters four to seven inclusive. The findings are discussed with relation to psychophysiological stress in competition golf, its relationship to golf performance and the implication for golfers, and relationship between psychophysiological stress parameters. Chapter nine outlines the contributions of this research including suggestions for further work.

Chapter 2

REVIEW OF LITERATURE

2.1 Overview

Stress is an inherent aspect of life, being implicated in human disease states (coronary heart disease), mental health (depression and chronic anxiety), and sport (athletic performance). Despite multi-disciplinary research in areas including biochemistry, immunology, psychology and exercise science, much about stress remains unclear. Stress is acknowledged as being a psychophysiological process, so research has focused on having reliable tools to measure psychophysiological changes in individuals exposed to various stress paradigms. More recently, competitive sport research has focused on employing non-invasive, psychophysiological stress measures during actual sport contests.

This review of literature focuses on psychological and physiological responses to stress, their measurement and interpretation in sport, with particular emphasis on golf. The first section (2.2) provides an overview of stress and the related terms arousal and anxiety, and describes competition stress and its definition in this thesis. Section 2.3 describes the physical and mental demands of golf, including anecdotal evidence for stress in competitive golf. Further empirical evidence for anxiety in competition golf is included in the latter section on state anxiety (Sub-section 2.5.4). Section 2.4 focuses on physiological stress parameters measured in this thesis, namely cortisol and the hypothalamus-pituitary-adrenal axis (HPA) activity (Sub-section 2.4.1) and heart rate (Sub-section 2.4.2). Section 2.5 includes the measurement of anxiety in sport, in particular research employing the Competitive State Anxiety Inventory-2 (CSAI-2). Theoretical and methodological

developments in multidimensional anxiety theory are firstly outlined, followed by the CSAI-2 research on the anxiety-performance relationship. Section 2.6 includes studies examining psychophysiological parameters, and the use of field environments, Section 2.7 describes research into the role of aerobic fitness in reducing psychological and physiological responses to stress whilst Section 2.8 is a summary and conclusion of the literature.

2.2 Stress: an Overview

Early notions of stress emphasised the physiological consequences for organisms when exposed to situations involving threat. For example, Cannon (1929) described the “fight or flight” response, which resulted in changes to the internal physiological steady-state (equilibrium) of the organism. Whilst these acute perturbations were considered advantageous for survival, Seyle (1946) implicated prolonged stress with disease states. Stress was not always considered negative in affect. Seyle (1976) differentiated between positive (eustress) or negative (distress) stress, with an organism’s ability to cope with stress being related to their ability to modify the physiological responses. Hyperstress was used to describe conditions of panic states, as opposed to a low or hypostress. Seyle (1946) also regarded stress was a non-specific or generalised phenomenon, with many diverse and challenging environmental stimuli capable of eliciting physiological responses involving whole body systems.

Today, the importance of psychological processes are also widely acknowledged, with stress being regarded as a psychophysiological process. Pfister and Muir (1992) define stress as physiological and psychological responses to physical and emotional stimuli which disrupt the internal environment (homeostasis) of the individual. The existence of specific neuroendocrine systems which play a central role in orchestrating stress, such as the hypothalamus-pituitary-adrenal (HPA) axis, further highlights a link between

psychological and physiological elements in the human stress response. Furthermore, the HPA's ability to respond sensitively to various physical and psychological stress paradigms (Ur, 1991) tends to refute stress being a non-specific and generalised phenomenon. Factors, or elements which initiate psychophysiological responses in individuals, may arise from internal or external stimulation, with Spielberger (1989) emphasising that both real and perceived threats may initiate stress responses.

2.2.1 Stress, arousal and anxiety

Much confusion in multi-disciplinary stress research has been attributed to the definition of the term stress, in particular, the fact that a single, unified definition of the word is yet to be agreed upon (Grossman, 1987). Stress been defined as a class of stimuli, a set of behavioural responses or an intervening psychophysiological process (Toates, 1995). Moreover, terms such as arousal and anxiety which also relate to psychophysiological phenomenon, have not always been clearly differentiated from the term stress. Physiological activation, referring to the activity of whole body systems, has typically been termed arousal (Duffy, 1972). Physiological arousal is thought to vary on a continuum, ranging from sleep states to intense excitement. More recently, Martens et al. (1990) has argued that arousal should include psychological responses, with others even stating that psychological stress and arousal are essentially synonymous (Hennessy and Levine, 1979). Hence, composite views of arousal describe the general or whole system physiological and psychological activation of the individual (Gould and Krane, 1992). Anxiety is an emotional state, generally referring to the subjective feelings of nervousness, tension, apprehension and worry accompanied by physiological arousal, such as racing heart rate (Spielberger, 1989). Anxiety is a commonly experienced by athletes in competitive sport settings, so has been termed competitive anxiety.

To clarify the concepts of stress, anxiety and arousal in sport, and understand their relationships in sporting environments, researchers have proposed models of stress (Gould and Krane, 1992). Models emphasise stress as a cyclical process and illustrate the interrelationships between major elements. For example, the initial stages of McGrath's (1970) model, depicts the interaction between the individual and their environment, because the individual's perception of their environment, and not the competition environment per se, will determine the individuals subsequent response. This partly explains individual differences in stress responses between individuals exposed to the same competition environment. The response stage of the model refers to the individual's psychophysiological responses, namely increased physiological arousal and anxiety. Physiological responses include cardiovascular, respiratory, and neurohormonal system activity and are measured by indicators such as heart rate, blood pressure, hormones such as cortisol and catecholamines, and skin conductance (Hackfort and Schwenkmezger, 1989). Anxiety is commonly measured using self-report psychometric inventories (Vealey, 1990). The final outcome stage of the model, relates to the individual's motor performance or behaviour. In sport, there has often been anecdotal evidence suggesting a relationship between an athlete feeling 'stressed'(distressed) in competition and consequent poor motor performance.

2.2.2 Competition as a stressor

Competition environments are situational paradigms which are regarded as being inherently stressful. Competition is a process of social evaluation (Scanlan, 1984), the purpose being to determine a winner. The closer the competitor's ability levels and the more important the event, the greater likelihood for athletes to experience pressure (Rotella and Lerner, 1993). An individuals' interpretation of the situation is important. Some frequently experience competition as stressful, whilst others may experience top level competitions, for example National events, as stressful (Baron et al., 1992). Two athletes may perceive different

elements in the same competition environment differently, or the same element as either stressful or challenging (Jones and Hardy, 1990).

Martens (1977) stated competition involves threat, which occurs when athletes perceive an imbalance between competition performance demands and their ability to meet those demands, particularly when the consequences of failure are thought to be important. For example, the importance of performing well for elite athletes may relate to their career and/or monetary earnings (Jones and Hardy, 1990). Sport competition may also comprise elements of uncertainty and therefore involve evaluation apprehension (Masters, 1992) which can threaten an athletes self-esteem (Vealey, 1990). In some sports, fear of injury may be stress evoking (Hackford and Schwenkmezger, 1989), as may the presence of peers, crowds and coaches (Wright et al., 1991; Zeigler et al. 1982). Some sporting contexts are regarded as more stressful than others. Individual sports such as golf, or individual performances within sports, such as free-throwing in basketball, may be more stressful than team performances because greater responsibility for the outcome is attributed to the one individual (Scanlan, 1984).

The quality of sporting performance may rely on the individuals ability to cope with competition stress. Particularly in elite sports, where technical ability is equivalent, the best performer may be the golfer who can execute golf shots whilst coping with the additional (cognitive and physical) demands of competition (Patmore, 1986, cited in Jones and Hardy, 1990). Those unable to cope may demonstrate consistently better performances in practice than in competition (Vealey, 1990). In sport, stress can occur at any point in the competition. Athletes may feel stress in anticipation of the event, relating to their upcoming performance, or to specific events during a competition performance, or even afterwards if they feel performance was inadequate. McCaffrey and Orlick (1989), for example, found elite golfers often experienced pressure in the final stages of tournaments when they had a

chance of success. Young golfers expressed that a particular type of shot in golf was often stress-evoking (Cohn, 1990).

In this thesis, the emphasis is on measuring validated psychological (state anxiety) and physiological parameters (cortisol and heart rate) of stress in competition, similar to the response stage of the model described above. The terms psychophysiological stress, or arousal, are used to refer to an increase in activity in individual's state anxiety, cortisol, and heart rate, indicative of a stress response. It is not the intention to necessarily link high stress to negative outcomes such as impaired sporting performance, however one of the aims is to examine the relationships existing between stress and performance.

2.3 Stress and Golf

Golf, as does other sports, involves physical and psychological demands consistent with the nature of the activity. This section focuses on the nature of the physical and mental demands of golf activity (Section 2.3.1), and anecdotal and empirical evidence for psychophysiological changes in golfers related to stress (Section 2.3.2).

2.3.1 Physical demands of golf

Golf requires a degree of technical skill, power, flexibility and neuromuscular coordination (Wiren, 1990) for players to strike the ball long distances (tee and fairway shots) and over shorter distances (putting and chipping) with increased precision and accuracy. Getchell (1967) reported that golfers spent approximately 35 % of the time walking, 35% standing, 10% playing tee, fairway and iron shots and 20 % putting.

The physiological demands of golf activity are evident from heart rates responses measured during non-competitive golf rounds. A field study by Murase et al. (1989) found five

middle-aged male golfers, scoring around 95 shots for 18 holes, had an average heart rate of $108 \text{ b} \cdot \text{min}^{-1}$. A similar average heart rate was reported by Crowell (1970) where elite golfers (handicaps 10 and below) had higher heart rates than less skilled players. However this study was compromised by the low number of participants ($n=7$). By measuring maximal oxygen capacity ($\text{VO}_2 \text{ max}$) in a laboratory, Murase et al. (1989) estimated that golfers exercised at approximately 38% $\text{VO}_2 \text{ max}$. Hence, the physical demands of golf are consistent with exercise of low to moderate intensity. The total amount of energy expended over a four hour 18 hole golf round was estimated to be 1000 kcal, with an average rate of $4.6 \text{ kcal} \cdot \text{min}^{-1}$. Therefore golf has been considered suitable to assist in weight control programs (Batt, 1993). Whilst golf would not improve aerobic power in running athletes, it has been advocated for maintaining fitness in older people (Batt, 1993). Exercise of light to moderate intensity such as golf, may be particularly suitable to middle-aged populations. It may assist in maintaining cardiovascular health, and assist in preventing heart disease (Scheuer and Tipton, 1977). It is also especially suitable as a rehabilitation exercise (Murase et al. 1989).

However, a contention of this thesis is that if golf is played under stress, this may evoke less desirable physiological responses including hypersecretion of cortisol from the HPA axis and elevated heart rates. These responses may partly offset the potential health benefits described above for older players, and may result in a relative catabolic state occurring (Munck et al. 1984). Another outcome may be that persistent elevated stress may lead to early fatigue in golfers, and influence performance indirectly, for example through loss of attention or concentration.

2.3.2 Mental demands of golf

Mental (cognitive) skills are also important in golf performance, such as those involved in decision-making, target alignment and skill automaticity (Kirschenbaum and Bale, 1984).

More proficient golfers report greater mental preparation and concentration, and fewer negative emotions than less skilled counterparts (Thomas and Over, 1994). To concur with this, Cohn (1991) has previously found that ten top professional golfers were in control of emotions, cognitions and arousal, considering heightened arousal as an indicator of preparedness. Peak performances related to high self-confidence, and Cohn (1991) concluded that best performances in golf were associated with positive psychological states. Another line of research has focused on pre-performance routines and the role of cognitive skills such as attention and concentration on successful golf shot execution. Elite golfers in particular adopt pre-shot routines to prepare themselves for shot-making (McCaffrey and Orlick, 1989). Crews and Boutcher (1986a) found twelve elite lady tour golfers demonstrated consistent patterns of cognitive-behavioural activity (pre-shot routines) before putts and full swings. Pre-shot routines were found to relate to better golf performance (Crews and Boutcher, 1986a, 1986b), maybe by allowing golfers to attend to task relevant cues (Crews, 1994).

Attentional processes have been studied in relation to putting performance by recording cardiac patterns (Boutcher and Zinsser, 1990) and electroencephalograms (Crews and Landers, 1993) either before, and/or during and after golf putting in controlled laboratory environments. Putting is a fine motor skill, involving fine-muscle movements and co-ordination together with hand steadiness (Jones and Hardy, 1990). Similar to another fine motor skill sport, such as pistol shooting (Tremayne et al., 1993), heart rate slows prior to the point of release or impact. Boutcher and Zinsser (1990) found cardiac deceleration in golf putting was particularly evident during three to four cardiac cycles before ball strike, with elite golfers showing greater deceleration compared to non-elite players. Masters (1992) concurred that attention was important in expert putting performance, but that attentional disruptions are most likely to occur when individuals are highly motivated to succeed, such as in competition environments. Whilst laboratory situations allow precision

in physiological measurements, they do not emulate real-life competition experiences (Masters, 1992). Laboratory research findings therefore, may be enhanced by physiological recordings during competition performances. A field study by Molander and Backman (1994) measured heart rate, attentional focus and state anxiety in competition and practice mini-golf performance, comparing young and old groups of players. They found that attentional skills were important to putting performance, however, only infrequent heart rate and attentional measurements ($n=3$) were employed. Lightweight heart rate monitors can collect continuous heart rate data during competition and practice golf and may better reflect heart rate activity compared to isolated measures (Jorna, 1992). Such patterns of cardiac activity during tournament golf in elite and recreational golfers has not been extensively examined.

2.3.3 Stress in competition golf

The perceived relevance of mental stress to golf performance, is evident from the large number of articles published on the topic in golf magazines and books (Kirschenbaum and Bale, 1984). Several qualitative studies have examined the sources of stress in golf and how elite players cope mentally with tournaments. McCaffrey and Orlick (1989) interviewed professional and top tour players, and found they were familiar with feeling 'stressed' in pressure situations and its physiological effects. These feelings heightened when they wanted to perform well, for example toward the end of a golf round or conclusion of a tournament. McCaffrey and Orlick (1989) also found that players coped differently with pressure. Some golfers consciously tried to slow themselves down and breath deeply, whilst others viewed stress in a positive way (challenge) to build confidence. These golfers were equally aware that their performance suffered sometimes due to competition pressure, especially when they felt tense or distracted, lost confidence and patience, and focused on their poor play. Cohn (1990) interviewed young collegiate golfers and found the main sources of stress in golf were attributed to pressure in meeting

expectations (their own or others) and executing particular golf shots. The latter sometimes elicited negative emotions, such as apprehension, tension and anxiety, physical effects, such as nervousness and shaking, and cognitions including self doubt. The consequences of performance pressure in these young golfers was a lack of enjoyment in the sport and “burnout” periods where they gave the game away (Cohn, 1990). In contrast, young golfers’ best or peak performances were times they were highly focused, self-confident, physically relaxed and without fear of negative consequences (Cohn, 1991).

A condition in golf which is poorly understood, but which can have serious implications on golfers’ performance, is termed the ‘yips’ (Masters, 1992; Batt, 1993). The yips refers to an involuntary motor disturbance which interferes with the execution of the fine motor skills, especially chipping and putting. Although the underlying mechanisms for interruptions to motor performance are not understood, Oxendine (1970) predicted that optimal arousal levels for the performance of fine motor skills in golf would be low to moderate. High levels of anxiety and arousal may not be appropriate because adrenaline may cause limb tremor and muscle tension and subsequently affect the quality of the putting stroke. There has been little consistent support for Oxendine’s theory, however general support was found by Weinberg and Genuchi (1980) when lower pregame state anxiety levels resulted in better golf performance scores. Cook et al. (1983) found this to be the case on day 2 and 3 of a golf tournament, but not the first day. The relationship between competitive state anxiety and golf performance, has been more extensively researched using sport-specific, multidimensional psychometric measures of anxiety, including the Competitive State Anxiety Inventory-2 (CSAI-2) (Martens et al, 1990; McAuley, 1985; Krane and Williams, 1987; Krane et al., 1992). The findings will be discussed in Section 2.5 on Anxiety.

Few studies have measured golfer's psychophysiological states during competitive golf performances. Molander and Backman (1994) found that both young and older mini-golf players demonstrated parallel increases in heart rate and self-reported state anxiety, but attentional focus, concentration and golf performance (number of shots) declined in older players. They concluded that age resulted in a reduced ability to cope with competition stress, but these conclusions are seriously limited by the infrequent and global nature of the psychophysiological measures. For example, heart rate was measured by attaching an ear-lobe monitor on only three occasions, holes 1, 9 and 17, and state anxiety was measured on a 10 point scale. It is also feasible this method of heart rate data collection may be distracting for the players, and the influence of attaching and detaching the heart rate monitor and its effect on heart rate cannot be determined. The current thesis does not examine attentional states in golfers, rather it measures psychophysiological parameters more extensively during competition and practice golf.

2.4 Physiological parameters of stress

Physiological parameters of stress may be indexed by changes in hormones, neurotransmitters, metabolites, or nervous activity associated with the integrated activity of physiological systems. This includes cardiovascular (Herd, 1991), neurohormonal axes (Ur, 1991) and respiratory systems (Boiten, 1993). Physiological measures such as heart and respiration rate, electrophysiological indicators such as skin resistance have been more frequently used compared to biochemical indices including adrenaline and cortisol.

2.4.1 Cortisol

Cortisol (hydrocortisone) is a steroid hormone and a major glucocorticoid in humans. As a counter-regulatory hormone to insulin, it stimulates the catabolism of carbohydrates, lipids and proteins (Munck et al., 1984), and may serve a metabolic function in supplying energy

substrates during strenuous exercise (Tharp, 1975; Kirschbaum and Hellhammer, 1989). Cortisol is released through stimulation of a neuroendocrine system, the hypothalamus-pituitary-adrenal (HPA) axis, according to many different psychosocial and physical factors or stressors (Mason, 1968). The HPA axis is also stimulated according to an inherent 24-hour pattern of activity, or circadian rhythm. Cortisol stimulation and release from the adrenal cortex is pulsatile, with agents (stressors) resulting in a increased frequency and amplitude of cortisol release (Hellman et al., 1970). Consequently, stress results in large or small elevations in cortisol concentration above resting (circadian) concentrations for a particular time of day (Vining et al. 1983b). By controlling for resting cortisol concentrations, cortisol functions as a valid marker of altered physiological states in response to stressful stimulation (Mason, 1968; Ur, 1991).

2.4.1.1 HPA axis and circadian variation

The hypothalamus-pituitary-adrenal (HPA) axis plays a central role in orchestrating stress responses (Ur, 1991). In response to biochemical or psychosocial stress stimuli, the hypothalamus releases a peptide, corticotrophin releasing factor (CRF), which stimulates the anterior pituitary to release adrenocorticotropin (ACTH). ACTH reaches the adrenal cortex via the circulation, stimulating the synthesis and release of cortisol into circulating blood. Under resting conditions, serum cortisol concentration follows a relatively consistent (episodic) pattern of secretion (Krieger, 1971; Weitzman et al., 1971), being elevated in the morning (after waking) and declining toward evening (Hiramatsu, 1981; Vining et al. 1983b). A study of 23 healthy males found the mean morning (0800hr) and evening (2000hrs) saliva cortisol concentrations were 16.2nmol.l^{-1} and 3.9nmol.l^{-1} respectively (Laudat, et al. 1988), however different methodologies used by investigators have led to a wide range in the reported concentrations of cortisol at baseline (Kirschbaum and Hellhammer, 1989). Cook et al., (1987) measured individual cortisol baselines on five separate days, $n=3$ prior to and $n=2$ after a marathon run. They found no significant

differences between the mean values representing similar times of day ($p < 0.05$) and combined the values for an average cortisol baseline.

HPA activity is regulated partly by negative feedback mechanisms, where circulating cortisol and ACTH act at the level of the hypothalamus (Vining and McGinley, 1987). Cortisol is bound to proteins in serum (cortisol binding globulin, CBG, and albumin), with unbound (free) cortisol exerting metabolic effects (Munck et al., 1984). The half-life (mean \pm SD) of 20mg of intravenously administered cortisol in eight cortisol-suppressed males was found to be 72 ± 12 minutes in saliva (Tunn et al., 1992), whilst Hiramatsu et al. (1981) reported a half-life of around 60 minutes for salivary cortisol. Physical and psychological stressors, originating from sources both outside and within the central nervous system (CNS) (Tepperman and Tepperman, 1987), may result in hypersecretion of cortisol. Hence, many different situational paradigms have examined stress-related cortisol responses to particular mood states, cognitions and behaviors.

2.4.1.2 Stress and HPA activity.

A wide range of laboratory and real-life paradigms, have been found to stimulate HPA activity (Mason, 1968) including medical procedures (Czeisler et al., 1976), public speaking (Bassett et al., 1987), marathon running (Cook et al., 1987), watching suspense films (Hubert and de Jong-Meyer, 1989) and academic examinations (Jones et al., 1986). Cortisol responses are attributed to physical stress such as strenuous exercise (Port, 1991) or pain (Stahl and Dörner, 1982). The stress stimuli may be acute, such as venepuncture (Mason et al., 1973) or prolonged periods of threat or high demand (Rose et al., 1982). Anticipation of the stressful event is a potent factor in cortisol release (Arthur, 1987), where cortisol concentration is elevated just prior to the stressful events (Petraglia et al., 1988), moreso in situations which are novel (Mason et al., 1973) or unpredictable (Mason, 1968). Individual factors, such as personality type (Jones et al., 1986), fitness (McDowell

et al., 1992) and coping strategies (Herbert, 1987) can modulate cortisol responses and may explain individual differences in HPA activity to similar environments. Less well understood are the influences of meal status (Brandenberger et al., 1982), diet (Anderson et al., 1987) and smoking (Cherek et al., 1982) on HPA activity and cortisol release. Although cortisol responses and their proposed physical and psychological antecedents are often examined separately, many stress paradigms comprise both psychological and physical factors, which may be difficult to differentiate (Harris et al., 1989; Mason et al., 1973; Petraglia et al., 1988).

Physical activity and cortisol

The level of physical exertion involved in competitive running sports, such as marathon running (Cook et al., 1989) and athletics (Petraglia et al., 1988) results in large cortisol increases during and after the event. Davies and Few (1973) examined serum cortisol responses in 10 male participants performing an hour of exercise (walking or running) at exercise intensities ranging from 36 to 96% of their VO_2max . By relating the relative (as opposed to absolute) workload performed over one hour exercise period, they determined a critical threshold of exercise intensity needed to elicit an increase in plasma cortisol was approximately 60% of maximal oxygen consumption (VO_2max). This intensity threshold has also been supported by studies using less invasive saliva sampling methods as a means of measuring adrenocortical activity (Port, 1991; Stupnicki and Obminski, 1992), which eliminates potential confounds from cortisol release in response to venepuncture (Rose et al., 1982). O'Connor and Corrigan (1987) found eight males averaging 23 years of age, showed elevated salivary cortisol immediately (prior to) and after 15 minutes of a 30 minutes cycling task at 75% (VO_2max).

Low intensity exercise per se, is not thought to stimulate the HPA axis (Tharp, 1975). Although studies involving low intensity exercise have demonstrated slight increases or

decreases in plasma cortisol concentration, these may be due to confounds including psychological factors (Mason et al. 1973) or changes in blood circulation of the hormone (Port, 1991). Davies and Few (1973) found plasma cortisol concentration declined slightly over a one hour testing period for exercise workloads below 50% VO_2max . They attributed the decline to the normal diurnal pattern rather than an adrenocortical response to the exercise intensity. Hartley et al. (1972) did not find that serum cortisol levels changed compared to resting values in seven males during mild bicycle exercise (< 40% VO_2max), however, Mason et al. (1973) suggested that anticipatory elements, such as the novelty of the exercise and venepuncture may contribute to changes in cortisol concentrations. Although this effect was more pronounced prior to novel, exhaustive exercise bouts, they did not exclude that in some individuals, psychological elements may also contribute to a cortisol response. The HPA response to competitive sports involving low intensity physical exertion accompanied by relatively high stress such as golf, has not widely been examined. The exercise intensity of golf is approximately 40% VO_2max (Murase et al. 1989), which is much lower than the threshold of exercise intensity needed to evoke a cortisol response (Davies and Few, 1973). Therefore, if saliva cortisol rises during a round of golf against the setting of the normal circadian decline, it is unlikely that the mechanism responsible is physical exertion. The effects of competitive golf on cortisol concentration is a primary focus of this thesis.

Apart from exercise intensity, an individual's fitness level and the duration of the exercise may influence the cortisol response. Petraglia et al. (1988) found the longer distance (10,000 and 15,000 meter) runners, had significantly higher plasma cortisol compared to the 100 meter sprinters after completing their respective races. Discus throwers competing in the same athletic meet, did not have elevated post-event cortisol despite showing elevated pre-game cortisol concentrations. Fit individuals tend to show a blunted adrenocortical response to exercise at submaximal (moderate) workloads (McDowell et al., 1992), whilst

cortisol concentrations at supramaximal workloads are higher compared to unfit individuals (Farrell et al., 1987). Training-related adaptations and the adrenocortical response to exercise are further discussed in Section 6.6.

Psychological stress

In an early review of psychoendocrine studies Mason (1968) concluded that cortisol is a sensitive and potent indicator of psychological stress, resulting in small increases above baselines. There is often little correspondance between absolute hormone concentrations measured in different studies according to the different assays and commerical salivary kits used (Kirschbaum and Hellhammer, 1989; Seth, 1987). However psychological events generally result in small increases in saliva cortisol, which ranged from around 3 nmol.l⁻¹ to 16 nmol.l⁻¹ (Bassett et al., 1987; Cook et al., 1987; Hubert and de Jong-Meyer, 1989; Stahl and Dörner, 1982).

Anticipation of noxious or threatening situations, is potent in eliciting HPA activity. For example, elevated cortisol responses have been measured prior to public speaking (Bassett et al., 1987), parachuting (Levine, 1978), academic examinations (Allen et al., 1985; Jones et al., 1986), and rappelling (Brooke and Long, 1987). Arthur (1987) argues that the adrenocortical response is important in preparing an individual to cope with threatening confrontations. Anticipatory cortisol responses are generally small in magnitude and evident just prior to the onset of the stressful event. Czeisler (1976) compared serum cortisol levels in patients awaiting elective surgery to a hospitalised control group. The commencement of pre-operative procedures, namely washing and shaving, was found to elicit a cortisol increase in the patients. Although only four patients were involved in the study, Czeisler (1976) speculated that anticipation associated with apprehension of personal injury provoked the HPA axis. The environmental setting may also influence cortisol

responses. Ben-Aryeh et al. (1985) found that women awaiting medical procedures in hospital had elevated cortisol compared to women waiting in their homes.

Situational elements involving novelty, unpredictability or where individuals experience lack of control may also evoke HPA activity (Ur, 1991). Mason et al. (1973) found that cortisol increased in individuals prior to the first of three exercise-to-exhaustion trials. They believed anticipation of the threatening event and novelty of the situation may have contributed to the response. Hubert et al. (1989) studied the effect of novelty on two groups of students exposed to a painful venepuncture procedure (LHRH). Twelve medical students who were well-familiarised with the procedure, reported similar levels of pain during the LHRH test compared to five unfamiliarised controls, yet the unfamiliarised group showed significantly higher plasma cortisol concentrations. Although the control group was small, this study showed that the novelty of the procedure evokes HPA activity, irrespective of the actual pain experienced. Familiar tasks in real-life situations also stimulate cortisol secretion. Leedy and Wilson (1985) found higher post-flight serum cortisol concentrations in non-pilots seated adjacent to pilots who were flying and landing the aircraft. Although airforce personnel are a select group in terms of physical and psychological characteristics, Leedy and Wilson (1985) attributed the elevated cortisol in passengers to their lack of situational control during aircraft landing. Many psychologically stressful situations which are ego-involving, such as suspense films (Hubert and de Jong-Meyer, 1992) and examinations (Jones et al., 1986) may evoke HPA activity, especially when the individual becomes involved and anticipates negative consequences of the situation (Kirschbaum and Hellhammer, 1989).

Early studies examining the influence of situational factors on adrenocortical responses to stress, relied on urine or blood sampling. Urinary cortisol is limited by the timing of bladder emptying, making only pre-event and post-event sampling feasible. Samples

cannot be easily synchronised with the stressful event, resulting in a measure of average HPA activity over the stressful period. Measuring salivary and urine cortisol concurrently, both before and after public speaking, Bassett et al. (1987) found only salivary cortisol concentrations were elevated in anticipation of the stressful paradigm. They suggested that the inherent lag time between cortisol release into the blood and its subsequent appearance in the urine, was the reason for their findings. Bassett et al. (1987) concluded that salivary cortisol was more sensitive in measuring psychologically stressful events compared to urinary cortisol. Studies have also attempted to elucidate the nature of the provoked cortisol secretory episodes by measuring salivary cortisol concurrently with mood states. These studies are reviewed in Section 2.6 relating to psychophysiological measurement.

Psychophysiological stress and cortisol

During exercise at moderate to high intensities it is likely that psychological factors contribute to the overall cortisol response (Mason et al., 1973). Differentiating between cortisol responses to physical as opposed to psychological antecedents is difficult, however in situations when physical exertion is low or has been controlled, small increases in cortisol may reflect psychological stimulation. A study by Cook et al. (1987) measured saliva cortisol responses in eight non-elite male runners, prior to, during and after competing in marathon. Prior to the onset of the race, where physical activity was minimal, they measured small but significant increases in saliva cortisol concentration over baseline averages measured at similar times on rest days. They attributed this 40% rise above baseline (6.6nmol.l^{-1}) in cortisol to anticipation of the imminent event. In contrast, during the marathon the runners showed marked increases in cortisol concentration, of some 470% over baseline, whilst the highest responses (73nmol.l^{-1}) or 845% over baseline were measured 30 minutes after the run. The high levels of cortisol at this time are typical of those found after exhaustive exercise (Farrell et al., 1987). The magnitude of the cortisol

response therefore, may indicate the nature of the evocative stimulus. Anticipatory rises prior to exercise in non-competitive settings have also been found (Mason et al., 1973).

2.4.1.3 Salivary determination of cortisol concentration

Saliva cortisol concentration is a reliable indicator of plasma cortisol levels (Vining and McGinley, 1987; Al-Ansari et al., 1982; Hiramatsu, 1981; Tunn et al., 1992), reflecting the biologically active (free) cortisol concentration in serum (Peters et al. 1982; Hiramatsu, 1981; Walker et al., 1978). Salivary cortisol has advantages for both sample collection and analysis. Salivary sampling permits serial sample collection during activities, in addition to pre and post stressor periods (Cook et al., 1987). It is easy to collect, compared to venepuncture or catheterisation which is at best impractical and at worst illegal, in competitive sporting contexts. Furthermore, blood sampling may be psychologically stressful for some individuals, masking any sport-specific stress responses (Mason et al., 1973; Rose et al., 1982). Saliva cortisol has an additional advantage because it has been reported as being stable at room temperature for up to four weeks (Kirschbaum and Hellhammer, 1989), which enhances its usefulness in field studies where cold storage of samples is not practical (Cook et al., 1987).

Sensitive radio-immunoassay (RIA) techniques allow detection of small quantities of steroid hormones from saliva (Walker et al., 1978), where cortisol is found in only small concentrations. Cortisol passes easily into the salivary glands from the blood, with Vining et al. (1983b) reporting that it equilibrated with unbound serum concentrations in approximately five minutes. Hubert and de Jong-Meyer (1989;1992) found that cortisol concentration increased during a psychologically stressful film paradigm, but the highest cortisol concentration was measured after the film. The time latency between the onset of a mild laboratory stress and peak salivary cortisol response may therefore be up to 30 minutes. Studies employing multiple serum and saliva samples have found that changes in

saliva concentration closely parallel those in serum, (Peters et al., 1982; Riad-Fahmy et al., 1982), especially during submaximal exercise workloads (Port, 1991). O'Connor and Corrigan (1987) and Port (1991) have advocated its use in assessing the adrenocortical response to exercise, after finding close associations between saliva and serum cortisol. Saliva enables frequent sample collection from individuals over a resting period. Stupnicki and Obminski (1992) found a greater variation in individual's pre-exercise cortisol baseline value using serum as opposed to salivary cortisol, concluding that saliva cortisol produced more reliable baseline measures.

2.4.2 Heart Rate

The cardiovascular system serves to transport nutrients and metabolites around the body, but also plays an important role in stress. The cardiovascular stress response is thought to prepare an individual confronted with physical and/or psychological stressors to respond effectively, and results in diffuse physiological responses including tachycardia, increased systolic blood pressure and cardiac output, redistribution of blood flow to the heart and skeletal muscle (Herd, 1981). Regulation of the cardiovascular stress response involves the antagonistic actions of the sympathetic and parasympathetic branches of the autonomic nervous system (ANS), and the sympathetic-adreno-medullary system (SAMS) (Christensen and Galbo, 1983). Increased sympathetic activity increases heart rate (tachycardia) through adrenergic transmitters, whilst increased parasympathetic activity slows the heart rate via cholinergic (bradycardia) mechanisms. The neuroendocrine system potentiates the rapid neural response to stress, by increasing circulating adrenaline. Sympathetic adrenal activation and reduced parasympathetic tone are typical of the underlying mechanisms of a cardiovascular response to acute and chronic aversive stimuli in man (Herd, 1981). In addition to stimulating cardiac activity, adrenaline influences the vascular system and mobilises energy substrates.

Heart rate has traditionally been used to index physiological stress or arousal to psychologically stressful tasks, or a subject's task involvement or emotions, such as anxiety states (Porges and Byrne, 1992). The advantage of heart rate data is that it is easy to measure, even in ambulatory individuals, and can be done so with minimal invasiveness to the individual. Because heart rate is neurally mediated, it was thought to relate (directly) to central nervous system status, or arousal. However, complex regulation of cardiovascular activity by the ANS, including constant feedback from intrinsic and extrinsic factors has led many to regard the theoretical basis for heart rate as a unitary indicator of arousal level as being too simplistic (Neiss, 1988). The complexity of the response is further evident, given heart rate can increase in anticipation of exercise prior to motor cortical stimulation arising from skeletal muscle at the onset of exercise. With more sophisticated equipment, such as high frequency electrocardiograms, researchers have measured cardiovascular parameters and their relationship to psychological factors including consciousness, alertness, attention and effort (Jorna, 1992). Spectral analysis of heart rate variability provides more precise information on the level of neurohormonal activation, in particular autonomic activity (Porges and Byrne, 1992). Previously, controlled laboratory conditions were required to minimise recording artifacts. With the advent of improved recording apparatus, field studies can now benefit from increased precision in recording data.

In this thesis, it was decided to measure the HPA axis rather than SAMS because the latter would be expected to be qualitatively similar to the heart rate responses which were also measured. This approach enabled observations of two independent neurohormonal mechanisms.

2.4.2.1 Heart rate responses in sport

In sport and other real-life settings, heart rate increases in response to physical factors, such as exercise intensity and increased metabolic demands, but also to psychological factors, including cognitions and emotions (affective state) (Wilson, 1992). In sportspeople, emotional heart rate responses result in increased heart rates over those expected from the physical demands of the exercise. Heart rate responses to stress, defined by “additional heart rate” responses (Strømme et al., 1978), refers to a psychologically mediated heart rate response which is greater than that required to support only the physical exercise demands. Physiological demands of the exercise can be measured directly using expired gases, according to the direct relationship between heart rate and oxygen consumption (Astrand and Rodahl, 1977). Measuring oxygen consumption is not practical in competitive sport settings and therefore has to be estimated.

Instead, emotional tachycardia in stressful sporting contests may be observed during periods of low or minimal physical activity. For example, Hanson (1966) found that the heart rates of 12 year old baseball players were highest when standing ‘at bat’. They attributed these heart rates, around $163 \text{ b}\cdot\text{min}^{-1}$ to emotional factors since the same individuals standing in the field had average heart rates of only $127 \text{ b}\cdot\text{min}^{-1}$. Baron et al. (1992) used other physiological indices of emotional and physical stress to demonstrate the heart rate response to competitive sport. They measured urinary epinephrine (E) as an indicator of the psychological demands of the situation, urinary norepinephrine (NE) as an index of physical demands, and average heart rates in sixteen elite table tennis players, during a National tournament, a practice competition, and a training session. When comparing 100 minutes of play for each condition, they found that E and heart rates were significantly higher in competition compared to the other two conditions, which indicated the psychologically stressful nature of the situation. The NE levels were similar for the

three conditions, so they concluded that the physical demands were similar. Heart rates averaged $170 \text{ b}\cdot\text{min}^{-1}$ in competition, which was approximately $23 \text{ b}\cdot\text{min}^{-1}$ higher than the average heart rates measured during the practice and training sessions. By interpreting the physiological data together, Baron et al. (1992) concluded that competition table tennis evoked higher psychophysiological stress than practice conditions.

The field environment for analysing heart rate data has been widely advocated (Wilson, 1992) to understand human behaviour in natural environments. In particular studies examining cardiovascular reactivity to emotional stress in real life and laboratory settings are interested in the association between hyperactivity and cardiovascular disease (Krantz and Manuck, 1984). Despite numerous factors which may influence heart rate responses in natural as opposed to more highly controlled laboratory environments, there is no strong and consistent evidence for cardiovascular reactivity in laboratory settings to be highly predictive of those in real-life situations (Van Doornen and Turner, 1992). Sport generally involves multiple tasks, so heart rate measurement will reflect cardiovascular activity over a period of multiple stressors rather than for a definite cognitive task with discrete onset and offset times. Theoretically, the flow of stimuli and cognitive processing which occur throughout sporting performance, makes it difficult to correlate physiological responses precisely with specific events (Wilson, 1992). Heart rate measures in sport settings provides information as to the conditions under which the task is executed rather than a discrete task.

A consideration in field studies is to account for the many extraneous variables which influence heart rate. These arise from both intrinsic and extrinsic sources including those unrelated to stress, such as body posture, physical fitness, age, time of day, and variations in muscle movements, metabolism and respiratory activity (Johnston et al. 1990; Jorna, 1992), as well as factors including health status and drugs (Porges and Byrne, 1992).

Heart rate acceleration parallels inhalation. Breath holding causes heart rate to slow until exhalation occurs and the heart rate accelerates (Porges and Byrne, 1992). Although heart rate monitors are providing more comprehensive heart rate data to examine cardiac activity to real-life stressors protocols, Porges et al. (1983) states the information is especially useful especially when interpreted with other psychophysiological variables, such as subjective measures of psychological anxiety states.

2.5 Anxiety and psychological stress

Anxiety is a common emotional manifestation of stress in sport competition. Over the last 25 years, sport psychologists have measured self-reported competitive state anxiety in athletes to understand the nature of anxiety in sporting contexts, and in particular, the relationship between competitive state anxiety and sports performance. Self-report measures have commonly been employed to index state anxiety responses in competition. Behavioural or observational indices can also provide an index of state anxiety (Hackfort and Schwenkmezger, 1989). The development of sport-specific, multidimensional psychometric inventories, such as the CSAI-2, has assisted research by providing more precise psychometric tools to assess competitive stress in sport contests.

2.5.1 Development of multidimensional anxiety

Anxiety was originally regarded as a unidimensional phenomenon. Subsequently, anxiety measures reflected the general tendency of an individual to become anxious across a wide range of situations (Smith et al. 1990). The inverted-U concept was popular amongst researchers in explaining the relationship between global anxiety and sport performance (Krane, 1992), predicting that optimal levels of anxiety or arousal were associated with best performances. As depicted by the inverted-U shape, higher or lower levels (a shift to the left or right) than this predicted optimum, would have a negative influence on

performance. Whilst there was some support for arousal in predicting performance (Klavora, 1977; Sonstroem and Bernardo, 1982) including golf performance (Weinberg and Genuchi, 1980), the global anxiety-performance concept was considered too simplistic to explain the complex relationship between anxiety, sport performance and the individual (Neiss, 1988). As Neiss (1988) argued, the concept assumes functional changes in general arousal systems to be monotonic. Krane and Williams (1987) and Burton (1988) also attributed the many ambiguities and inconsistencies in anxiety-performance research to this oversimplified approach.

Anxiety in sport has been conceptualised as a multidimensional construct, on the basis that it could be separated into different types of anxiety. Spielberger (1966) differentiated and later measured anxiety as a personality trait (trait anxiety) and a mood state (state anxiety). Competitive trait anxiety was defined as an individuals' predisposition to regard situations as threatening and respond with state anxiety. State anxiety was a transitory state, whereby individuals respond with feelings of tension and apprehension accompanied by physiological arousal. State-Trait anxiety inventories are currently used in sport psychology research (Spielberger, 1989). State anxiety was also considered as multidimensional, based on the work of Liebert and Morris (1967) and Davidson and Schwartz (1976) in clinical psychology. They had differentiated state anxiety as comprising mental and physical or emotional components of anxiety, which corresponded to cognitive and somatic anxiety adopted in the sport psychology field (Gould et al., 1984; Martens et al., 1990). According to Davidson and Schwartz (1976), cognitive anxiety is characterised by negative concerns or expectations and the inability to concentrate, whilst somatic anxiety is the perception of physiological symptoms of autonomic arousal, such as experiencing butterflies in the stomach or racing heart rate.

2.5.2 Measurement of Competitive State Anxiety

Martens et al., (1990) developed a multidimensional state anxiety measure, designed specifically for sportspeople which is termed The Competitive State Anxiety Inventory (CSAI-2). The CSAI-2 measures intensity of the mental anxiety component (cognitive A-state) and the physiological or affective component (somatic A-state) which frequently arise in competitive sporting situations. Martens et al. (1990) specifically defined cognitive A-state as worrying thoughts, or negative expectations which arise when an individual expects to perform poorly. This negative evaluation of their perceived performance ability is often characterised by negative self-talk and unpleasant visual imagery (Gould et al., 1984; Martens et al., 1990). Somatic anxiety refers to a person's perception of their autonomic arousal, which includes self-reported feelings of a racing heart rate, sweaty palms, tense muscles and butterflies in the stomach. Martens et al. (1990) determined a third related yet independent construct, which was state self-confidence. Self-confidence comprised a positively worded scale which was originally thought of as part of cognitive anxiety.

Validating cognitive and somatic A-state, and state self-confidence as independent state anxiety components, relies on the three sub-scale having different antecedent conditions. Some covariance is expected (Borkovec, 1976), because high levels of somatic anxiety may induce cognitive worry, or sudden increases in worry may result in increased physiological symptoms. Initial validations by Martens et al. (1990) found moderate and positive correlations between cognitive and somatic anxiety components ($r = .55$), moderate and negative correlations between cognitive and self-confidence ($r = -.61$) and somatic anxiety and self-confidence ($r = -.57$), and concluded these were indicative of partial independence. Subsequent research has conferred with similar, moderate intra-correlations existing, providing support for the CSAI-2 being a valid, multidimensional measure of state anxiety in sport (Caruso et al., 1990; Krane & Williams, 1987).

Self-report inventories such as the CSAI-2 are useful research tools. Questionnaire assessments are suitable for use in real-life sports settings, which are widely advocated in competitive sport research to enhance the validity of the anxiety response (McCann et al., 1992; Weinberg and Genuchi, 1980). They are easily administered at sporting venues without undue distraction or invasiveness to the athlete (Vealey, 1990). They also provide a qualitative account of how the athletes perceive their situation, which cannot be obtained from physiological measures directly, such as heart rate. The disadvantage of self-report assessments is they are susceptible to response bias, for example when the individual responds to please others such as their coach (Vealey, 1990). A criticism of the CSAI-2 is that the length of the current 27 item format has prevented its use during many types of sporting performance (Martens et al., 1990) leading Jones (1995) to recommend short-forms be validated. The CSAI-2 has been used in laboratory and field settings to examine antecedents and temporal patterns of state anxiety, the influence of individual factors on state anxiety such as sport type and skill level, and perhaps most commonly, the relationship between state anxiety and sport performance. There is also a role for psychometric inventories in stress management research (Jones and Hardy, 1990). The current thesis proposes to investigate temporal patterns and the anxiety-performance relationship.

2.5.3 Antecedents and temporal patterns of the CSAI-2

Martens et al. (1990) predicted temporal changes for the three CSAI-2 components based upon their respective antecedents. Somatic state anxiety, being a conditioned response to non-evaluative factors, should increase when an individual arrives at the competition venue, commences their warm-up routines, or becomes aware of the presence of spectators and peers. Theoretically, somatic anxiety should be highest just prior to the event, and dissipate when competition commences because athletes then focus their attention on task

relevant factors. Cognitive anxiety and self-confidence are proposed to be influenced by performance related cognitions, so should change when performance feedback occurs (during the sports event) and remain constant during the precompetition period unless performance expectancies change.

The CSAI-2 has been employed to examine multidimensional temporal patterns for cognitive and somatic anxiety and self-confidence components in the days, hours and minutes prior to the start of sporting contests with the research providing some empirical, but not always consistent support, for the theoretical anxiety antecedents. (Gould et al., 1984; Gould et al., 1987; Jones et al., 1988). Krane and Williams (1987) did not find support for the predicted temporal patterns in golfers, in the lead up to a golf tournament. Golfers' cognitive anxiety decreased whilst self-confidence increased and somatic anxiety remained constant. Temporal patterns for self-confidence have also provided inconsistent support for the predicted changes in the pre-competition period. Martens et al. (1990) found no change in self-confidence as competition approached, Ussher and Hardy, (1986) found it increased after competition finished, and Jones et al. (1988) found cricketers' self-confidence decreased as their time to bat approached. Studies of temporal patterns also highlighted many factors which could influence state anxiety responses.

Other factors including skill level (Cook et al., 1983; Martens et al., 1990), sport type (Krane and Williams, 1987), gender (Jones et al., 1991) and competitive setting (McCann et al., 1990), may influence CSAI-2 responses, as do individual factors including personality traits (Weinberg and Genuchi, 1980) and gender (Krane and Williams, 1994). McCann et al., (1990) emphasised the importance of using genuine sporting environments and sports contests in competitive anxiety research. They found that the same cyclists showed higher intensities of state anxiety to a road cycling competition compared to a simulated laboratory time trial, even though both tasks were used as a team selection

criteria. Different skill components for different sport types (Martens et al., 1990) and the nature of their performance assessments (Krane and Williams, 1987), have also led to variations in state anxiety intensities reported. Krane and Williams (1987) found that performance assessment in gymnasts was more anxiety provoking than golf, with gymnasts showing higher absolute levels of state anxiety. In this study however, the competitive conditions were not considered of similar standard. Within sports types, the ability level may also influence the intensity of the anxiety responses. In general, highly skilled (elite) athletes exhibit lower absolute cognitive and somatic anxiety levels and higher self-confidence than less skilled athletes (Martens et al., 1990), which has been supported by studies on golfers (Cook et al., 1983). Krane and Williams (1987) found that moderately skilled gymnasts demonstrated an increase in cognitive anxiety whilst self-confidence decreased in the lead up to competition. They suggested that moderately skilled performers were unable to regulate their anxiety cognitions or self-doubts. Mahoney and Avenier (1977) suggested that successful athletes have fewer self-doubts, lower anxiety and greater confidence. Cook et al. (1983) concluded that unless individual factors such as ability level are controlled for, the CSAI-2 anxiety-performance relationship may be confounded.

2.5.4 Multidimensional (CSAI-2) anxiety and sport performance

To understand the relationship between competitive anxiety and sport performance, each of the CSAI-2 subscales has been compared to performance outcome, according to specific anxiety-performance hypotheses (Martens et al. (1990). These hypotheses are based on the proposed antecedents for individual subscales. State anxiety has generally been measured prior to competitive performances. The rationale is that athlete's cognitive state in the preparatory (pre-competition) period, may influence impending performance (Jones and Hardy, 1990), and self-report measurements during this time are less distracting for athletes compared to during performances.

2.5.4.1 Anxiety-performance predictions

Theoretical predictions for the influence of multidimensional state anxiety and motor performance were developed, and incorporated two main premises. Given that cognitive worry is proposed to interfere with cognitions relevant to performance (Wine, 1980), high levels of cognitive anxiety are proposed to be detrimental to performance. Since antecedents for somatic anxiety are not directly performance based, and should decline or even dissipate with the start of competition in most situations (Morris et al., 1981), cognitive anxiety was also predicted to influence performance more consistently and strongly than somatic anxiety. Only high, persistent levels of somatic anxiety might influence performance through physical mechanisms, such as limb tremor or tension, especially for fine motor skills (Gould et al., 1987). The anxiety-performance hypotheses proposed by Martens et al. (1990) relating to the CSAI-2 subscales were that cognitive A-state would show a negative linear relationship with performance, somatic A-state would show an inverted-U relationship, and self-confidence, a positive linear relationship with performance.

2.5.4.2 Pregame (CSAI-2) state anxiety and performance

An early study by Gould et al. (1984) used the CSAI-2 to measure A-state, 20 minutes prior to wrestling matches. Multiple regression analyses revealed that only cognitive anxiety predicted match outcome ($r=.53$) which was defined as a match win or loss. Whilst this provides some support for the anxiety-performance predictions, their findings were not consistent. For example in a wrestling match prior, none of the CSAI-2 components related to wrestling performance. Also when they used a different performance measure, points scored, there was no relationship between anxiety and performance. One reason for their discrepant findings was highlighted by Sonstroem and Bernardo (1982), who had previously shown that intra-individual anxiety and performance assessments were more

sensitive measures than absolute performance scores such as win/loss. They concluded that the use of intra-individual performance assessments would strengthen the anxiety-performance relationship. Intra-individual performance measures involve calculating a deviation score for each individual, where the current performance is compared with a typical performance. In golfers, a typical performance measure is golf handicap, which is an average of seasonal golf round scores. An additional methodological problem highlighted by Gould et al. (1987) was that since wrestlers faced different opponents in successive bouts, the performance task was not standardised and may have accounted for the different findings for the two matches. A subsequent study by Burton (1988) adopted Sonstroem and Bernardo's (1982) recommendations and used intra-individual performance and anxiety scores in swimmers. They attributed this methodological design to findings supporting all three of Marten et al.'s (1990) CSAI-2 anxiety-performance hypotheses. Cognitive anxiety was negatively related to intra-individual swimming times, self-confidence showed a positive linear relationship with performances, and an inverted-U relationship existed between somatic anxiety and swimming time. Furthermore, Burton (1988) found that cognitive anxiety was more consistently and strongly related to performance than somatic anxiety.

In contrast to swimmers, Krane and Williams (1987) implemented the CSAI-2 approximately 10 minutes prior to a tournament practice round in female golfers. After standardising performance scores with the golfer's handicap, they used multiple regression analysis to test the hypothesis that cognitive anxiety would be the best predictor of performance. Instead, they found that none of the CSAI-2 subscales predicted performance, but attributed these findings partly to the use of a practice as opposed to a genuine tournament round. They did however, find some indication that standardised performance scores showed greater sensitivity to subtle changes in psychological variables compared to absolute golf scores. Gould et al. (1987) also used intra-individual

performance analysis procedures together with polynomial trend analysis to examine linear and curvilinear relationships between precompetition A-state and 12 successive pistol shooting performance trials. Unexpectedly, they found that somatic, and not cognitive A-state measured with the CSAI-2 related to performance, and that the relationship described by somatic anxiety and performance was curvilinear (inverted-U). In contrast to predictions, they found a negative relationship between state confidence and pistol shooting. Although the reasons for these findings are unclear, Burton (1988) suggested that the police trainees were non-competitive shooters and that competition was simulated. Ego-involvement in the situation may have been less than when examining elite performers in real competitive situations. A further confound for the cognitive anxiety and self-confidence findings, may have been that Gould et al., (1987) used a standardised performance measure based upon only three previous performance trials as opposed to an individual's seasonal performance pistol shooting average (Burton, 1988). However despite these criticisms, Gould et al. (1987) showed in contrast to Martens et al. (1990)'s predictions, that somatic and not cognitive anxiety may influence fine motor skills performances which require neuromuscular control. Ussher and Hardy (1986) and Parfitt and Hardy (1987) also indicated that neuromuscular task demands associated with fine motor performance are sensitive to physiological (somatic) body responses. Golf combines a series of fine motor performances, however the relationship between cognitive and somatic state anxiety and performance during golf play, when these skills are being executed, is yet to be fully examined.

Another approach to examining anxiety-performance relationships in sport has been to use different performance assessments. The above studies in swimmers (Burton, 1988), shooters (Gould et al. 1987) and wrestlers (Gould et al, 1984) used global measures of sports performance outcome, such as total score or swimming times, whereas other researchers have used subcomponents of performance related to the relevant performance

skill or task. Jones et al. (1988) used reaction time tasks to assess cricketers prior to their batting performance because they regarded this an important element of batting performance. They found that increased errors on the discrimination reaction time (DRT) task coincided with increased somatic anxiety and decreased self-confidence for this period. The direct relevance of the DRT tasks to batting performance, despite reaction time being important in cricket batting performance, may be questioned. Bird and Horn (1990) used a cognitively based performance variable, mental errors, to investigate the anxiety-performance relationship in softball competition. Intra-individual comparisons revealed there was a negative relationship between the performance variable, mental errors and cognitive anxiety, supporting theoretical anxiety-performance predictions. Players with higher cognitive anxiety had increased attentional disruptions. These authors argued that the more specific nature of measuring this cognitive performance subcomponent strengthened the cognitive anxiety-performance relationship. Yet, Bird and Horn (1990) did not account for different skill levels in these softballers, and the performance ratings involved subjective ratings by a coach. As a different approach, Kleine et al. (1988) assessed physiological performance measures, heart rate and VO_2 max, in addition to the outcome measure, running times, in track athletes during laboratory and field trials. They found that increased state anxiety in a stress condition compared to practice related to a negative effect on physiological running performance in addition to running times.

Many researchers have stated that A-state measures are better predictors of performance when they are close (in time) to the performance measure they are predicting (Martens, et al., 1990; Vealey, 1990). Burton's (1988) precompetition A-state measures related to swimmers' performances minutes later, whilst McCann et al.'s (1992) precompetition A-state related to cyclists performance measured 9 to 10 minutes later. In golf, pre-performance measures of A-state may be predicting performance up to several hours later (Martens et al., 1990). McAuley (1985) and Martens et al. (1990) have emphasised that

temporal patterns and state anxiety-performance predictions in golf would be best examined during golf performance and this is examined in this thesis.

2.5.4.3 CSAI-2 state anxiety during sporting performance

Methodological problems have confronted researchers proposing to measure changes in cognitive A-state during sporting contests. These include the feasibility of introducing the CSAI-2 mid-game without unduly disrupting play (Jones, 1995), and gaining permission from coaches to do so using genuine as opposed to contrived competition (Martens et al., 1990). Subsequently, the few studies employing mid-game state anxiety measures have used retrospective reporting or else contrived competition. Some studies measured state anxiety mid-way through a designated number of competitive performance trials (Caruso et al., 1990; Karteroliotis and Gill, 1987). For example, Karteroliotis and Gill (1987) examined CSAI-2 changes prior to, during and upon completion of a contrived competition involving a peg-board task.

Martens et al. (1990) measured pregame and midgame A-state responses using the CSAI-2 and found that forty-nine collegiate golfers competing in a National tournament showed an increase in cognitive A-state from pre-competition to mid-competition and a decrease in self-confidence and somatic anxiety over the same period. These temporal patterns supported their hypothesised changes for the three CSAI-2 components based on the respective antecedents. In particular, cognitive A-state increased after nine holes of play, reflecting changes in their performance expectancies with knowledge of their performance. In relation to the anxiety-performance relationship, mid-game A-state should correlate with score on the first nine holes because it is temporally closer. Unexpectedly, they found no correlations between precompetitive A-state and initial performance assessments (score on the first nine holes). Rather, cognitive and somatic anxiety correlated with score on the second nine holes. Furthermore, the correlations between midgame A-state and

performance prior to (holes 1 to 9) and performance after (holes 10 to 18) were mostly significant. Only somatic A-state midgame failed to correlate with golf score over the first nine holes. Martens et al. (1990) also used multiple regression analysis using the three CSAI-2 subscales as the predictor variables and each performance score as the criterion variable. The results were other than expected. They confirmed that precompetition A-state did not significantly predict performance scores which were temporally closer (holes 1-9), however midcompetition A-state was a significant predictor of performance over the first nine holes. This would tend to indicate that performance influenced state anxiety, as opposed to A-state predicting performance. Several methodological problems with this study are apparent and may contribute to the complex and discrepant findings. Martens et al. (1990) employed retrospective reporting to attain mid-game anxiety measures after golfers had completed their round. They used less sensitive, non-standardised performance scores, and did not control for differences between subjects for ability levels, and they used group comparisons of the A-state subscales.

Martens et al. (1990) had suggested that performance may be an antecedent of anxiety state and not the other way around, and McAuley (1985) had earlier lent support for this notion in a study involving seven female collegiate golfers. McAuley (1985) measured pre and postcompetitive state anxiety using the CSAI-2 over ten golf tournament rounds. Intra-individual comparisons were used, unlike Martens et al.'s study, but performance scores were not standardised. None of the pre-competition CSAI-2 subscale scores correlated with 18 hole performance score, however golf score was correlated positively with cognitive state anxiety and negatively with self-confidence ($p < 0.05$). The reason for somatic anxiety showing no relationship to golf score was attributed to it dissipating over the three hours of play. Multiple regression was used to further analyse the data. This also revealed that CSAI-2 subscale scores at precompetition did not predict 18 hole performance, but rather golf scores were a significant predictor of cognitive state anxiety and self-confidence. Golf

performance influenced cognitive A-state more than self-confidence, accounting for around 26% and 15% of the performance variance respectively. They concluded that the influence of performance on subsequent anxiety was greater than the influence of pre-competitive anxiety on subsequent performance. McAuley (1985) only measured CSAI-2 pre and post competition in relation to 18 hole performance scores, which does not satisfy the recommendation that performance and anxiety measures should be in close proximity to each other. Although these two studies question whether state anxiety is a strong predictor of performance, or whether the CSAI-2 simply reflects golfers' feelings regarding their performance, studies measuring state anxiety at several stages during golf play are needed to confirm this notion. Studies which overcome the methodological problem of representativeness, as opposed to actual mid-game state anxiety measures, may assist in verifying the nature of the anxiety-performance relationship in competitive golf.

A further study by Krane et al. (1992) on golfers, elucidates the complexity of factors in addition to anxiety which may combine to influence performance. Krane et al. (1992) used path analysis to assess performance expectations and the influence of performance on state anxiety, by measuring precompetitive CSAI-2 measures in a series of practice golf rounds associated with a golf tournament. The best predictor of performance was previous performance. State self-confidence was not a predictor of anxiety state, but was a co-effector. Cook et al.'s (1983) study of 103 collegiate golfers ranging in ability levels (0-16 handicap), measured golfers' state anxiety prior to three days of a prestigious tournament. They also concluded that performance influenced anxiety and not the other way around.

More recently, research has challenged contemporary views in sport psychology assuming elevated anxiety impairs performance, by finding that high levels of anxiety can facilitate performance in some individuals (Turner and Raglin, 1996; Jones and Cale, 1989; Parfitt and Hardy, 1987). Jones and colleagues have shown that frequency, that is number of

anxiety cognitions, and direction, whether athletes label anxiety as debilitating or facilitative is important (Jones and Swain, 1995; Jones et al., 1993), and consider it important to examine issues beyond the intensity of state anxiety in athletic performance. At the time the thesis was conceived, the current form of the CSAI-2 which measures state anxiety intensity was a well-validated and frequently used measure of state anxiety in sport.

2.6 Psychophysiological measurement of stress

2.6.1 Somatic anxiety and physiological arousal

Studies in competitive sporting contexts are amongst those who have found little evidence for a strong correlation between self-reported anxiety (perceived physiological arousal) and physiological or biochemical (actual) indicators of arousal. Individual differences in autonomic responses is one reason cited for these low correlations, with Lacey and Lacey (1958) arguing that one individual may respond to a stressful situation with elevated heart rate, compared to another person who responds with greater muscle tension or gastrointestinal activity. Stress or arousal indicators demonstrate similar directional changes, so the use of multiple physiological measures including autonomic responses parameters, and self-report measures in individuals are advocated (Hatfield and Landers, 1983). Yet another reason for low psychophysiological correlations may be the nature of the measures used. Global measures of arousal or anxiety provide generalised measures of emotional or arousal state compared to multidimensional and situation-specific measures such as somatic anxiety.

The somatic anxiety component of CSAI-2 measures an athletes' self-perceived physiological arousal common to competitive sporting situations. Although this is regarded as a more specific measure, it has provide little empirical support for a relationship between somatic A-state and physiological changes in competition. Somatic anxiety responses did

not relate to frontalis muscle activity (Caruso et al., 1990), or heart rates (Karteroliotis and Gill, 1987; Yan Lan and Gill, 1984) in competitive paradigms, although Caruso et al. (1990) mentioned that the reported levels of somatic anxiety may have been influenced adversely by the perceived physical exertion of the cycling task. Karteroliotis and Gill, (1987) used multiple physiological measures to account for individual response stereotypy, yet found no relationship between heart rate, two blood pressure measures and CSAI-2 somatic anxiety, or between the different physiological measures. Contrived competitions set in laboratory environments may have influenced these findings. Molander and Backman (1994) used a competition environment and multiple psychological and physiological dependent measures of stress in mini-golfers, but assessed state anxiety using a five-point, unidimensional scale. There were similar directional responses amongst the psychophysiological measures.

Duffy (1972) argued a linear relationship between dependent measures of stress is not in accordance with the different response latencies and the speed of responses inherent in physiological systems. Hence correlation may be too simplistic and that more complex statistical analysis is required to understand a complex relationship between subjective and objective physiological measurements (Hatfield & Landers, 1983; Neiss, 1988). Hubert and de Jong-Meyer (1992) found a peak cortisol response occurred at least 20 minutes after the end of an unpleasant film, demonstrating the time latency in a hormonal response. Changes in mood states, such as anxiety may be rapid in contrast. The psychophysiological relationship may strengthen by comparing series of CSAI-2 somatic anxiety with a more sensitive hormonal correlate of psychological stress such as cortisol and greater frequency of heart rate data collected during golf tournaments.

2.6.2 Cortisol and state anxiety

There is some evidence for a relationship between cortisol and mood states such as sadness and elation (Brown et al., 1993), depression (Francis, 1979), joy (Hubert and de Jong-Meyer, 1989) and hostility (Harris et al., 1989). A few studies have reported correlations between global state anxiety measures and cortisol (Benjamins et al., 1992; Hubert et al., 1989), however in general affective state does not consistently relate to endocrine correlates. Several studies have employed academic examinations as psychological stress paradigms, and measured serum cortisol and state anxiety concurrently over time. In a longitudinal study, where endocrine and mood was rated every alternate week for an academic term, Francis (1979) found both serum cortisol and anxiety were elevated during three separate peak periods of stress (exam weeks) compared to normal school weeks. Allen et al. (1985) examined anxiety and cortisol responses over a four week exam period and found changes in anxiety and cortisol were directionally similar but they showed different temporal patterns. Students' state anxiety was elevated two weeks prior to the exams whereas serum cortisol increased during the exam period. When they further analysed their findings using intra-individual analyses, no intra-individual relationships between the two measures were apparent. Based on these different temporal patterns, Allen et al. (1985) suggested that cortisol and state anxiety had different antecedents. These findings were partially supported by Jones et al. (1986), who measured saliva cortisol and self-reported anxiety in forty medical students (Type A and non Type A), three days prior to and on the day of an academic exam. Cortisol and anxiety were elevated on the day of the exam, however cortisol correlated with personality type and exam performance but not with state anxiety. Diurnal effects on cortisol responses were controlled, however they believed the Visual Analogue Scale (VAS) used to measure state anxiety may have confounded the findings. The VAS (a 100 point linear scale) resulted in considerable between-subject variability in the range of anxiety scores marked (highest to lowest) and

the portion of the scale used. Also, Type A personalities may be prone to response bias by suppressing feelings of distress. In light of their concerns with the anxiety measure, Jones et al. (1986) concluded that the psychophysiological relationship is complex. They stated that psychological and physiological experiences may be substantially different phenomena, based on the level of physiological arousal. For example, low to moderate physiological arousal is not perceived as distressing but higher levels are. This would feasibly explain the different patterns in psychophysiological responses they found on pre-exam days compared to on exam days.

A Visual Analogue (five point) scale was used by Hubert et al. (1989) to measure anxiety, tension and pain ratings in response to a painful medical procedure. Whilst those familiar and unfamiliar with the procedure reported similar levels of tension and anxiety, salivary cortisol correlated with anxiety only in the unfamiliarised participants. Just prior to and after watching a suspense film, Hubert and de Jong-Meyer (1989) measured eight mood ratings (including anxiety) using a VAS in twenty-seven males. Saliva samples were collected prior to and at 20 minute intervals for the duration of the film. They found specific mood state changes, namely elevations in anxiety and decreases in joy over the film period, correlated with cortisol responses in individuals. The increased sampling frequency of cortisol and the provocative nature of the film as a psychological stimulus to alter mood state, may have contributed to a stronger relationship between the VAS measure and salivary cortisol.

Further studies have investigated the relationship between psychological stress and cortisol during real-life activities. Heart rate, state anxiety and cortisol increased significantly from resting baseline measures, prior to a rappelling manoeuvre (Brooke and Long, 1987). Although the researchers did not correlate the changes at the four measurement times, that is pre-rappel, immediately post, 15 and 30 minutes post-rappel, cortisol concentration

remained elevated from baseline in the recovery period unlike heart rate and state anxiety. This suggests different temporal patterns within and between the psychophysiological parameters. They explained the slow recovery of cortisol to its relatively long half-life (60minutes) and persistence in the blood. Since epinephrine (E) has a much shorter half life (minutes) it had returned to baseline in the post stressor period. Heart rate decreased from around $100\text{b}\cdot\text{min}^{-1}$ to $80\text{ b}\cdot\text{min}^{-1}$. In competitive marathon runners, Harris et al. (1989) found that pre-race salivary cortisol and anxiety were significantly higher than their respective mean resting (baseline) measures obtained at comparable times on non-competition days. On the morning of the race day, salivary cortisol changes did not correlate with anxiety. However, a small number of the participants ($n=5$ runners) agreed to psychometric testing within minutes of the event, and a correlation between their cortisol concentrations and anxiety responses was found. Although a relationship was indicated ($r = .6$), it failed to reach significance due to the small sample size. These preliminary results suggests that the relationship between anxiety and cortisol existed, only when the start of the race was imminent (minutes). These findings confer with Allen et al. (1985) in that anxiety may be elevated in the days before the event, but the hormonal response is evident only with the onset of the stressful event. In Harris et al.'s study, psychometric testing did not continue during the marathon which raises questions as to the psychoendocrine relationships during the course of a competitive sporting event.

In contrast to the measures of general anxiety measured by unidimensional VAS scales, a preliminary study by Benjamins et al. (1992) used a specific psychometric dental-anxiety measure together with salivary cortisol. Rank-Order analysis showed that patients high in self-rated dental anxiety could be differentiated according to their elevated salivary cortisol concentrations, which were close to double those found in the non-anxious controls. Benjamins et al. (1992) used individuals who were known as having extreme responses to dental procedures and conceded that selecting such individuals may lead to false positives.

Such groups tend to exaggerate their anxiety if they believe they will receive greater empathy and support. It is unclear from this study, whether the specific nature of the anxiety scale contributed to the strength of the relationship, however the use of situation-specific anxiety measures are regarded as being more efficacious than general anxiety scales (Vealey, 1990). There is no published research as to whether sport specific anxiety scales such as the CSAI-2, and saliva cortisol will show a relationship.

Other studies have utilised individual phobias because they generally instigate a reliable and sustained level of stressful anxiety in a controlled laboratory setting, however, similar to Benjamins et al. (1992), such populations are not representative of the norm. In a randomised slide presentation of either phobic or neutral material, Fredrickson et al. (1985) found individuals reporting high levels of distress did not necessarily show elevated urinary cortisol. Using a similar study design, Nesse et al. (1985) measured state anxiety and physiological parameters including heart rate, blood pressure and salivary cortisol in ten middle-aged women. In contrast, a VAS anxiety scale, from one to a 100, revealed subjective anxiety increased with salivary cortisol before and during exposure to their phobias. Nesse et al. (1985) measured eleven stress parameters simultaneously over four sessions of three hour durations. Using a repeated measures analysis they found that acute anxiety in each individual corresponded with a different physiological response pattern and concluded that endocrine responses to stress were definite, but not co-ordinated in a way simple stress theory may predict. Anxiety as an enduring state, namely a personality disposition (trait anxiety) predicts whether a person will respond to certain situations with state anxiety. Most studies have found no correlations between trait anxiety and salivary responses during a four hour continuous mental stress (Bohnen et al., 1991) or a suspenseful film (Hubert and de Jong-Meyer, 1992). The latter study found that sixty-four trait anxious individuals showed lower saliva cortisol responses compared to a low trait

anxious group, and the researchers suggested that habituation of the HPA axis may occur with repeated exposure to stress stimuli.

These studies measuring psychological mood state and physiological measures of psychological states, generally indicate that psychophysiological variables may have similar but not necessarily the same antecedents. Overall, the relationship is likely to be complex, and complicated further by their measurement, such as global as opposed to more specific, multi-dimensional measures of mood states. Individual differences and using laboratory compared to field settings could also produce discrepancies between studies. Arthur (1987) proposed that cortisol is more strongly linked to the anticipation of the event, and that anxiety does not stimulate cortisol response per se. In general, emotional anxiety is common in the days and hours prior to the onset of a stressful event, whereas the neuroendocrine response is close to the onset of the stress.

2.6.3 Field studies

Stress research in the past has often required the use of controlled laboratory settings and equipment. However the development of more sophisticated equipment to measure ambulatory responses non-invasively, has led many to advocate the use of field environments in order to broaden understanding the nature of stress (Neiss, 1988). Genuine sporting situations are especially suitable to examine stress, because they offer valid incentive and threat which are difficult, if not impossible, to create in a laboratory setting. For example, Jorna (1992) stated that often in laboratory settings, there are no genuine consequences for failure or realistic reasons to go to the limits of performance or endurance. Dimsdale (1984) suggested that in field environments there is unlikely to be a pure culture of subjective state, such as anxiety. Hence, the mixture of emotions experience in competitive sporting environments could not be genuinely evoked in a laboratory. Sports competition involves quantifiable performances so are suited for investigating

psychological state and human motor performance. Ecological validity of task demands and environments is important, as stress responses depend on the interaction between the individual and their environment (Hatfield and Landers, 1983). McCann et al (1992) found that anxiety responses were enhanced in real as opposed to laboratory competitive cycling conditions, even when the laboratory cycling was simulating the race ride with meaningful results for cycling coaches.

Neiss (1988) and Hatfield and Landers (1983) affirm the benefits of a multi-method approach because reliance on a single measure limits the potential amount of stress-related information. Additionally, such approaches better reflect the psychophysiological nature of the process and could lead to holistic understanding of stress (Neiss, 1988). A problem with multiple measures however, are the findings are likely to be complex and difficult to interpret. Physiological measures do not provide direct measures quality of an emotion, such as differentiating anxiety from fear, nor do they indicate the direction of the emotion such as positive (eustress) as opposed to negative stress (distress). Psychological inventories are subject to responders' biases, whether they are intentional or unintentional, but may compliment physiological information by allowing qualitative measures of stress. Because they are easier to administer, there has been a reliance on self-report measures in sport research (Martens et al., 1990). Neiss (1988) argues that because cognitive, affective and physiological components are known to interact and show interdependence, there is a need to investigate them conjointly as psychobiological states. They justify the present accumulation of data on discrete psychobiological states including affect and cognition in relation to human motor performance, could also be interpreted in the future.

Whilst acknowledging the benefits of field studies in providing greater provocation through more realistic stressors, Dimsdale (1984) acknowledged the poor control associated with field settings. The validity of field data may be compromised by the inherent lack of control

arising from many and varied extraneous variables inherent in field environments. Data may be difficult to interpret accurately, contributing to discrepant findings between studies. Field environments introduce methodological difficulties if measurement interferes with athlete's performance, but this situation is changing with the availability of portable, non-obtrusive measurement devices and the development of highly sensitive hormonal assays (Dimsdale and Moss, 1980). Future advances in technology will render the necessary equipment less obtrusive and less susceptible to movement and other artifacts. Harris et al. (1989) found that saliva collection to assess cortisol and testosterone did not impede competitive marathon runners who collected samples during the event in addition to pre and post-run. These allow a greater frequency of serial measurements to interpret stress responses.

Clearly the relationship between stress and performance is complex, with many individual and environmental factors interacting to elicit a response. By employing multiple measures of competitive stress, this thesis proposes to examine golfer's psychophysiological stress responses in genuine competitions.

2.7 Aerobic Fitness and Stress

Exercise is beneficial for physical health and psychological well-being in humans, and may play an important role in stress management (Kerr and Vlaswinkel, 1990; Petruzzello et al. 1991). Physical fitness has been found to diminish responses to life (global) stress in middle aged men and women (Roth and Holmes, 1985). Additionally, exercise may reduce anxiety responses to specific psychosocial stressors (Crews and Landers, 1987). Schwartz et al. (1978) found that physical exercise and meditation both reduced anxiety, but exercise reduced the somatic (or physiological stress) component whilst meditation reduced both cognitive and somatic symptoms. Exercise and the mediating effects of aerobic fitness on

reducing psychophysiological responses to stressors is unclear, however Rostad and Long (1996) proposed that exercise may influence emotions because it is a form of relaxation, in addition to providing time for problem solving. Adaptations in cardiorespiratory and neurohormonal systems with physical training are postulated to reduce emotional stress responses, such as anxiety. Exercise as a coping strategy for stress has examined the role of aerobic fitness and the prevention of ischaemic heart disease and the treatment of depressive illness and chronic anxiety, however the role for aerobic fitness in reducing competitive stress in low-aerobically demanding sports, such as golf has yet to be examined.

2.7.1 Physiological adaptations to exercise training

Chronic exercise stress induced by physical (aerobic) training, reduces sympathetic and neuroendocrine responses to subsequent acute exercise bouts. The level of aerobic training required to induce beneficial changes in physiological systems, or a training effect, involves vigorous and sustained exercise (utilising large muscle groups) for between 20 to 60 minutes, three times per week for at least eight weeks (Rostad and Long, 1996; Petruzzello et al., 1991). Functional changes in cardiovascular activity are mediated through peripheral and central changes in the sympathetic nervous system (Galbo, 1983), whereas longer term training may be required to mediate adrenomedullary responses (Kjaer, 1992). The same systems which adapt to physical stressors, such as the autonomic nervous system (ANS), SAMS and HPA, are also involved in psychological stress responses. Hence, diminished physiological stress responses to stressors, or faster recovery times are equated to an increased coping efficiency.

Enhanced aerobic capacity, typically found in fit individuals, is evident by their lower resting heart rates, faster heart rate recovery after exercise and greater maximum aerobic power ($VO_2\text{max}$) (Astrand and Rodahl, 1977). Enhanced heart stroke volume allows these

persons to sustain exercise for longer and with a lower heart rate for a standardised workload. Training decreases noradrenaline and adrenaline responses to absolute submaximal workloads (Kjaer, 1992). Training adaptations to the HPA axis may result in lower ACTH and cortisol responses to submaximal workloads (White et al., 1976; McDowell et al., 1992) and increased cortisol and ACTH responses following a severe exercise (supramaximal) load (Farrell et al., 1987). After four months of aerobic training, White et al. (1976) found reduced cortisol responses to graded exercise in trained middle-aged individuals compared to a sedentary group. Luger et al. (1987) found that using absolute workloads was crucial in measuring attenuation of HPA activity at submaximal exercise loads. Buono et al. (1987) used absolute submaximal workloads and measured ACTH responses, before and after a 12 week training program. An 11% increase in VO_{2max} resulted in a significant reduction in ACTH post training, whereas there was no change in ACTH concentration in a control group who received no training. Training therefore may influence cardiovascular and HPA responses at submaximal workloads, resulting in lower heart rates, decreases in cortisol concentration and its regulating hormone ACTH.

2.7.2 Aerobic fitness psychological stress responses

2.7.2.1 Cross-sectional studies

Increased levels of fitness are also associated with increase feelings of psychological well-being (Roth and Holmes, 1985). To examine the relationship between aerobic fitness and psychological stress, stress responses in groups of fit individuals have been compared to those of less fit counterparts. These cross-sectional studies have measured physiological responses prior to, during and/or after psychologically stressful tasks. Experimental designs have often used heart rate as a dependent variable (Crews and Landers, 1987), and employed either one (Holmes and Roth, 1985) or more (Hull et al., 1984; Plante and Karpowitz, 1987) psychologically stressful tasks. These tasks ranged from cognitive tasks,

such as memory tasks or mental arithmetic, to passive tasks such as cold pressor tests and films of industrial accidents.

Fit individuals have shown a faster heart rate recovery post-stressor compared to unfit individuals (Sinyor et al., 1983; Keller and Seraganian, 1984). Holmes and Roth, (1985) and Hull et al. (1984) found heart rate attenuation in fit groups during the psychological stressful period, but Light et al.(1987) found no evidence for this effect in fit groups exposed multiple stressors (in series). Studies employing the same psychological stress task have reported different heart rate responses (Hull et al., 1984; Light et al., 1987), which suggests that individual or methodological differences may contribute to the findings, rather than the stimulus per se. Plante and Karpowitz (1987) corrected for differences in baseline heart rates for high, low and medium fit groups exposed to psychological stressors, and found this negated fitness-related differences in heart rate responses. Other studies have examined cardiovascular responses to psychological stressors by measuring other parameters of cardiac function. Shulhan et al. (1986) found that T-wave amplitude was attenuated in the fit group, whilst Cantor et al, (1978) found differential responses in blood pressure and skin temp between the two groups. Neither of these studies found differences in heart rate responses.

Cross-sectional study designs which have measured self-reported anxiety responses together with cardiovascular and sometimes hormonal responses to psychological stressors, have produced diverse findings. When comparing fit and unfit groups to arousing film stimuli and an exercise task, Cantor (1978) found no correlation between actual physiological responses and two questions assessing self-reported emotion responses and perceived physiological arousal. Fitness level therefore, did not alter self-reported emotional or somatic responses to the psychologically arousing stimuli. Holmes and Roth (1985) measured cognitive and somatic anxiety responses on a scale of 1 to 5, by

individuals retrospectively reporting stress during the psychological task. Although fit subjects showed smaller pulse rate increases in response to stress than low fit subjects, the subjective responses to stress were similar. Sinyor et al (1983) measured heart rate, cortisol, catecholamines, and self-reported anxiety and arousal in 15 highly trained and 15 untrained subjects before, during and following exposure to a series of psychosocial stressors. Heart rate and subjective arousal increased during the stressor in both groups. Trained subjects showed higher levels of noradrenaline (NE) and prolactin early in stress, more rapid heart rate recovery following the stressors, and lower levels of anxiety at the conclusion of the session. Sinyor et al. (1983) suggested that trained individuals recover faster in both physiological and subjective dimensions of emotionality. After performing a meta-analysis, Crews and Landers (1987) concluded that irrespective of whether psychological or physiological dependent variables were examined, aerobically fitter individuals show attenuated responses to psychological stress.

Aside from the meta-analysis, the inconsistencies between cross-sectional studies may be attributed to the range of subjects tested, the different types, number, duration and magnitude of psychological tasks employed (Holmes and Roth, 1985), along with the different number and types of dependent measures. Often, the definition of high fit and low fit groups was not clearly delineated. For example, Holmes and Roth (1985) selected the ten highest and ten lowest fit persons from 75 candidates and measured a heart rate difference to a psychological stressor. This indicates that only extreme differences in fitness level may reveal an effect on heart rate. In some studies fitness categories were subjective, distinguishing fit and unfit on the basis of activity questionnaires assessing an individual's participation in aerobic activities. Fitness should be more appropriately defined in physiological terms, with maximal VO_2 testing in preference to estimates from submaximal testing. Without this, a genuine distinction cannot be made between the two groups. A study by van Doornen and de Geus (1989) used subject groups with largely different

fitness levels based on VO_2max tests, namely $48 \text{ ml.kg}^{-1}.\text{min}^{-1}$ and $67 \text{ ml.kg}^{-1}.\text{min}^{-1}$. Heart rate was attenuated in the fit group, but the largest influence according to fitness level was on vascular parameters, such as pre-injection period, cardiac output and peripheral resistance.

Where correlational studies have shown differences according to fitness level, they do not allow conclusions as to whether enhanced aerobic fitness is causal (Fillingham and Blumenthal, 1992). For example, differences in fitness may be related to personality differences or characteristics inherent in those predisposing them to participate in exercise. Subsequently, training protocols have been employed. Also, Myrtek and Spital (1986) questioned the relevance of these single stressor laboratory studies to responses in real-life situations. They argued that natural settings involve multiple stressors, and found that responses differed accordingly. Comparing psychophysiological responses including heart rate and blood pressure, to a single stressor then a series of psychological stressors, they found physiological responses were synergistic. The theoretical importance, they believed, was that naturalistic settings involve combinations as opposed to single stressors and that real-life settings should also be used to examine the relationship between aerobic fitness and physiological responses.

2.7.2.2 Training studies

Studies employing training interventions, where stress responses are measured before and after aerobic training in the same individuals, can determine whether aerobic fitness is causal in attenuating physiological responses to psychological stressors. Jasnoski et al. (1981) emphasised the need for appropriate control groups to attribute psychological changes to aerobic fitness per se. In their study, they found that 20 women participating in the aerobic program not only increased aerobic fitness, but also their self-perceptions. Group participation and achieving set fitness goals increased their ability and confidence in

physical areas, such as running greater distances, as well as non-physical areas, such as tolerating frustration compared to a control group.

Blumenthal et al. (1990) employed a controlled longitudinal study on thirty-seven Type A males, who were randomly assigned to either a 12 week aerobic exercise or a strength training group. Compared to the strength training group, an increase in $VO_2\text{max}$ from 33.6 to 38.4 $\text{ml.kg}^{-1}.\text{min.}^{-1}$ with training, resulted in the aerobically fit group showing reduced heart rate, blood pressure and epinephrine concentrations during and after a 15 minute mental arithmetic challenge. Although the increase in epinephrine was small and may be attributed to the novelty of task participation, they concluded that aerobic fitness was causal in reducing cardiovascular and sympathoadrenal responses to mental stress. In a study using middle aged, non-Type A men, Sothman et al.(1992) were unable to support Blumenthal's findings. They found no evidence that a 16 week aerobic training program altered catecholamine, heart rate or state anxiety responses to an 18 minute Stroop test in fit individuals. The participants who underwent training were selected on having initially low $VO_2\text{max}$ s, and Sothmann et al. (1992) was able to achieve a 20% increase in $VO_2\text{max}$ across the 12 subjects. However they acknowledged that the control group did not actually control for participation effects described by Jasnoski et al. (1981). A study by de Geus et al., (1990) examined high and low fit groups' responses to psychological stressors, prior to all individuals undergoing a seven week aerobic training program. The fitter subjects showed lower absolute heart rates during the stressful tasks pre-training. Further aerobic training however failed to effect further changes in cardiovascular effect or recovery to the psychological stress in either group. Training of longer than seven weeks may have been required to initiate a change. Keller and Seraganian (1984), following on from a correlational study, randomly assigned the participants to 10 week exercise training, music appreciation or meditation group. They concluded that aerobic training enhanced recovery from a stressful mental task as measured by electrodermal measures.

A criticism of laboratory settings and the types of psychological stressful tasks they employ, is related to their relevance for real life stress situations. Matthews et al. (1986) compared a natural stressor, that is speech making, with a laboratory stressor which was a serial subtraction task, in the same individuals. The pre and post stress differences in heart rate, systolic blood pressure and state anxiety were significantly greater with speech making and they concluded psychological stress in naturalistic settings had a more potent influence on cardiovascular variables compared to laboratory stressors. Brooke and Long (1987) compared nine high and low fit individuals psychophysiological responses to a real-life psychological stressor, namely rappelling. The high fit group had VO_2 max averaging $58 \text{ ml kg}^{-1} \cdot \text{min}^{-1}$ whilst the low fit was averaging $48 \text{ ml.kg}^{-1} \cdot \text{min}^{-1}$. For these novice rappellers, the fit group showed greater coping efficiency according to a criteria of faster recovery from subjective anxiety and plasma epinephrine measured directly after the task, and 15 and 30 minutes into recovery. The pre and post response differences in stress reactivity across the measures did not vary according to fitness level. The high fit group maintained overall lower absolute heart rates, but otherwise the two groups did not show differential heart rate activity to the psychosocial stressor. Unlike Sinyor et al (1983) they did not find that fitness resulted in a faster recovery of heart rate. This was possibly due to their more stringent measures of baseline heart rates, which were measured on a separate day to the stress task. Brooke and Long (1987) also measured other physiological parameters, including noradrenaline and plasma cortisol. Similar to heart rate, they found these did not parallel the faster recovery time of adrenaline. Serum cortisol response to the stressor were no different in high and low fit groups, and showed a large anticipatory response to the stressor in both groups which remained elevated 30 minutes after the task.

There is currently no strong support for a consistent relationship between aerobic fitness and the psychological responses to stress when measuring cardiovascular or hormonal

parameters. However, some positive results from individual studies indicated that methodological differences may largely account for variations between the studies. Measures of cardiovascular and hormonal parameters in naturalistic settings and psychosocial stressors and the increased potency of the response, may provide further evidence.

2.8 Summary and Conclusions

Stress has been extensively studied in many scientific disciplines including sport science, where stress, anxiety and arousal have been implicated in sporting performance. There is general agreement that stress is a complex psychophysiological process, but there is yet to be consensus on a single definition of the term. Real or perceived factors or stressors in a persons environment are recognised as evoking psychological and physiological changes to the internal milieu, as part of a stress response. Such changes are appropriate for an individual to respond to environmental demands, however there are health implications with prolonged exposure to stress. Acute stress responses are common in sportspeople in competition environments with strong anecdotal support in the literature between individual's perceptions of psychophysiological stress responses and increased pressure on subsequent performance.

Anxiety is a common emotional response to competition environments, and has been measured prior to and at the conclusion of competitive performances, across different sport types and in athletes of different ability levels and genders. Sport psychologists have more recently conceptualised anxiety as a multidimensional concept, differentiating between cognitive dimensions such as worry about performance, and physiological (somatic) dimensions, such as their perceptions of racing heart rate, increased sweating and butterflies in the stomach. In accordance with these more specific definitions of the state anxiety construct, specific anxiety-performance hypotheses have been examined based on

high levels of anxiety having a negative influence on sports performance. There has been no strong and consistent support for a relationship between self-reported state anxiety and sport performance, rather the research has highlighted the complexity of the relationship. This is further emphasised by research which has found competitive anxiety or elevated psychophysiological arousal may be beneficial to sports performance.

Self-report measures of competitive state anxiety, such as the Competitive State Anxiety Inventory (CSAI-2), have been used more extensively than physiological measures of stress or arousal, to examine stress in sporting contexts. Knowledge regarding anxiety and performance has progressed, however there are many questions which remain unclear. Various methodological and measurement recommendations have been advocated, including the use of ecologically valid sporting environments, the use of psychometric measures together with physiological measures, intra-individual comparisons for stress and performance analysis, and employing psychophysiological measures during sporting events. The more recent development and validation of salivary cortisol techniques are advantageous for field studies to measure biochemical responses to psychological and physical stress paradigms. Cortisol is an index of HPA activity, and provides a more sensitive indicator of psychological and physical stress, compared to heart rate which reflects general activity of the autonomic nervous system. Compared to moderate and high levels of physical exertion ($> 60\% \text{ VO}_2\text{max}$), psychological factors evoke small increases in cortisol concentration in serum or saliva, above the normal resting (basal) cortisol concentration. Psychological factors such as novelty, anticipation of events where the outcome is unpredictable and/or ego-involving, such as public speaking and academic examinations elicit increased HPA activity. Salivary cortisol has been employed to measure adrenocortical responses before, during and after competitive marathon running, but longer duration, low intensity sports such as golf have not been studied.

The literature does not provide strong and consistent evidence for a relationship between psychological and physiological parameters of stress, having examined cortisol and global anxiety measures, or competitive anxiety with global measures of physiological stress or arousal such as heart rate. The concurrent measurement of salivary cortisol, heart rate and CSAI-2 state anxiety as psychophysiological parameters during competitive sport has not been examined. Relationships between psychophysiological measures may be strengthened by the use of valid tasks in genuine sporting environments. Such environments are advocated as eliciting a more potent psychophysiological response than contrived competitions in laboratory settings. A disadvantage of field studies, however, is the inherent lack of control for non-stress related factors which may influence heart rate in particular.

Anecdotal accounts of golfers experiencing pressure in competition are frequently cited in the literature. Theoretically, fine motor skills and neuromuscular co-ordinations which are important in golf shots, may be adversely influenced by limb tremor, and loss of attention and concentration associated with high levels of stress. Empirical evidence for different psychophysiological states experienced by golfers in competition compared to practice has been less frequently examined, with little indication on how these might change during golf performance. There is no consistent support for psychophysiological responses, in particular anxiety, and an influence on golf performance, which may arise from only a few studies and differences in methodologies accounting for the variations in findings. There is evidence that aerobic fitness modifies psychophysiological responses to stress, yet the support in the literature is not consistent. Training paradigms allow conclusions as to a cause and effect relationships between aerobic fitness and stress responses.

Chapter 3

METHODS

3.1 Overview

This chapter provides an overview of the golfers tested, data collection, testing procedures and treatments common to the three main studies in this thesis. The study design for Chapters four and five are similar, but differ slightly in the intervention study (Chapter six). Further methodological details are included in the Methods sections for the separate chapters (Chapters four to seven inclusive).

The current chapter comprises seven sections. Section 3.2 describes the three groups of golfers participating in the research: trainee professional (PRO, Chapter four), recreational (REC, Chapter five) and elite amateur (AMA, Chapter six). Section 3.3 outlines the study designs used for golf testing. The next two sections include the data collection and treatment for psychophysiological (Section 3.4) and golf round (Section 3.5) measures. Psychophysiological parameters include salivary cortisol (3.4.1), heart rate (3.4.2) and the Competitive State Anxiety Inventory-2 (CSAI-2) (3.4.3). The section on golf data collection describes the recording of shot types, ball strike times and 'events' such as the time spent on each hole and on the putting green, in addition to methods used to standardise golf performance scores (3.5.1). Section 3.6 describes game conditions and treatments, including competition and practice games (3.6.1) and familiarisation procedures (3.6.2). Section 3.7 provides an overview of the statistical procedures and presentation of the data.

3.2 Participants

A total of forty-two male golfers participated in one of the three studies (Chapters four to six) comprising this thesis. Twenty-three elite golfers (PRO and AMA) had golf handicaps of five and below, whilst nineteen golfers were recreational players (REC) with handicaps from 6 to 24.

Table 3.1 Descriptive statistics (mean \pm SEM) for the golfers participating in the three studies (Chapter four, five and six).

Chapter	Golfer	Sex	n	Age (SEM) yrs	Height (SEM) cm	Body mass (SEM) kg	Handicap (SEM) stroke
Four	PRO	m	15	22.5 (0.4)	180.1 (0.7)	82.3 (1.3)	3.8 (0.5)
Five	REC	m	19	52.3 (3.7)	176.2 (2.2)	78.4 (2.6)	11.0 (0.7)
Six	AMA	m	8	20.8 (1.4)	175.8 (2.2)	70.6 (2.9)	2.8 (0.5)

Prior to the recruitment of participants, ethics approval was obtained from the Victoria University Human Research Ethics Committee. Eligible golfers volunteered for one of the three studies, then were provided with written accounts of the study purpose, protocols, benefits and risks. Each golfer signed a consent form with the understanding that they could withdraw from the study at any time. Participants were thoroughly familiarised with study procedures and equipment before testing commenced.

3.3 Study design

The research design for the three studies were similar. Golfers played two 18 hole stroke rounds of golf and psychophysiological data was collected four times during each round: prior to tee off (PRE), after hole 6 (H6), after hole 12 (H12) and at the completion of the game (H18). On each occasion, saliva was collected for cortisol analysis, immediately followed by the completion of the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Vealey, Bump and Smith, 1990) to measure state anxiety. These self-administered collections required no more than two minutes. Heart rate data was collected and stored at 15 second intervals by a heart rate monitor (Polar Sports Tester PE3000; Polar Electro, Finland) worn by each player for the duration of play. An observer followed each golfer and recorded details of the golf round including saliva and CSAI-2 sample times, golf shots played, time of shots and golf scores. Basal cortisol samples were collected on separate resting days (Basal 1 and Basal 2) to determine baseline cortisol levels.

3.3.1 Golf testing procedures

On the designated golf testing day, players arrived at the golf course, a heart rate monitor was fitted and recording commenced. Players proceeded with a pre-game warm up routine. Ten minutes prior to their allocated tee time, each golfer collected a saliva sample, then completed the first psychometric measure of competitive A-state (CSAI-2). Saliva was collected prior to state anxiety measures on each occasion, in case anxiety cognitions from the questionnaire confounded the cortisol data. Each golfer was a member of a group of three players. An observer followed the group at a discrete distance behind play, and collected data on sampling times and golf play. After golfers completed play on hole 6, the player collected the second saliva sample and responded to a second CSAI-2 questionnaire. The same procedure was repeated at the completion of holes 12 and 18. Within one week

of the golf round, each golfer underwent a basal testing day (Basal 1). Golfers were restricted to mild activity (no golf) and collected six saliva samples at hourly intervals, spanning the hours of the preceding golf round. Individual basal (resting) cortisol curves were established, and subsequently used to control for diurnal changes in cortisol concentration. Each golfer was subsequently re-tested on the same ($n=38$), or similar ($n=4$) course within one month of the first golf round. The same procedures were followed as outlined above, with the starting (tee-off) time in the second game as close as possible to that of the first. The second basal day (Basal 2) was completed within a fortnight of the second round, following the same procedures as Basal 1. At the conclusion of the study, golfers were debriefed to deal with any concerns arising from the study and were presented with a copy of their individual and aggregate group results.

In the PRO and REC studies (Chapter four and five), golfers played a competition and practice golf round. Two competition rounds were used in the AMA study (Chapter six), with the second round following an aerobic training intervention. For PRO and REC golfers, the aim was to randomise game order with half the golfers completing the competition before the practice round. As detailed in the Methods (Section 4.4.2), this was not practical for the PRO golfers. Additionally, as many golfers as possible were tested on the same competition testing day, to minimise differences in environmental conditions between players. Equipment resources restricted this number to twelve golfers. Therefore in this thesis, three competitions were required to complete testing for the PRO golfers, two for REC golfers whilst the AMA group were tested together in each competition round.

3.4 Psychophysiological data collection and treatment

3.4.1 Salivary cortisol

Stress-related HPA activity stimulates the adrenal cortex to release the hormone cortisol into the blood serum (Ur, 1991). The plasma concentration of free (unbound) hormone can be determined from saliva (Walker et al., 1978).

3.4.1.1 Saliva collection

To collect PRE, H6, H12, H18 samples during golf testing and basal samples, participants allowed saliva to accumulate in the mouth for 60 seconds before expelling the sample (approximately 1.5 to 2ml) into a 5ml screw-top plastic vial. This was similar to Cook et al.'s, (1987) study using marathon runners. Cortisol in saliva has been reported to be stable for several days at room temperature (Kirschbaum and Hellhammer, 1989). The saliva samples were frozen overnight, then transferred the following day to freezer storage (-80°C) until analysis.

3.4.1.2 Basal days

Golfers selected a suitable day within one week of the golf testing round, to complete basal data collection. They were required to refrain from strenuous physical exertion for 24 hours prior to and during the basal sampling period, including golf play or practice. Normal working activity such as walking, sitting and standing were permitted, but not heavy lifting. Each golfer was provided with six plastic 5ml screw top vials, appropriately labeled with the individual's name and required sampling time. Each person collected approximately 2ml of saliva according to the procedures already described into the appropriate tube, and entered the actual sample time (hr:min) on a recording sheet. The sample times for basal collection were determined from the preceding golf round. The first sample time was approximately 30 minutes prior to the tee-off time with subsequent

samples collected at hourly intervals for the next five hours. Each golfer's samples were used to generate individual basal curves (described later in this section).

3.4.1.3 Determination of saliva cortisol using radioimmunoassay (RIA)

Cortisol concentration was determined from duplicate 200 μ l non-extracted saliva samples in the PRO study (Chapter four) using Radio Immuno Assay (RIA) techniques (Clinical Assays; Gamma Coat [125 -I] Cortisol Radioimmunoassay Kit, CA-1549). The scatter plot compiled from this duplicate data in Figure 3.1 shows a high test/ reliability ($n=276$, $r=.87$). Due to this high reliability and the cost of the cortisol assay, it was decided to perform single analyses on samples collected in subsequent studies (Chapters five and six).

Each player's total number of saliva samples (golf round plus basal samples) was thawed one hour prior to the assay and analysed in the same batch. After thawing, saliva samples were vortexed then centrifuged, at 3600rpm for 5min. All samples and reagents for the assay were allowed to reach room temperature. The assay was performed in antibody coated tubes (rabbit anti-cortisol serum; titre < 1 μ g/tube). A serum blank and five serum cortisol standards were prepared in duplicate, by adding 10 μ l of cortisol serum standard (1,3,10,25,60 μ g.dL $^{-1}$) to 200 μ L of phosphate buffer solution (PBS). Standard curves were plotted for the range of concentrations from 0 to 80 nmol. $^{-1}$. A set of three known samples (Ligands 1, 2 and 3) with mean expected values of 8.7, 23.1 and 65.1nmol. $^{-1}$ respectively, were analysed as control samples. The expected concentrations versus actual concentrations for ligand samples are illustrated in Figure 3.2. To analyse the saliva samples, 200 μ l of saliva supernatant was added to 10 μ l of equine protein suspension (cortisol free). The protein suspension was added to the saliva samples to modify the serum assay for saliva analysis. This conformed with the manufactures recommendations (Smith and Lancon, in Perspectives). The radiotracer (4 μ Ci of 125 -I in 100ml PBS), was added to

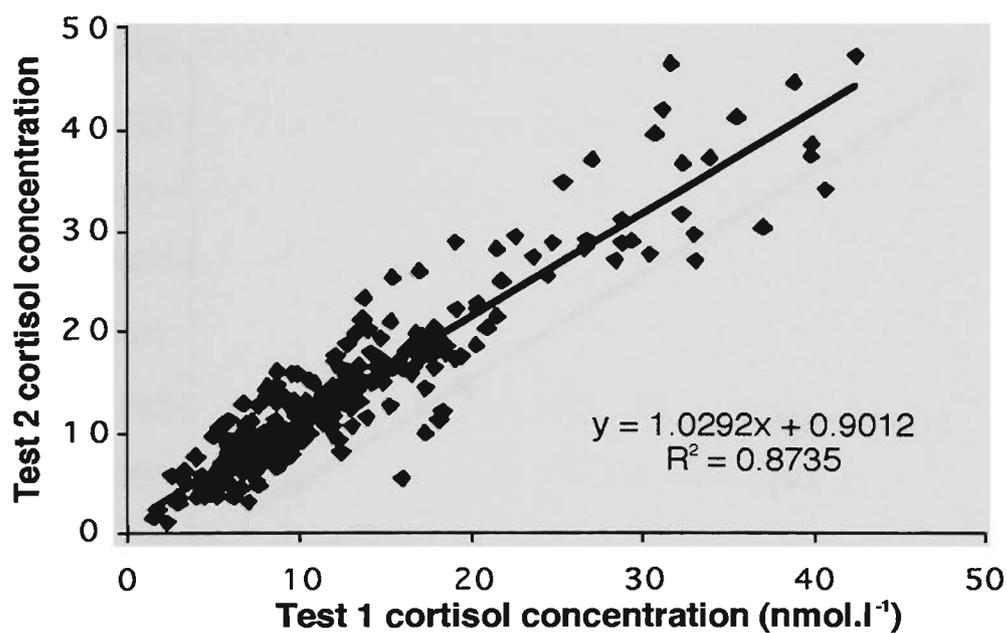


Fig 3.1 Test/re-test reliability for (n=276) 200 μ l duplicate cortisol concentrations (nmol.l⁻¹) measured using radioimmunoassay (RIA) for fifteen PRO golfers.

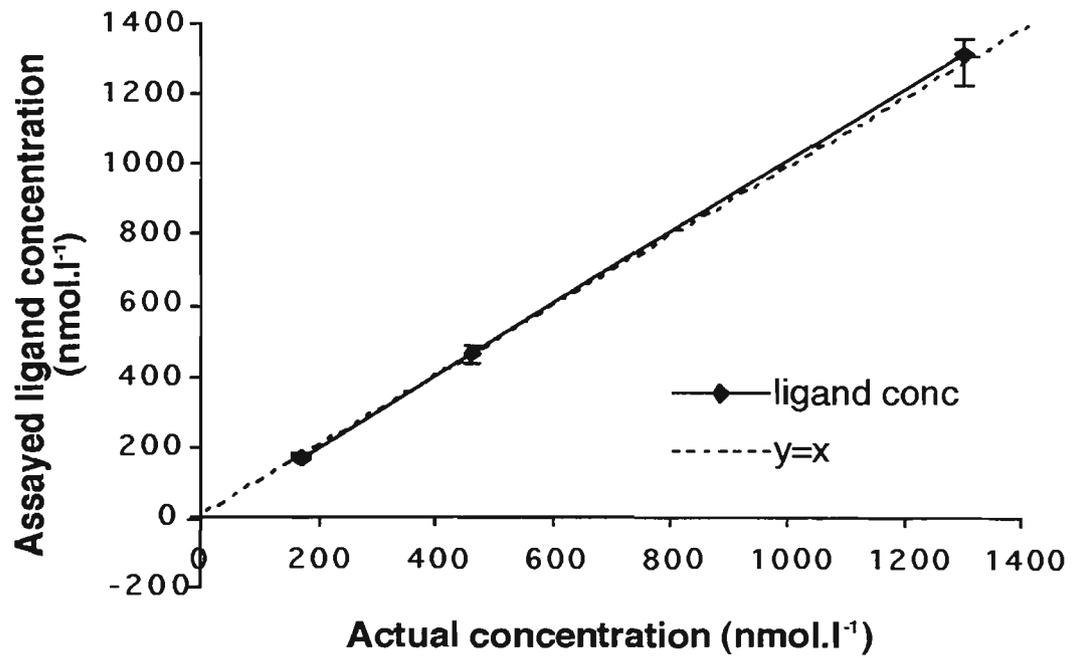


Fig 3.2 Actual versus assayed duplicate ligand (Ligand 1, 2 and 3) cortisol concentrations (nmol.l⁻¹) used as controls in PRO, REC and AMA studies.

each tube which was gently vortexed before incubating at 37 ± 2 °C for 45 minutes. Tubes were decanted by tipping and then allowed to drain for 3-5 minutes before counting. A gammacounter (LKB 1260 Multigamma, Wallac) was used to count each tube for 60 seconds, and unknown cortisol concentrations were calculated.

3.4.1.4 Correction for diurnal rhythm

Cortisol concentration varies with time of day according to a well-defined circadian rhythm in humans (Krieger, 1971). Appendix A.1 presents the group (n=15) basal curve for PRO golfers comprised from saliva cortisol samples collected on Basal Days 1 and 2, to illustrate the diurnal changes in this sample population of golfers.

Individual basal curves, rather than the group basal curve were used to calculate each golfer's cortisol responses at PRE, H6, H12 and H18 and control for diurnal cortisol changes. The six saliva samples collected on each basal day (Basal 1 and 2) were plotted against time of day to establish baseline curves. The four cortisol concentrations from the golf round were then plotted against time of day and the corresponding basal (baseline) value interpolated. The average value for Basal 1 and 2 was determined and this value used where the two curves overlapped. Finally the interpolated baseline value was subtracted from the corresponding golf round cortisol concentration, to determine cortisol responses ($\text{nmol}\cdot\text{l}^{-1}$) at PRE, H6, H12, H18. This thesis reports cortisol responses ($\text{nmol}\cdot\text{l}^{-1}$) representing a positive deviation from baseline. The rationale for this is to correct for diurnal changes expected in baseline cortisol when measuring adrenocortical responses over long periods of time (Kirschbaum and Hellhammer, 1989), in this case approximately five hours, and also to control for golfers commencing their golf rounds at slightly different times of day. (See example in Appendix A.2)

3.4.2 Heart rate

The time of day (hr:min:sec) and heart rate ($\text{b}\cdot\text{min}^{-1}$) were automatically recorded at 15 second intervals and stored to memory using a Polar Sport Tester PE 3000 (Polar Electro, Finland). The transmitter device, housed in a plastic casing, was moistened before being placed against the chest wall. The elastic strap was secured to hold the transmitter in place. The watch receiver was attached to the back of the player's waistbelt, so the heart rate display would not be visible. The majority of golfers reported the heart rate monitor did not interfere with their golf swing or distract them during the game. After the game, the heart rates were downloaded.

The heart rate data was entered onto a spreadsheet corresponding to the time of day (hr:min:sec; refer to Appendix A.3). Each player's 15 second heart rate data ($\text{b}\cdot\text{min}^{-1}$) was entered across four columns, which were averaged (column 5) over each minute for holes 1 through 18. This format was necessary to determine heart rate responses for golf shots and heart rates during putting (Section 7.4). To calculate the average heart rate per hole (Chapter four, five and six), the 15 second data was averaged from the time the player entered the teeing area, to the time he exited the green (refer to Section 3.5).

3.4.3 Competitive state anxiety inventory-2 (CSAI-2)

Competitive state anxiety (A-state) was assessed with the Competitive State Anxiety Inventory-2 (CSAI-2; Martens et al., 1990) which is a self-report psychometric inventory consisting of 27 items (Appendix A.4). At the time this study was conceived and executed, the CSAI-2 was considered to be the most appropriate, well-validated, self-report measure of competitive anxiety. For the basis of comparison, the CSAI-2 was used in all three studies. The CSAI-2 assesses two components of state anxiety (A-state), cognitive worry and somatic anxiety, and a related construct, self-confidence, with 9 items representing

each subscale. The CSAI-2 has high reliability and validity (Martens et al., 1990) and has been widely used in research on anxiety in sport (Vealey, 1990). Each participant completed four CSAI-2 questionnaires (PRE, H6, H12, H18) for each golf round, immediately following saliva collection. Each CSAI-2 subscale is rated on a scale from 1= 'not at all' to 4 = 'very much so', relating to extremes of intensity. Each subscale, therefore, has a range from 9 to 36. Higher scores on cognitive and somatic anxiety indicate higher levels of anxiety, whereas higher scores on the self-confidence sub-scale correspond to higher levels of state self-confidence.

3.5 Golf round data collection and treatment

The details of each player's 18 hole golf round were recorded on a Golf Round Record Sheet (see Appendix A.5) by the observer following the group of golfers, and were used in later analyses. Prior to each golf round, the observer's watch was synchronised with the time displayed on the heart rate monitor. The times of day recorded by the observer for pre-determined 'event markers', were subsequently matched with the heart rate data. Event markers for each hole included: time the player walked (i) onto the tee area, (ii) onto the green and (iii) off the green. Time to play each hole was the difference between (iii) and (i). Time spent on the putting green was the difference between (iii) and (ii). Additional event markers included, the time (hr:min:sec) at ball strike for each golf shot and the type of shot. Ball strike was defined as the second at which the clubface was heard making contact with the golf ball. Shot types included tee shots (TEE); wood shots, long, medium and short irons and trouble shot (FAIRWAY); sand shots, pitch and chipping (APPROACH); and putts (PUTT). The rationale for categorising golf shots is explained in Methods (7.4). A performance score total for each golfer was determined as the sum of the number of golf shots played. Sample times (hr:min) for salivary cortisol were recorded upon their

collection at PRE, H6, H12, H18 and used to calculate cortisol responses. The local weather conditions were obtained from the Melbourne Metropolitan Weather Bureau.

3.5.1 Standardised performance scores

A performance outcome measure, namely golf score, was used to assess golfing performance. All performance scores reported in this thesis were standardised for ability level, as advocated by Sonstroem and Bernardo (1982), by subtracting each golfers' official golf handicap from their golf score. This compares current performance to seasonal averages and has previously been recommended for use with golfers (Krane and Williams, 1987). These intra-individual performance scores were calculated as 18 hole scores (SC18) and six hole average scores (ie.average scores for holes one to six (SC1-6), seven to twelve (SC7-12) and thirteen to eighteen (SC13-18). The latter were calculated for comparison with the psychophysiological data which was collected at six hole intervals (Chapters four and five). These six hole average scores were standardised by subtracting one-third of the total handicap allowance from each of the six hole averages.

3.6 Game conditions and treatments

3.6.1 Competition and practice games

All three studies were completed on metropolitan Melbourne golf courses, using competitions organised by official golfing associations. The golf courses selected for testing were located mainly in the "sandbelt" region because they are considered to have generally flatter terrain. Other criteria for golf course selection was the ability to have access to the same course for re-testing at the required time of day, and permission from the golf club to use the course for testing.

The PRO golfers (Chapter four) competed in a Professional Golfers Association (PGA) sanctioned tournament. These tournaments are played throughout the year on pre-arranged golf courses. The PRO golfers receive monetary rewards on tournament days, which supplements their trainee wages. Additionally, their tournament scores are used by the PGA to assess their playing standard. In the next study (Chapter five), a formal club competition (Monthly Medal) organised by The Spring Valley Golf Club, was used to test REC golfers. This event is popular, reflected by the large number of golfers entering to play, and winning is considered prestigious amongst the players. The winner, or golfer with the lowest nett (handicap adjusted) score, receives a club medallion. Monetary rewards are generally not permitted in amateur club level golf. In the third study, (Chapter six) the Australian Institute of Sport (AIS) golfers competed against each other in a competition format organised by the AIS coach. The lowest handicap-adjusted score on the day received monetary rewards from the other players in the group. Although the competition was considered a 'training competition' format, re-testing at the same course and time of day was ensured. Furthermore, selecting tournaments for testing to include a nine week period for training between games, would have meant using games played inter-state. This was not financially feasible in this study.

To standardise task demands (Gould and Krane, 1992), the practice round comprised an 18 hole stroke round played on the same golf course, commencing at the same time of day as the competition round. Players arranged to play in a group of three players. There was no incentive offered for golfers to score well on practice days.

3.6.2 Familiarisation

At least one week prior to commencing the first golf testing round, each golfer was familiarised with equipment and testing procedures. The individual was fitted with a heart

rate monitor and requested to hit golf balls on the practice fairway, chip and putt until they felt comfortable. Where possible, this same heart rate monitor was used for that player during the golf round because the chest-belt size did not have to be re-adjusted. Saliva collection procedures were explained prior to the golfer completing a trial collection, with particular instructions on collecting the required amount of saliva in the plastic vial. This sample was discarded. Players were also made aware that samples during golf testing may be slightly more difficult due to increased sympathetic activity causing the secretion of mucus (rather than serous) saliva. Golfers were also familiarised with the CSAI-2 questionnaire, being instructed to record their initial responses with minimal deliberation. Each player completed a second questionnaire while being timed, to complete the form within 90 seconds or less if possible. A second CSAI-2 and 5ml plastic vial to collect saliva was provided so that golfers could practice again before testing. Finally, the labeling of the four saliva vials and four questionnaires was explained, so there was no further instructions needed on golf testing days.

3.7 Statistical Presentation of the Data

To calculate the number of participants required to demonstrate a significantly greater cortisol response in competition compared to practice, a power test was performed for an effect size similar to that found in other saliva cortisol psychophysiological research (Cook et al., 1987; Cherek, 1982; Hiramatsu, 1981; Laudat et al., 1988; Port, 1991; Vining et al., 1983b). The data from all studies are reported as mean and standard error of the mean (SEM) for cortisol and heart rate, and mean and standard deviation (SD) for CSAI-2 subscales. This conforms with published data in these parameters (Port, 1991; Martens et al., 1990). Physiological data and standardised performance scores were generally analysed using a univariate approach with repeated measures design. Apart from the ANOVA's comparing differences between PRO, AMA and REC groups, ANOVAs

performed involved intra-individual data comparisons. The three studies (Chapter four to six), used 2 x 4 ANOVAs to analyse the effects for Game and Time (competition and practice by PRE, H6, H12, H18). Tukey's post-hoc analysis were used (Sokal and Rohlf, 1969) where further analysis was required. Psychological data was analysed using multivariate analysis (MANOVA) for the three CSAI-2 subscales (cognitive A-state, somatic A-state, and state self-confidence). A MANOVA was selected to control the risk associated with multiple ANOVAs of increasing Type 1 error. Further analysis was performed on the individual CSAI-2 subscales using separate ANOVA's.

Pearson Product Moment Correlation Coefficients (r) were calculated to compare the three CSAI-2 subscales (Chapters four to six), psychophysiological parameters (Chapters four) and psychophysiological measures and performance scores (Chapters four and five). Multiple (Quadratic) or Linear Regressions were used to determine whether performance scores predicted, or were predicted by physiological and psychological anxiety parameters. Students t-tests were conducted to determine if the means for AMA golfers (height, mass, VO_{2max}) in Chapter 6 were different in the pre- compared to post-aerobic training conditions. In general for statistical analysis, the .05 level of significance was accepted.

Chapter 4

PSYCHOPHYSIOLOGICAL STRESS IN PROFESSIONAL TRAINEE GOLFERS DURING COMPETITION AND PRACTICE

4.1 Overview

The current study (Chapter 4) is the first of two field studies investigating competitive stress in golfers by comparing psychophysiological stress responses in competition to those in practice. This study focuses on elite trainee professional golfers (PRO) during tournaments and further examines the relationship between psychophysiological variables and their relationship to performance score.

4.2 Abstract

This study investigated psychophysiological stress in fifteen male Professional Golfing Association (PGA) trainees (aged 21 to 25 years) during tournament play. Self-reported state anxiety (cognitive anxiety, somatic anxiety and self-confidence) measured by the Competitive State Anxiety Inventory-2 (CSAI-2; Martens et al., 1990) and physiological responses (salivary cortisol and heart rate) were measured during an 18 hole PGA sanctioned tournament and a practice round played on the same or similar golf course. Players completed the CSAI-2 and collected saliva on four occasions: prior to tee off (PRE), and after completing holes 6 (H6), 12 (H12) and 18 (H18). Cortisol concentration was corrected for circadian variations in cortisol secretion, using baseline cortisol measures

and performance scores were standardised for players ability level using seasonal performance averages (golf handicap). Within-subject analyses revealed elite golfers experienced elevated cortisol, heart rate, cognitive anxiety, somatic anxiety and lower self-confidence during competition when compared to practice. Salivary cortisol in competition and practice was lower at the conclusion of golf play, compared to those measured before and during the rounds, whilst state anxiety and state self-confidence showed no temporal changes across the competition round. There was no correlation between psychological and physiological stress parameters and between these parameters and performance, however, higher precompetition cortisol responses and low precompetition cognitive anxiety predicted 18 hole performance score. In conclusion, elite golfers experience changes in psychophysiological state consistent with competitive stress during tournament compared to practice golf, however these changes do not appear to have a strong influence on performance score.

4.3 Introduction

Stress is an inherent part of sports competition, especially for elite athletes whose skills are frequently tested in pressure situations. Professional golfers perceive competition environments differently, with some responding positively to the challenge whilst others feel debilitated and their performance suffers (McCaffrey and Orlick, 1989). Stress is manifested as a complex of psychophysiological changes (Pfister and Muir, 1992), often resulting in emotional, cognitive and physiological changes to the internal milieu of the sportsperson. For elite golfers especially, attaining appropriate mental and physical states during shot preparation and execution is considered a principal factor in successful performance (Crews and Boutcher, 1986b; Crews, 1994). Heightened muscle tension, lack of concentration, inability to visualise which often accompany increased feelings of pressure to perform, are often regarded as being detrimental to the performance of fine

motor skills (Cohn, 1991). Despite much anecdotal support for competitive stress in elite golfers, there is a paucity of studies which have measured these changes in golfers during practice and tournament situations. Such information could not only help verify whether elite golfers experience psychophysiological changes during competition but could assist in understanding whether such changes can influence their on-course performance.

Anxiety is a common emotional manifestation of stress in sport (Spielberger, 1989), with sport-specific measures such as the CSAI-2 (Martens et al., 1990), differentiating between cognitive, somatic anxiety and state self-confidence subcomponents. Multi-dimensional theory predicts that cognitive anxiety, or worry about performance, will have a strong and negative influence on golf performance. Weinberg and Genuchi, (1980) found that golfers with higher precompetition anxiety performed worse than those with lower anxiety, but in general the predicted relationship between precompetition anxiety subcomponents and golf performance has received little support (Krane and Williams, 1987; McAuley, 1985; Martens et al., 1990). Multidimensional anxiety research employing the CSAI-2 has generally measured state anxiety prior to and/or after golf tournaments (Cook et al., 1983; Krane and Williams, 1987; Martens et al., 1990; McAuley, 1985), which has led to some advocating that the anxiety-performance relationships would strengthen when measurements are made during golf performance (Martens et al., 1990; McAuley, 1985). As a broader approach to measuring competitive stress, others have recommended the use of physiological indices of stress as opposed to self-reported anxiety alone (Hatfield and Landers, 1983; Neiss, 1988). There is little evidence for a strong and consistent relationship between psychological and physiological stress variables, however the use of general measures of autonomic activity such as heart rate and global measures of anxiety, may have confounded such relationships. Salivary cortisol is a sensitive indicator of psychobiological stress (Ur, 1991), and has been employed in competitive sport to examine stress-related hypothalamus-adrenal pituitary (HPA) responses before, during and after

marathon running (Cook et al., 1987). In particular, marathon runners experienced elevated saliva cortisol concentration in anticipation to the start of the run. The non-invasive nature of saliva sampling offers the potential to examine adrenocortical responses to competition stress in low intensity, long duration sports such as golf. Additionally, the use of a more sensitive psychometric measure of sport anxiety (CSAI-2) together with saliva cortisol during tournament golf, may reveal a relationship between psychological and physiological (biochemical) parameters of stress.

The current study adopts a non-invasive, multi-method protocol to measure psychophysiological stress responses in professional trainee golfers during tournament golf and compare these with standardised golf performance scores at various times over 18 hole golf rounds. Identifying stress in elite golfers and understanding its relationship to golf performance is important to assist golfers better prepare and perform according to their ability in tournament situations.

Purpose:

The purpose of this study is to examine the effects of game condition (competition and practice) on psychophysiological stress parameters (state anxiety, salivary cortisol and heart rate) in professional trainee golfers, and the time course of changes in these individual parameters across the 18 hole golf rounds (pregame, after holes 6, 12 and 18). A second purpose is to examine the relationship between psychophysiological parameters and performance score.

Hypotheses

1. Saliva cortisol, heart rate, cognitive and somatic anxiety is higher and self-confidence is lower in competition in professional golfers than in practice.
2. Saliva cortisol is higher in anticipation of the start of play in competition compared to practice.
3. The CSAI-2 subscales, (cognitive, somatic and self-confidence) will show moderate correlations with one another indicating they are related, yet independent psychological measures.
4. Cortisol responses will correlate positively with somatic anxiety.
5. Cognitive anxiety is more highly correlated with performance score during golf play than somatic anxiety.
6. Cognitive anxiety influences subsequent performance scores (examined for six hole intervals) and is negative in affect.
7. Performance score is predicted by changes in the individual parameters and combinations of psychophysiological parameters.

4.4 Methods

4.4.1 Participants

Fifteen male professional golfers (handicap 3.8 ± 0.5 ; age 22.5 ± 0.4 years; height 180.1 ± 0.7 cm; body mass 82.3 ± 1.3 kg; mean \pm SEM) volunteered for the study. All

participants were enrolled in the Professional Golfers Association (PGA) Traineeship Scheme, which qualified them as golf professionals after a three year period. To successfully complete a traineeship, these players are required to meet a golf playing standard assessed by the PGA during official tournaments. These tournaments were scheduled throughout the year and were organised six months in advance. Forty tournament performances were averaged for each golfer, which determined whether they passed or failed the year level. Players who fail may be allowed to repeat that year. These golfers are deemed professional under the rules of golf, because they earn their living from the game. Players receive a salary from working under the guidance of a trained professional at a golf club, but earn additional money from playing tournaments. For the purpose of this study, these professional golfers are considered elite, with playing averages of five and below. Approval was sought from the PGA to test their trainees during PGA tournaments. From a total of twenty golfers contacted, two declined to participate, and three golfers were unable to complete all the testing requirements. The fifteen golfers were reported as healthy, and only one participated in physical training outside golfing commitments.

4.4.2 Design

The study design is described in Methods (Section 3.3), with specific methodological details as follows. In the current study, it was considered intrusive for PRO golfers to alter their normal pre-tournament warm-up routines which comprised of one or more of stretching, practice swinging, hitting golf balls and finally putting before teeing off. In addition to slightly different pre-game activities, the consumption of food, drink and smoking was according to the players discretion. To control for these factors, each player agreed to follow similar activities and food and beverage consumption across both golf games.

Each golfer completed the tournament round before the practice round, to maximise the number of golfers re-tested on the same golf course and time of day. The aim was to randomise game order, however, this problem arose because the tournaments were frequently re-scheduled by the PGA due to changes in golf course availability. If practice rounds had been completed before the competition round at the designated tournament venue, there was no guarantee that the tournament would eventuate on that same course. The golfers therefore, were thoroughly familiarised with the study prior to testing as this was important to reduce any novelty influences which may arise through a game order effect (see Section 4.4.4). All golf testing commenced in late winter and was completed by early spring to minimise seasonal variations in temperatures which may influence heart rate measures.

4.4.3 Measures

Salivary cortisol and basal days

The collection, treatment and analysis of cortisol is detailed in Methods (Chapter 3.4). Saliva samples were analysed from duplicate 200 μ l non-extracted saliva samples by Radio Immuno Assay (RIA).

Heart rate, CSAI-2, golf round data collection and performance score

These measures are as detailed in Methods (Sections and Sub-sections 3.4.2.; 3.4.3; 3.5; and 3.5.1 respectively).

4.4.4 Treatments

Familiarisation

The familiarisation procedures for the PRO golfers are detailed in Methods (Sub-section 3.6.2). Familiarisation was an important aspect of this study for two reasons. Firstly, to minimise the potential novelty effects confounds on game condition (see Section 4.4.2), and secondly, it allowed more efficient sample collection, thereby minimising testing-related distractions to the golfer and interruptions to the flow of golf play.

Competition

The competition round was a PGA sanctioned tournament, which comprised a significant sport contest where players compete for monetary rewards in addition to the scores contributing to player's yearly ranking. The PGA tournaments are played on Victorian golf courses, in the Melbourne metropolitan and country areas. From the tournament schedule, four Melbourne golf courses of similar length and flat terrain were chosen for testing. This was to minimise extraneous responses on heart rate imposed by variable terrain. Testing was performed during late winter to early spring, where ambient temperatures are cooler than summer to reduce heat related influences on heart rate data.

Practice

Eleven players were retested on the same four golf courses and at similar times of the day. Two additional golf courses were required to complete practice round testing. The golf courses were of similar lengths (6134 ± 41.5 metres). There was no incentive offered for players to score well during practice rounds.

4.5 Results

Psychophysiological parameters and game condition

To examine the effects of game condition and time on physiological parameters, separate intra-individual repeated measures ANOVAs were used. Values are mean \pm SEM.

4.5.1 Cortisol

The mean cortisol responses for the PRO golfers measured at PRE, H6, H12 and H18 for competition and practice rounds are illustrated in Figure 4.1. Salivary cortisol responses analysed by a Game x Hole (2 x 4) two-way repeated-measures ANOVA revealed cortisol was significantly higher in competition (5.8 ± 1.6 nmol.l⁻¹) compared to practice (2.4 ± 1.1 nmol.l⁻¹; (F(1,14) = 6.62, p<.02). Analysis revealed a significant effect for hole (F(3,42) = 4.14, p<.02), but no interaction (F(3,42)=1.10, p=.36). Univariate F tests located the significant differences to postgame (H18; 2.6 ± 0.7 nmol.l⁻¹), compared to the other three times for competition and practice (PRE, H6, H12; 4.6 ± 1.6 nmol.l⁻¹; F(1,14) = 14.03, p<.002). Tukey's revealed that in competition, cortisol measured at PRE and H18 just failed to reach significance.

4.5.2 Heart Rate

The golfers' average heart rate responses for holes 1 to 18 in competition and practice, are shown in Figure 4.2. A Game x Hole (2 x 18) two-way repeated-measures ANOVA revealed that heart rate was significantly higher in competition compared to practice rounds (117 ± 3.0 and 100 ± 3.0 b.min⁻¹, respectively; (F(1,14) = 38.45, p<.001). There was no significant interaction (F(17,238) = 1.34, p=.17), but there was a significant hole effect (F(17,238) = 3.74, p<.001). Univariate F tests located these differences to H18, H17, H16, H6 and H2 (competition and practice) being significantly greater than the combined means of the holes prior (p<0.05). Other factors concerning game conditions were

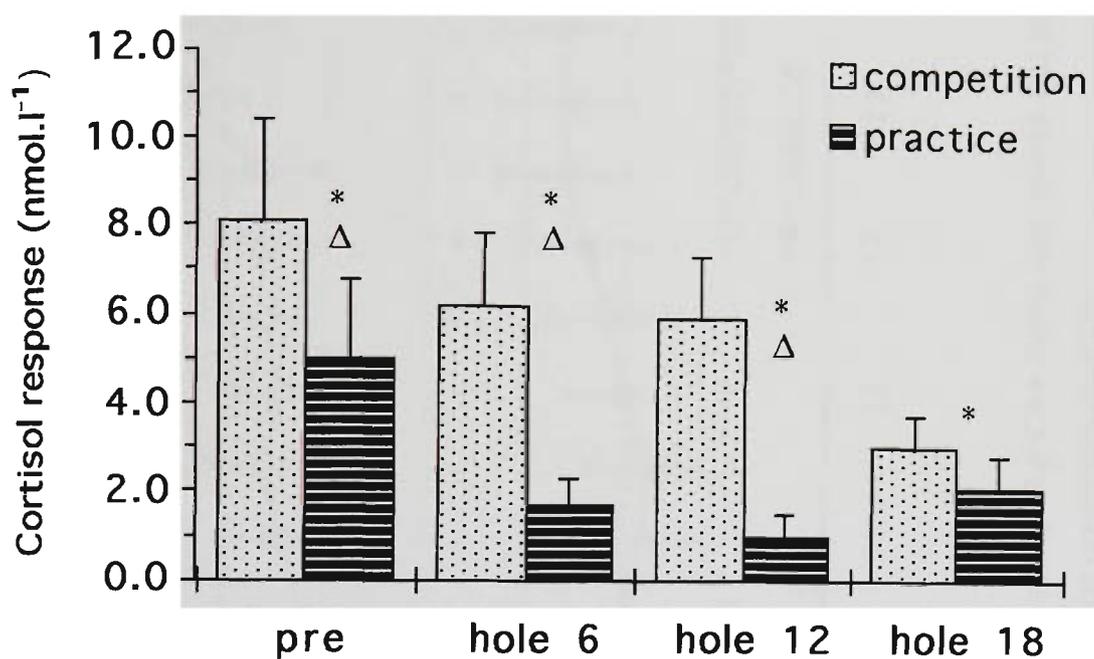


Fig 4.1 Cortisol responses (nmol.l⁻¹) for n=15 PRO golfers at pregame (pre), hole 6 (H6), hole 12 (H12) and hole 18 (H18) for competition and practice rounds. Values are mean \pm SEM. * denotes difference between game conditions, Comp>Prac ($p < 0.02$); Δ denotes a difference from H18(Comp and Prac), ($p < 0.05$).

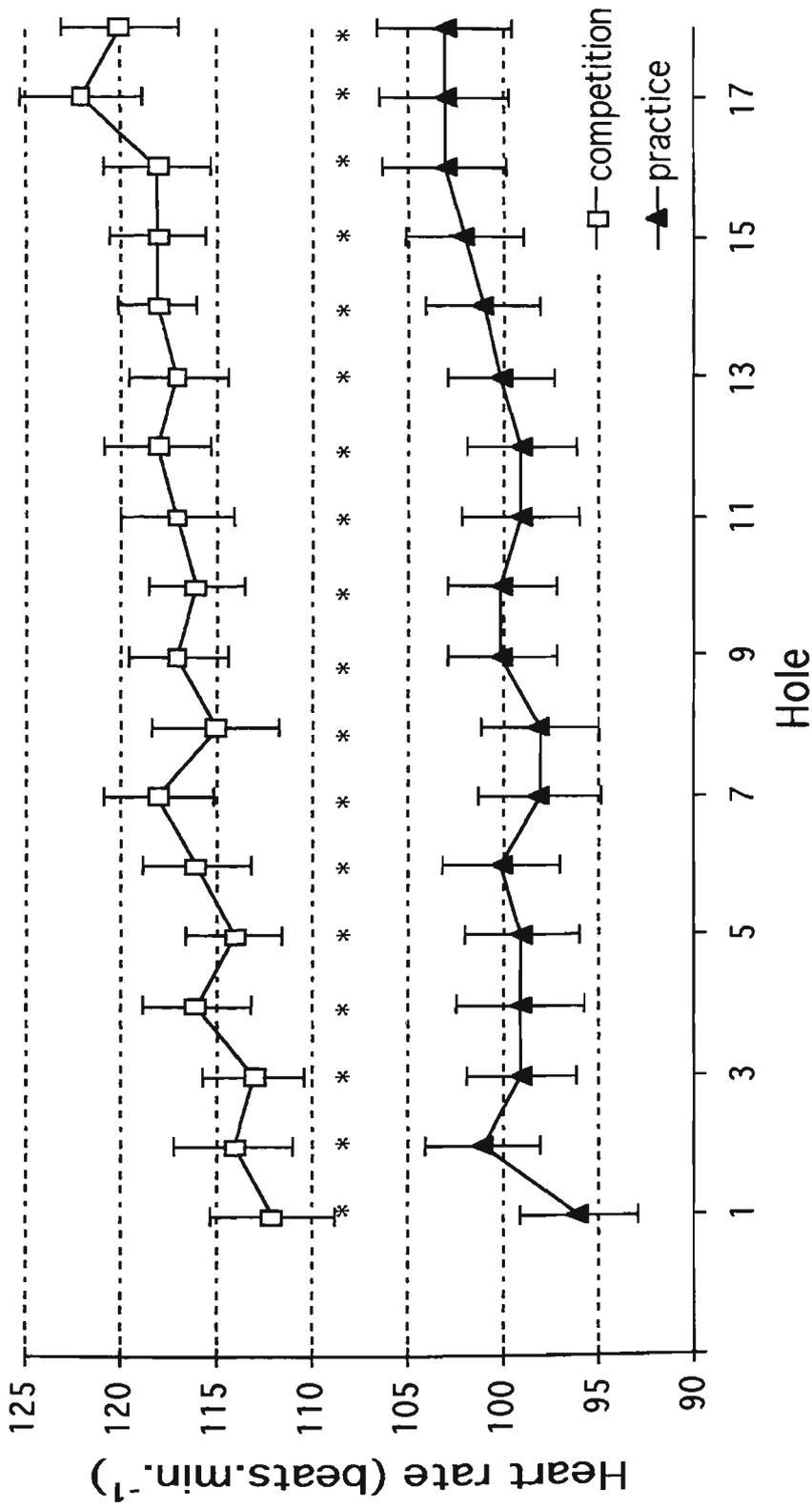


Figure 4.2 Average heart rate responses for holes 1 to 18 for n=15 PRO golfers during competition and practice rounds. Values are mean \pm SEM. * denotes difference between game conditions ($p < 0.05$).

analysed using Student t-tests. The number of shots over par (7.2 ± 0.8 and 6.0 ± 1.0 strokes; competition and practice, respectively) were not significantly different ($t(14) = -1.03$, $p=.3$). Time to complete the golf rounds was longer in competition compared to practice (267 ± 5 and 221 ± 7 min, respectively; $t(28) = 5.6$, $p<.001$) and temperature during competition rounds were significantly lower than during the practice games (13.1 ± 0.5 and $16.0 \pm 0.1^{\circ}\text{C}$, respectively; $t(14) = -2.78$, $p<.02$).

4.5.3 CSAI-2 state anxiety

To examine the relationship between game condition and time on state anxiety and self-confidence, a Game x Hole (2 x 4) repeated-measures MANOVA was conducted on the three CSAI-2 subscales. Table 4.1 shows the golfers' CSAI-2 scores for cognitive A-state and somatic A-state, and state self-confidence (mean \pm SD). State anxiety responses were higher in competition than practice ($F(3,12) = 14.38$, $p<.001$) as revealed by the overall Game x Time (2 x 4) MANOVA, however averaged multivariate tests revealed the effect for hole just failed to reach significance ($F(9,116) = 1.93$, $p=.06$). There was no interaction between game and time ($F(9,6) = 2.73$, $p=.12$). Separate Game x Hole (2 x 4) repeated-measures ANOVAs were then used to analyse the game effect for each of the CSAI-2 subscales. Cognitive anxiety was higher in competition compared to practice (19.0 ± 1.0 and 13.8 ± 1.2 , respectively; $F(1,14) = 34.64$, $p<.001$) as was somatic anxiety (14.5 ± 0.9 and 10.7 ± 0.7 , respectively; $F(1,14) = 22.59$, $p<.001$). Self-confidence was higher in practice (28.2 ± 1.1) than in competition (24.6 ± 0.9 ; $F(1,14) = 11.75$, $p<.004$). These analyses also confirmed the non-significant time and interaction effects for each of the CSAI-2 subscales.

Table 4.1 CSAI-2 cognitive and somatic anxiety and self-confidence scores for n=15 PRO golfers at pregame (PRE), after 6 holes (H6), 12 holes (H12) and post round (H18), for competition and practice rounds of golf. Scores are mean \pm SD. A difference for game condition, Comp>Prac ($p<0.05$); B difference for game condition, Prac>Comp; NS no difference for hole, PRE,H6,H12,H18 ($p<0.05$).

	<u>CSAI-cog</u>		<u>CSAI-som</u>		<u>Self Conf.</u>	
	M (SD)		M (SD)		M (SD)	
Practice						
PRE	13.7 (5.1)		11.2 (3.1)		28.1 (4.6)	
H6	13.5 (4.5)	NS	10.5 (2.5)	NS	28.1 (5.1)	NS
H 12	13.9 (5.0)		10.7 (3.1)		27.1 (4.8)	
H18	13.3 (5.2)		10.3 (2.7)		29.3 (4.9)	
Competition						
	A		A		B	
PRE	17.1 (4.5)		13.9 (4.1)		25.9 (3.8)	
H6	19.6 (3.8)	NS	15.5 (4.3)	NS	24.8 (3.9)	NS
H 12	19.5 (4.5)		14.4 (4.8)		24.9 (4.8)	
H18	19.0 (5.4)		13.5 (4.9)		22.9 (6.0)	

Relationships between psychophysiological parameters

To examine the relationships firstly, amongst the CSAI-2 subcomponents and secondly, between the CSAI-2 subcomponents and physiological measures, Pearson Product Moment Correlation Coefficients were calculated in competition and practice. All correlations were calculated using within-subject comparisons.

4.5.4 Correlations amongst CSAI-2 subscales

To examine whether the three CSAI-2 sub-components were related yet independent measures, correlations were performed between each of the three subscales; cognitive anxiety, somatic anxiety and self-confidence. The correlations (r values) at PRE, H6, H12 and H18 for the practice and competition conditions are presented in Table 4.2. In competition, the mostly low and non-significant correlations between the three subscales, indicate a moderate to strong independence between the three subscales. Intra-correlations between somatic A-state and self-confidence at pregame were significant ($p < 0.01$), as were cognitive A-state and somatic A-state postgame ($p < 0.01$). In general, stronger correlations were found between the CSAI-2 subscales in practice.

4.5.5 Correlations between CSAI-2 and physiological measures

To examine whether self-reported physiological arousal (somatic A-state) was related to actual physiological measures, salivary cortisol and heart rate were correlated with somatic anxiety at the various stages of the competition and practice rounds. Table 4.3 reveals there was no relationship between these psychophysiological variables as shown by the low and non-significant correlations.

Table 4.2 Intercorrelations (r) among CSAI-2 subscale scores for cognitive and somatic anxiety and self-confidence, at pregame (PRE), after 6 hole (H6), hole 12 (H12) and postgame (H18) for $n=15$ PRO golfers during competition and practice.

	CSAI-cog and CSAI-som	CSAI-cog and Self Conf.	CSAI-som and Self Conf.
	r	r	r
Practice			
PRE	.71 _b	-.41	-.68 _b
H6	.54 _a	-.44	-.59 _a
H 12	.40	-.71 _b	-.76 _b
H18	.68 _b	-.63 _a	-.71 _b
Competition			
PRE	.48	-.33	-.65 _b
H6	.38	-.48	-.27
H 12	.31	-.42	-.22
H18	.83 _b	-.23	-.40

a, $p<.05$; b, $p<.01$; c $p<.001$

Table 4.3 Correlation coefficients (r) between CSAI-2 somatic anxiety and physiological parameters (cortisol and heart rate) for $n=15$ PRO golfers during competition and practice; where cortisol and somatic anxiety are measured at pregame (PRE), after hole 6 (H6), hole 12 (H12) and postgame (H18), and heart rates are averaged for consecutive 6 hole periods, holes 1-6 (H6), holes 7-12 (H12) and holes 13-18 (H18).

	Somatic anxiety and Cortisol	Somatic anxiety and Heart rate
	r	r
Practice		
PRE	.17	#
H6	.07	.35
H 12	.04	.24
H18	-.28	.35
Competition		
PRE	.03	#
H6	-.22	-.07
H 12	-.38	-.23
H18	-.22	-.40

a, $p<.05$; b, $p<.01$; c $p<.001$; # no heart rates measured pregame.

Psychophysiological parameters and performance

The standardised performance scores were analysed by a Game x Time (2 x 18) two-way repeated measures ANOVA and revealed that golfers' performance in competition was not significantly different to practice; $F(1,14)=1.79$, $p=.2$). To examine the relationship between psychophysiological parameters and golf performance in competition, these parameters were correlated with performance scores at various times of the golf game and multiple regression analysis was conducted.

4.5.6 Stress parameter and performance score correlations

High levels of anxiety are predicted to negatively influence performance (Martens et al., 1990), therefore correlations between golfers competition anxiety and performance score are of interest. Golfers anxiety in practice rounds were also correlated with performance during practice, however, it should be noted that there was no incentive offered for best performances and players were not as focused on score during these rounds.

To determine whether anxiety influenced competition performance or whether performance score is an antecedent of anxiety, the following correlations were made. To examine the former, anxiety scores at PRE, H6, H12 were each correlated with the performance scores SC 1-6, SC7-12 and SC13-18, respectively. To examine the latter, anxiety at H6, H12 and H18 were each correlated with performance scores SC1-6, SC7-12 and SC13-18, respectively. The same procedure was followed for practice. The correlation coefficients shown in Tables 4.4 (a, b and c) indicate the low and generally non-significant relationship between the CSAI-2 subscales (cognitive and somatic A-state and self-confidence) and competition performance for each six holes played. In competition, only pregame CSAI-cognitive showed a tendency toward a negative relationship with 18 hole performance score, however this just failed to reach significance ($r = -.50$, $p= .06$). Low pregame cognitive anxiety was associated with higher performance score. In golf, higher score

Table 4.4a Correlation coefficients (r) between CSAI-cognitive anxiety and standardised performance scores, including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for n=15 PRO golfers during competition and practice.

	CSAI-cognitive			
	pre r	hole6 r	hole12 r	hole18 r
Practice				
SC18	-.44			-.74 _b
SC 1-6	-.10	-.05		
SC 7-12		-.55 _a	-.49	
SC 13-18	-.28		-.27	-.46
Competition				
SC18	-.50*			-.36
SC 1-6	.28	.38		
SC 7-12		-.13	-.19	
SC 13-18	-.45		.14	-.26

a, $p < .05$; b, $p < .01$; * $p = .056$

Table 4.4b. Correlation coefficients (r) between CSAI-somatic anxiety and standardised performance scores, including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for $n=15$ PRO golfers during competition and practice.

	CSAI-somatic			
	pre r	hole6 r	hole12 r	hole18 r
Practice				
SC18	-.80 _b			-.70 _b
SC 1-6	-.18	-.38	-.20	
SC 7-12		-.26	-.45	-.55 _a
SC 13-18	-.67 _b			
Competition				
SC18	-.35			-.14
SC 1-6	-.22	.04		
SC 7-12		-.22	-.32	
SC 13-18	-.18		-.06	-.07

a, $p < .05$; b, $p < .01$

Table 4.4c. Correlation coefficients (r) between CSAI-self confidence and standardised performance scores, including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for $n=15$ PRO golfers during competition and practice.

CSAI-self confidence				
	pre	hole6	hole12	hole18
	r	r	r	r
Practice				
SC18	.57 _a			.62 _b
SC 1-6	-.31	-.15		
SC 7-12		.52 _a	.54 _a	
SC 13-18	.43		.33	.65 _b
Competition				
SC18	-.07			-.40
SC 1-6	-.16	-.07		
SC 7-12		-.34	-.12	
SC 13-18	-.03		-.15	-.03

a, $p < .05$; b, $p < .01$

relates to worse performance, hence the relationship between cognitive anxiety and performance was opposite to the hypothesis (6). Generally, the performance scores in practice correlated more often with the CSAI-2 subscales, in particular, state self-confidence.

Correlations between performance and salivary cortisol during competition for various times of the game revealed that only pregame cortisol correlated significantly with 18 hole performance score ($r=.60$, $p<.02$). Higher pregame cortisol related to worse performance. Similarly, there were no significant correlations between heart rate and performance (r ranged from $-.41$ to $.20$)

4.5.7 Stress parameter and performance score regressions

To examine the ability for the psychophysiological parameters to predict performance, multiple quadratic regression analysis was conducted. The criterion variable was the standardised performance measure (either SC18 or SC1-6, SC7-12 and SC13-18). Predictor variables in the multiple regression analysis included cognitive anxiety, somatic anxiety, self-confidence and cortisol measures (PRE, H6, H12 and H18) and heart rates for holes 1-6, 7-12 and 13-18. The results showed that neither CSAI-2 state anxiety or physiological measures significantly predicted performance (R values ranged from $.32$ to $.51$). However, multiple linear regression analysis for pregame cortisol and cognitive anxiety, revealed that these variables significantly predicted 18 hole standardised performance score (R square = 0.54 ; $F(12,14) = 7.13$, $p<.01$; Figure 4.3).

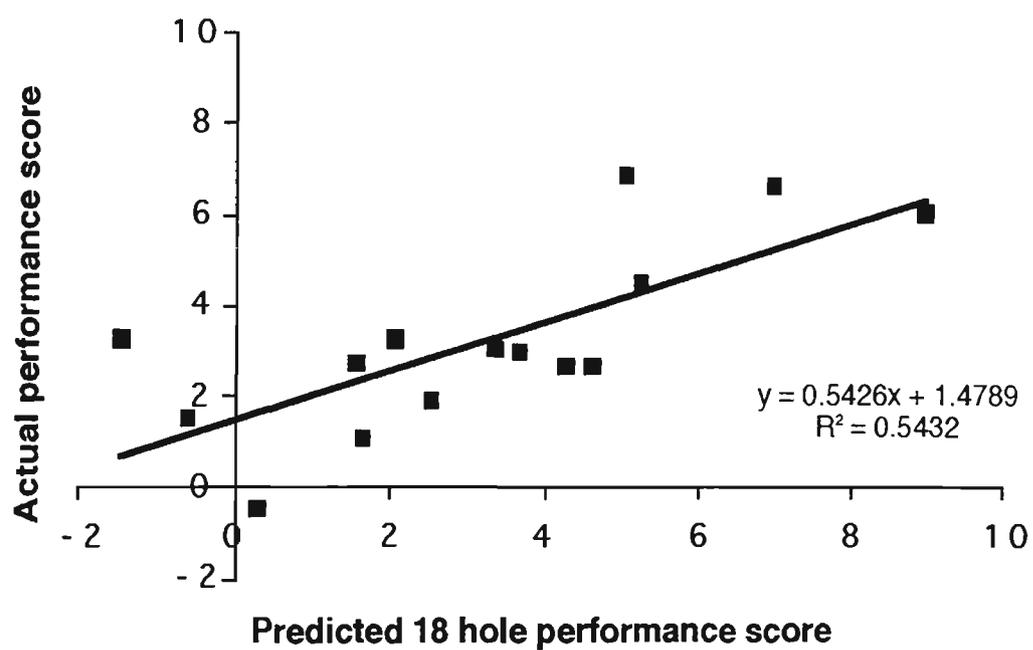


Fig 4.3 Multiple linear regression for pregame (PRE) cortisol responses (nmol.l^{-1}) and pregame (PRE) CSAI-2 cognitive anxiety predicting 18 hole standardised performance scores for $n=15$ PRO golfers during competition.

4.6 Discussion

This study comprised a field investigation of psychophysiological stress to tournament golf in fifteen elite male professional players. The results indicate that salivary cortisol, heart rate, cognitive and somatic anxiety and self-confidence were strongly influenced by competitive conditions, but golfer's 18 hole performance scores were similar in competition compared to practice. In general, psychophysiological parameters were not able to predict performance, however 18 hole performance score in competition was predicted by high pregame cortisol and low pregame cognitive anxiety. There was little support for psychological and physiological parameters being related, in particular self-reported physiological arousal (somatic anxiety) did not correlate with the physiological parameters, heart rate or cortisol. Salivary cortisol was elevated prior to the start of the golf rounds, and had decreased significantly by postgame measures, some four hours later. The CSAI-2 sub-scales revealed moderate intra-correlations before, during and after the competition reflecting some independence, however neither cognitive, somatic anxiety or state self-confidence showed temporal changes, nor did they relate to performance scores during or after the tournament. The main finding of this study is that although elite golfers experienced significant alterations to their psychophysiological state when playing in competition compared to practice, this appeared to have little influence on their performance scores.

Psychophysiological stress in golf

The diversity of psychological stress paradigms which can influence HPA activity in humans is widely recognised (Ur, 1991; Mason, 1968). To concur with this, the current study indicates that a competitive golf tournament can act as a potent stimulus for HPA activity in elite golfers. Few studies have examined the adrenocortical response to competition stress in sport (Cook et al., 1987; Petraglia et al., 1988) and these have

involved strenuous physical exercise such as running, as opposed to mild physical activity imposed by golf. In general, the salivary cortisol responses measured for elite golfers in both golf games were low, ranging from 1.0 to 8.0 nmol.l⁻¹, and similar to those measured during psychological stress paradigms with minimal physical exertion such as unpleasant films (Hubert and de Jong-Meyer, 1992), academic examinations (Jones et al., 1986) and public speaking (Bassett et al., 1987).

The finding that intra-individual cortisol responses in PRO golfers were significantly higher in competition compared to practice, would indicate that psychological factors inherent in the competition environment are likely to have been responsible. The observation that psychological factors, and not other confounds such as physical exertion, are the most likely antecedents of HPA activity in these golfers, is supported by several factors. Firstly, the magnitude of cortisol responses is small in contrast to large cortisol responses typically found in response to physical stress. A study by Cook et al. (1987) on marathon runners showed small elevations in saliva cortisol, which were similar to these golfers, just prior to a competitive race. They attributed a 2-fold (less than 7 nmol.l⁻¹) increase over baseline to psychological factors, compared to a 10-fold (approximately 80 nmol.l⁻¹) increase after the competitive race to the strenuous nature of the exercise. Secondly, the physical exertion in golf is not comparable to that of marathon running and there is little evidence for mild exercise stimulating adrenocortical activity (Tharp, 1975). Davies and Few, (1973) determined that the threshold for physical exercise required to elicit a large increase in HPA activity is approximately 60% of VO₂max. The average heart rates for golfers in competition, are consistent with a moderate exercise intensity of around 30% VO₂max, which is considered well below the physical exercise threshold (Cook and O'Conner, 1987; Mason et al., 1973). Studies which found small variations in cortisol during mild exercise have attributed these partly to factors other than exercise. For example, a laboratory study by Mason et al., (1973) determined that psychological stress responses to

venepuncture in some participants evoked HPA activity, whilst another study by Davies and Few (1973) attributed decreases in cortisol during low intensity exercise (less than 50% VO_2max) to circadian variations in the baseline cortisol concentration. By measuring salivary cortisol, regarded as being a relatively non-stressful procedure (Kirschbaum and Hellhammer, 1989) and controlling for circadian variations, these factors would not be expected to explain the findings in the current study. Also, the elevations in pregame cortisol in golfers, similar to the marathon runners in Cook et al.'s (1987) study, coincided with a period where physical activity was lowest. Finally, further support for psychological factors being involved in golfers cortisol response to competition, is that the stress variables measured concurrently with cortisol, namely state anxiety and heart rate were also elevated in competition.

Heart rate responses in sport are difficult to delineate into physical and psychological components, because the influences on cardiac activity in field environments are complex (Reilly et al., 1990). The average heart rate responses in both competition and practice rounds would reflect the physical workload and psychological elements of golf play, together with extraneous influences such as weather conditions. Elite golfers however, experienced an average $17 \text{ b}\cdot\text{min}^{-1}$ increase in heart rate throughout competition play compared during practice play. Attributing this response partly to emotional differences in game condition, is also supported by golfers reporting higher state anxiety during competition, and experiencing elevated cortisol concentrations. However, other factors which could have influenced heart rate differently in competition compared to practice must also be considered. For example, differences in physical exertion could not be controlled in this field study and although it was not measured directly, golfers shot similar low scores over a similar time period for both game conditions. Competition rounds took slightly longer to complete and were played in lower average temperatures compared to the practice rounds. Theoretically however, any thermogenic effects or influences from slightly faster

playing times would be expected to increase heart rates in the practice round as opposed to the competition rounds. Differences between individual golfers with respect to physical fitness, resting heart rate, body weight, body adiposity and sex, would not confound findings because each individual acted as his own control. Other potential influences on heart rate which cannot be accounted for in this study were influences such as wind and terrain of the golf holes, despite selecting golf courses of similar length and generally flat in appearance. Heart rates in both game conditions were observed to trend upward during both rounds, maybe due to fatigue or increased body core temperature.

Elite golfers experienced higher state anxiety (cognitive and somatic A-state) and lower state self-confidence, which is characteristic of the competitive anxiety response found in other golf situations (Weinberg and Genuchi, 1980). In practice, the low levels of state anxiety reported are consistent with golfers perceiving the practice game as being relatively non-threatening, which may explain the stronger relationship found amongst the CSAI-2 subcomponents in practice compared to competition. In competition, golfers' experienced greater worry and perceived more bodily sensations attributed to nervousness. The sensitivity of the CSAI-2 and its validity as a measure of multi-dimensional competitive state anxiety, is partly attributed to the fact it measures three independent, yet related subscales of state anxiety. The moderate to low correlations amongst cognitive anxiety, somatic anxiety and self-confidence in golfers at different stages of competition, support the independence of the CSAI-2 subscales and therefore corroborate with many studies, including Gould et al. (1984) and Jones et al. (1988), supporting the multi-dimensional nature of the CSAI-2. Furthermore, the fact that the relationship between CSAI-2 components did not strengthen in parallel when comparing competition to practice in these golfers, further supports the multi-dimensional nature of the state anxiety measure as well as indicating the individual variability in reported anxiety.

Physiological indices of stress, such as cortisol and heart rate, do not directly indicate the psychological status of the person, unlike measures of state anxiety. Many studies however, have described anticipatory rises in cortisol just prior to novel, unpredictable or psychologically threatening events, such as strenuous exercise (Cook et al., 1987; Mason et al., 1973), rappelling (Brooke and Long, 1987), and academic examinations (Jones et al., 1986). The PRO golfers showed elevations in salivary cortisol within 15 minutes of the start of the golf tournament. According to Arthur, (1987) golfers may be preparing to cope with an important event, or golfers may have considered the unpredictable nature of their ensuing performance somewhat threatening. Anticipation of the ensuing tournament is likely to have contributed to the pre-round cortisol elevations in golfers in competition, and to a lesser extent in practice.

Considering both game conditions, cortisol responses demonstrated a significant temporal pattern, being lower at the conclusion of play compared to pregame and mid-game measures. Postgame coincides with a period of diminished anticipation or potential threat. Within competition, the pre (PRE) and post-game (H18) cortisol responses just failed to reach significance, possibly due to the small effect size in the study. Although speculative, it is interesting that the trend in cortisol responses across the four measurement sites was different in competition compared to practice. In competition, elevated pregame cortisol appeared to remain so at holes 6 and 12, before declining during the final six holes of the tournament. In practice, a decrease from elevated pregame cortisol was evident after the first six holes of play. Cortisol has a half-life of approximately 60 to 90 minutes (Galbo et al., 1983; Hiramatsu, 1981). Theoretically, the 185 minutes it took golfers to play twelve holes should have allowed time for cortisol to decline given there was no further provocation of the HPA axis. Instead, cortisol concentration during this period remained elevated in competition, declining over the subsequent hour of play. Pregame cortisol responses in practice showed a tendency to decline during the first six holes of play and

remained low for the rest of the round. Further studies of salivary cortisol responses in golfers during practice and competition are necessary to verify these speculations, however it appears that psychological factors may continue to evoke HPA activity during competition and not in practice. It may be that anticipatory factors influence the HPA axis, indicated by the pregame cortisol responses, and that other factors related to evaluative social environments, such as involvement (Kiritz and Moos, 1974), may perpetuate HPA activity in competition.

Psychophysiological relationships between stress parameters

A more direct relationship between cortisol and state anxiety was examined in this study, after measuring golfer's cortisol responses concurrently with state anxiety during the competition round. Whereas some studies have found that cortisol and global (unidimensional) anxiety may increase during psychological stress paradigms (Hubert and de Jong-Meyer, 1992), it was contended that a more situation-specific and multidimensional measure of state anxiety may provide more consistent support for a psychophysiological relationship. A preliminary study by Benjamins et al. (1992) used patients prone to dental anxiety and found that the anxiety measure, which included situation-specific items related to dental anxiety, revealed strong correlations with salivary cortisol concentrations.

Despite golfer's experiencing elevated state anxiety and cortisol responses to competition, intra-individual correlations for somatic anxiety and cortisol indicated that these psychophysiological variables were not linearly related either before, during or after the game. These findings would suggest, however, that state anxiety measured by the CSAI-2 and the HPA axis may have common antecedents, but at the same time are sensitive to different elements in competition. In particular, elevated pregame cortisol is unlikely to have been attributed to emotional anxiety in these golfers. Higher levels of anxiety and

cortisol evoked by more stressful competition paradigms might be required to better examine this relationship. Alternatively, correlation may not be the most appropriate type of statistical analysis given the complexity of neuroendocrine function, and the subjective nature of psychometric responses. The emphasis with the CSAI-2 is on momentary feelings, which can change quickly according to the golfer's most recent experiences. The cortisol responses are subject to an inherent lag time (Hubert and de Jong-Meyer, 1992). For example, golfer's anxiety state at hole 6 could reflect feelings arising from events immediately prior. On the other hand, cortisol responses may reflect HPA activity over a longer time period, such as from the start of the tournament. It may be that the onset of the stress and time course of responses may confound a correlational relationship and that a more complex statistical analysis is required. To achieve this, future studies could benefit from more frequent measures of cortisol and state anxiety responses during golf competition. This study concurs with others who have found that anxiety, as a mood state, shows common variance, but does not correlate directly with cortisol (Allen et al., 1985, Jones et al., 1986).

Whilst studies had yet to compare multiple biochemical and CSAI-2 measures during a sporting event, common approaches to examine psychophysiological relationships have involved measuring heart rate. Martens et al., (1990) rationale was that perceived autonomic activity, measured as somatic anxiety by the CSAI-2, will relate to a persons actual physiological reactions. Contrived competition settings and relatively novel motor tasks were argued as methodological factors which confounded this relationship (Caruso et al., 1990; Karteroliotis and Gill, 1987). Whilst PRO golfers experienced higher heart rates and therefore greater arousal in competition than practice, and reported higher somatic anxiety during this time, there was no indication for a more specific relationship. Somatic anxiety remained unchanged during competition whilst heart rate increased over the same

period, possibly due to physical as opposed to psychological confounds. Heart rates during different stages of the tournament did not directly relate to somatic anxiety measures.

In examining the psychophysiological relationships amongst stress parameters, there was no relationship between a commonly used index of arousal, heart rate, a more sensitive biochemical correlate of stress, salivary cortisol, and self-reported physiological arousal, somatic anxiety. In this study, it was anticipated the ecologically valid golf tournament setting and valid task demands would enhance psychophysiological responses, their measurement, and consequently strengthen any relationship between the psychophysiological parameters. Although there was clear evidence that physiological responses and somatic anxiety were higher in competition than practice, self-report physiological arousal and actual physiological stress responses were not congruent. These findings further emphasise the conclusions of Gould and Krane, (1992) who state, a persons' cognitive interpretation of physiological arousal and physiological responses show common variance, but are conceptually distinct (Hatfield and Landers, 1983); Vealey, 1990). Future field research could examine somatic anxiety and more sensitive measures of heart rate, for example, heart rate variability, or beat to beat intervals (Malik, 1996).

Psychophysiological stress and performance

The current study extended previous research by measuring self-reported state anxiety twice during competitive golf performance, rather than being confined to observations before or after competition. In addition to using intra-individual analyses and standardised performance scores, it was anticipated that including mid-game measures, as advocated by McAuley (1985) and Martens et al. (1990), would strengthen the predicted anxiety-performance relationships.

Martens et al. (1990) argued that according to multi-dimensional anxiety theory, high levels of competitive anxiety are detrimental to performance. Task-irrelevant thoughts associated with cognitive anxiety would mean that cognitive anxiety would show a stronger relationship to performance than somatic anxiety. In the present study, cognitive and somatic anxiety intensities were greater in competition compared to practice, but there was little support for Martens et al.'s contentions because neither state anxiety measure was related to performance at any stage of competition. Pre-competition cognitive anxiety did correlate with 18 hole performance score, however higher anxiety was associated with better golf performance which was opposite to the hypothesis. Weinberg and Genuchi (1980) found that high levels of precompetition state anxiety are detrimental to golf performance and low levels are facilitative, however unlike the current study which used standardised golf scores, the influence of ability level golf performance score were not controlled. Cook et al., (1983) argued that elite golfers perform better and also are prone to lower anxiety. By controlling for ability level in golfers, Cook et al., (1983) found that state anxiety was unable to predict performance. The current study confers with McAuley's (1985) and Martens et al.'s (1990) study in golfers, where high pre-competition anxiety did not relate to 18 hole golf scores and also extends these findings to include mid-game state anxiety and performance measures.

Besides the paradox of pregame cognitive anxiety, neither CSAI-2 cognitive or somatic anxiety or self-confidence, measured prior to, during or after performance, was related to standardised golf performance score in elite golfers. For both game conditions, golfers' finished with scores around six shots greater than their predicted ability (handicaps). Scoring consistency in this group of elite players may have been one reason why there was not a strong relationship between anxiety and golf performance. For example, elite players will tend to show a small deviation in performance score when comparing a good with a

poor performance, maybe only one or two strokes, compared to a lesser ability golfer who might have a ten stroke difference in score. Hence, global performance measures such as score may not be sensitive indicators of performance changes in elite golfers. However, despite the similar scores, performance expectations (cognitive anxiety) would still be expected to change during the golf round. Cognitive anxiety did not show temporal patterns to indicate that this occurred. Another explanation between the weak to non-existent relationship between state anxiety and performance score, may be the CSAI-2 subscales were not sensitive to these cognitive changes. The recent work of Jones et al., (1994;1995) suggests the CSAI-2 in its current form is not sensitive because it does not measure frequency or direction of state anxiety.

Jones and colleagues found that elite or highly skilled performers are likely to interpret their anxiety as more facilitating and less debilitating than non-elite or less skilled performers (Jones et al., 1994), not only on one occasion, but routinely (Jones and Swain, 1995). They suggested that this might be associated with the adoption of a cognitive restructuring type of coping strategy, whereby the presence of bodily reactions and intrusive thoughts about the competition are interpreted as signs of being in the appropriate state for optimal performance. As the golfers examined in the present study would be regarded as highly skilled and elite or bordering on elite status, it is also possible that their experience of cognitive, and perhaps somatic, state anxiety was substantially facilitating. This might also be one reason why there were no relationship of the state anxiety intensity variables with performance. This study supports the work of Jones and colleagues, and is consistent with the research on temporal patterns of state anxiety and that on the anxiety-performance relationship as the whole. That is, it does not show clear patterns of state anxiety intensity associated with different times in relation to competition, or clear relationships of state anxiety intensity to performance. While the biochemical measure of cortisol did indicate some variation during performance, with pregame cortisol correlating with 18 hole

performance, the nature of the change was not indicated. It is possible that the measurement of cortisol at the same times that the intensity, frequency, and direction of cognitive and somatic state anxiety are assessed would provide a fruitful approach to the depiction of anxiety before and during competition and one in which the relationship of anxiety to performance is more clear-cut. Additional distinctions in pre-event and during-event anxiety state might also be forthcoming from a comparison of elite performers with non-elite, using the non-intrusive, biochemical and the multidimensional, self-report approaches together. Future research should explore these propositions.

Benefits and Limitations of field approach

Weinberg and Genuchi, (1980) suggest enhancing the situational validity by testing golfers in competition settings, increases the potency of the response. In this study, significant changes in psychophysiological parameter were found with game condition, suggesting tournament golf was more stress evoking for golfers than practice. A limitation from using actual golf tournaments was that it prevented game order randomisation. The rationale for competition rounds preceding practice rounds was to maximise retesting each player on the same golf course and at the same time of day. Theoretically, order of the game conditions may influence stress parameters, however, non-invasive measures and thorough familiarisation procedures may have minimised any order effect.

Acknowledging the specific limitations of this study and those inherent in field testing environments (Jones, 1995), these findings show that competition can evoke psychophysiological changes to golfers internal state, which contrast those existing during practice conditions. This study therefore provides scientific support for anecdotal accounts, that stress exists in tournament golf at elite levels. Of particular interest is that despite competition stress, golfers' performance scores were not influenced. Golf score was neither better nor worse in competition. The individual stress parameters used in the study,

provided no further evidence to suggest that psychophysiological stress parameters are consistently related to each other or performance, supporting the proposal that the psychophysiological relationship is complex. However, it is possible the stress related changes in this study may not have been sufficiently intense (eg cortisol) or directionally appropriate (eg cognitive anxiety) to adversely affect performance. It also poses questions as to whether the various golf skills, such as putting, may be influenced by psychophysiological changes. To better understand stress in golf, it is pertinent to determine whether less proficient golfers experience similar changes. This is the purpose of the subsequent study.

Chapter 5

PSYCHOPHYSIOLOGICAL EFFECTS OF STRESS IN RECREATIONAL GOLFERS DURING COMPETITION AND PRACTICE

5.1 Overview

In the previous chapter, there was evidence for PRO golfers experiencing a different psychophysiological state in competition when compared to practice. The current study aims to broaden understanding of competitive stress in golf by examining whether similar changes occur in lesser ability recreational golfers in club-level competition. Similar to the previous chapter, the relationship between psychophysiological stress responses and their relationship to golf performance score will also be examined.

5.2 Abstract

Psychophysiological stress responses to competition and their relationship to performance was examined in nineteen male recreational (REC) golfers (handicap range 6 to 24) (age 52.3 ± 3.7 years; height 176.2 ± 2.2 cm; body mass 78.4 ± 2.6 kg; mean \pm SEM). Intra-individual analysis was used to compare psychophysiological responses during an official 18 hole club level competition to a practice round on the same golf course, where the winner of the competition received a medallion. Salivary cortisol and CSAI-2 state anxiety (Competitive state anxiety; CSAI-2) were measured pregame (PRE), after holes 6 (H6), 12 (H12) and 18 (H18). A heart rate monitor (PE3000) measured heart rates at 15 second

intervals before and during golf rounds. Game condition was randomised and standardised (handicap) performance scores were used. Golfers' physiological stress responses, cortisol and heart rate, were not significantly different in competition compared to practice, however a MANOVA revealed a significant game effect for the CSAI-2 ($F(3,16) = 7.09$, $p < .003$). Univariate ANOVAs and Turkey's post-hoc tests revealed time effects for cognitive ($F(3,54) = 3.92$, $p < .013$) and somatic anxiety ($F(3,54) = 4.14$, $p < .01$). Cognitive anxiety at H6 and somatic anxiety PRE and H6 were significantly higher than their respective measures at H18. State self-confidence was higher in practice compared to competition ($F(1,18) = 16.23$, $p < .001$). Rather than anxiety influencing performance, multiple regression analyses revealed that golf score for holes 13-18 predicted postgame cognitive and somatic anxiety. In recreational golfers, competition stress is manifested as elevated psychological anxiety, more so than an increase in physiological stress related activity. Elevated competitive state anxiety does not directly influence performance, rather there is a tendency for worse performance in the final stages of the round to predict higher levels of cognitive worry at the conclusion of the round. Psychological and physiological stress responses may have different competitive stress antecedents, with state anxiety being influenced by (as opposed to influencing) performance score.

5.3 Introduction

Golf is a popular recreational sport and is played by a large number of people, both young and old alike. Exercise and participation in sports such as golf, has been advocated as having a positive effect for mental health and physical well-being (Clayton, 1991). In non-competitive settings, heart rate responses during golf reflect the low to moderate cardiac demands whilst the duration of aerobic activity assists in energy expenditure. For older people, golf activity may provide health benefits associated with moderate cardiovascular exercise (Batt, 1993), and be particularly suitable for rehabilitating patients (Murase et al.,

1989). Yet competition is an inherent part of sport and capable of increasing psychophysiological demands, including increased heart rate and cortisol, in the individual compared to more relaxed practice conditions. Whilst this may not be a problem for young, fit individuals, Cohn (1990) found that youth golfers attribute performance pressure in competition as being responsible for their loss of enjoyment in the game and a source of youth “burnout”. Previous studies have shown that professional golfers experience marked elevations in HPA and cardiac activity, and elevated state anxiety in competition compared to practice (McKay et al., 1997), however psychophysiological stress is yet to be examined at the recreational level of the game.

Whilst there was no evidence to suggest that psychophysiological stress influenced performance in professional players (McKay et al. 1997), the relationship between psychophysiological stress in moderate ability players is unclear (Weinberg and Genuchi, 1980; Cook et al., 1983). Such research would not only contribute to understanding psychophysiological stress to competition golf, but is important to determine whether the benefits of golf exercise and participation may be compromised by additional physiological demands in competition. Furthermore, examining the relationship between competition stress and performance in these golfers, may lead to better approaches to managing stress to enhance enjoyment and participation in the sport. This study proposes to examine psychophysiological stress responses, namely heart rate, salivary cortisol and state anxiety in recreational golfers, by comparing their responses during competition to those in practice. The competition was chosen because it comprised an ecologically valid competition setting, typically encountered by recreational golfers competing at the club level of golf.

Purpose:

The purpose of this study is to examine the effects of game condition (competition and practice) on psychophysiological stress parameters (state anxiety, salivary cortisol and heart rate) in recreational golfers, and the time course of changes in these individual parameters across the 18 hole golf rounds (pregame, after holes 6, 12 and 18). A second purpose is to examine the relationship between psychophysiological parameters and performance score.

Hypotheses

1. Saliva cortisol, heart rate, cognitive and somatic anxiety is higher and self-confidence is lower in recreational golfers during competition than in practice.
2. Saliva cortisol is higher in anticipation of the start of play in competition compared to practice
3. The CSAI-2 subscales, (cognitive, somatic and self-confidence) will show moderate correlations with one another reflecting their independence.
4. Cortisol responses will correlate positively with somatic anxiety.
5. Performance score is predicted by changes in the individual parameters and combinations of parameters.
6. Cognitive anxiety will increase from pregame to mid-game measures and somatic anxiety will decrease over the same time period.

5.4 Methods

5.4.1. Participants

Nineteen amateur male golfers (age 52.3 ± 3.7 years; height 176.2 ± 2.2 cm; weight 78.4 ± 2.6 kg; handicap 11 ± 0.7 strokes; mean \pm SEM) volunteered to participate in the study. The golfers are members of the Spring Valley Golf Club (SVGC) in metropolitan Melbourne. Permission was obtained from the Secretary of the SVGC, prior to an information sheet being placed on the club noticeboard requesting volunteers. All age groups and handicap levels were encouraged to participate. Interested volunteers were contacted individually and informed of the study requirements and protocols.

5.4.2 Design

The study design is detailed in Methods (Chapter 3.4). Two 18 hole Monthly Medal competitions, one month apart, were used to test the nineteen golfers. Practice rounds were arranged at each players convenience and were played on the same course, in a group comprising three players. Half the players completed the competition round before the practice game to control for possible effects of game order. All the players had completed both testing rounds by the completion of the second competition testing day. Due to various commitments, players were able to play early or late morning. Thirteen golfers commenced their golf round between 7 am and 10am and six players requested to play between 11am and 1pm. Each golfer played both golf rounds at very similar times of the day. Players were requested to refrain from eating, drinking and smoking before and during the golf round, with only one player smoking during both competition and practice. Players also agreed to modify pre-game routines to exclude hitting golf balls as part of a warm-up.

5.4.3 Measures

Psychophysiological parameters and golf round measures

Methods for saliva cortisol, heart rate and CSAI-2, golf round data collection and performance measures are outlined in Chapter 3 (Methods), Sub-section 3.4.1, 3.4.2 , 3.4.3, Section 3.5 and sub-section 3.5.1, respectively. Cortisol concentration (nmol.l^{-1}) was determined from 200 μl non-extracted saliva samples collected during the two golf games and basal days using RIA techniques.

5.4.4 Treatments

Familiarisation and competition and practice conditions

Details of familiarisation procedures are outlined in Methods (Chapter 3.6.2). The competition selected was a regular club event. The Monthly Club Medal competition is played at the SVGC each month and players compete for a club medallion. A stroke play format is used, and the winner is the person with the lowest golf score, after subtracting their official Australian Golf Union (AGU) handicap. Golf balls are awarded for second and third prize. The competition is only available to club members, and players are required to enter the competition one week in advance. The practice game comprised an 18 hole round on the same golf course. No incentives were offered to players to perform well in either game condition. Under the rules of club amateur golf, the golfers are not permitted to receive monetary rewards for play.

5.5 Results

Psychophysiological parameters and game condition

5.5.1 Cortisol and heart rates

To examine the effect of game condition and time on the physiological measures, separate intra-individual Game x Hole (2 x 4) two-way repeated measures analysis of variance

(ANOVA) were used to analyse cortisol and heart rates at different stages of competition and practice rounds. Means \pm SEM are reported.

Salivary cortisol responses (nmol.l^{-1}) measured at PRE, H6, H12 and H18 for competition and practice golf games for the nineteen recreational golfers are illustrated in Figure 5.1. The ANOVA revealed there was no significant main effect for game on cortisol responses ($F(1,18)= 0.11, p=0.74$). Averaged tests revealed the time effect for cortisol failed to reach significance ($F(2,32)= 2.32, p =0.08$) and there was no interaction between game and time ($F(3,54)=.06, p=.9$). The average heart rate responses for each of the 18 holes of competition and practice play are illustrated in Figure 5.2. The ANOVA revealed heart rate in competition was similar to that in practice (101 ± 3.1 and $98.5 \pm 3.0 \text{ b.min}^{-1}$, respectively; $F(1,18)= 2.71, p=0.1$). There was no interaction for game and time for heart rates ($F(17,306)=.65, p=.87$), however averaged tests revealed a significant time effect for heart rate ($F(17,306)= 13.15, p < .001$). Univariate F tests located these differences to H18, H17, H16, H15, H13, H9, H5 and H3 (competition and practice) being significantly greater than the combined means (competition and practice) of the holes prior ($p<0.05$).

Other variables measured during the two golf rounds were examined using Student t-tests. Golf play was significantly slower in competition compared to practice (264.5 ± 3.5 and $245.4 \pm 4.2\text{min}$; respectively; $t(18)= 3.35, p<0.004$), however the average 18 hole performance scores were not significantly different (92 ± 1.8 and 89 ± 1.4 strokes, respectively; $t(18)= 1.73, p=0.1$). Temperatures were similar between the two golf rounds (13.5 ± 0.4 and $14.0 \pm 0.5^{\circ}\text{C}$; competition and practice, respectively; $t(36)=-.63, p=.5$).

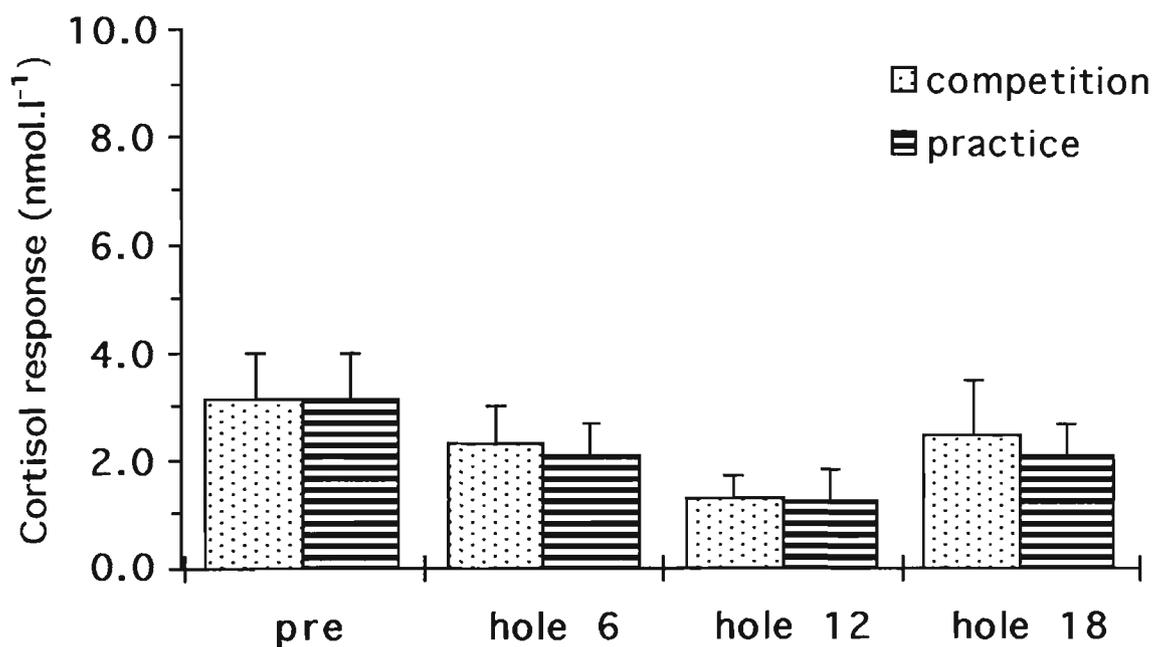


Fig 5.1 Cortisol responses (nmol.l⁻¹) for n=19 REC golfers at pregame (PRE), hole 6 (H6), hole 12 (H12) and hole 18 (H18) for competition and practice. Values are mean \pm SEM. No difference between game conditions ($p < 0.05$).

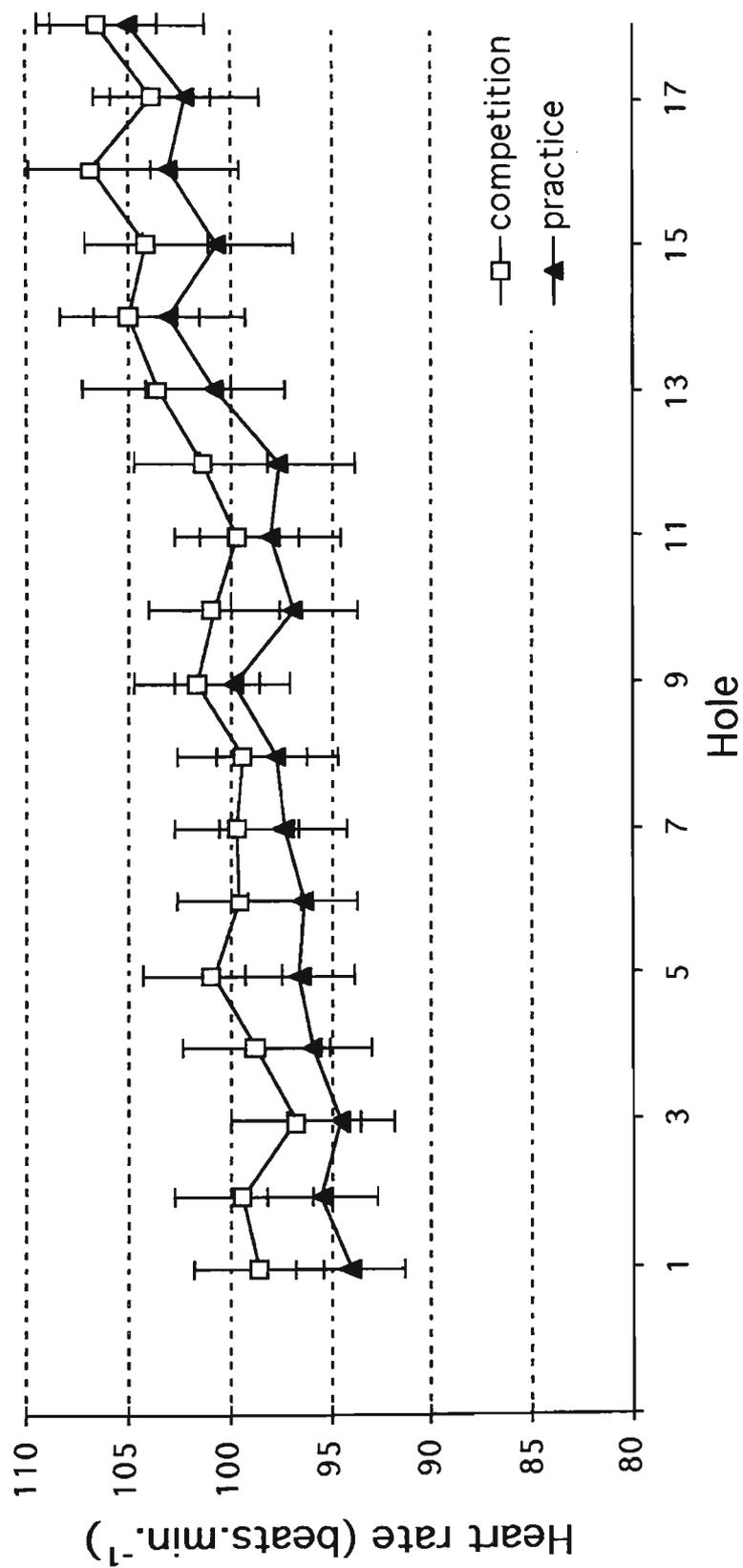


Figure 5.2 Average heart rate responses for holes 1 to 18 for n=19 REC golfers during competition and practice rounds. Values are mean \pm SEM. No difference between game conditions ($p < 0.05$).

5.5.2 Competitive State Anxiety (CSAI-2)

The CSAI-2 subscale scores for recreational golfers are presented in Table 5.1. A within-subject multiple analysis of variance (MANOVA) was used to examine the effect of game condition and time on CSAI-2 state anxiety and self-confidence scores. Analysis of the intra-individual subscale scores revealed a main effect for game ($F(3,16)= 7.09, p<0.003$), but not time ($F(9,152)= 1.68, p=0.1$). There was no interaction between game and time ($F(9,10)= 2.46, p=0.08$). The data was further analysed using separate repeated measures ANOVA's for cognitive anxiety, somatic anxiety and self-confidence. These confirmed that cognitive and somatic anxiety were higher in competition compared to practice ($F(1,18)= 14.5, p<0.001$ and $F(1,18)= 15.5, p<0.001$; cognitive and somatic anxiety, respectively), but contrary to the MANOVA, revealed significant time effects for both anxiety subscales ($F(3,54)= 3.92, p<0.02$ and $F(3,54)= 4.14, p<0.01$; cognitive and somatic anxiety, respectively). No significant interaction was found for either cognitive ($F(3,54)= 0.72, p=0.54$) or somatic anxiety ($F(3,54)= 1.96, p=0.13$). Tukey's post-hoc analysis revealed cognitive A-state was significantly higher at H6 compared to H18, and somatic A-state was higher at PRE and H6 compared to H18 ($p<.05$). Self-confidence was significantly higher in competition than practice ($F(1,18)= 16.23, p<0.001$), but there was no effect for time ($F(3,54)= 1.15, p=0.34$), or interaction ($F(3,54)=.07, p=.9$).

Table 5.1 CSAI-2 cognitive and somatic anxiety and self-confidence scores for n=19 REC golfers at pregame (PRE), hole 6 (H6), hole 12 (H12) and postgame (H18), for competition and practice. Scores are mean \pm SD. A denotes a difference for game condition, Comp>Prac ($p<0.05$); B denotes a difference for game condition, Prac>Comp; NS: non-significant effect for hole ($p<0.05$); * different from CSAI-cog at H18 in Comp ($p<0.05$); & different from CSAI-som at H18 in Comp ($p<0.05$).

	<u>CSAI-cog</u>	<u>CSAI-som</u>	<u>Self-conf.</u>
	M (SD)	M (SD)	M (SD)
Practice			
PRE	12.9 (2.6)	10.7 (2.1)	26.4 (5.1)
H6	13.6 (3.9)	11.5 (3.2)	26.5 (5.8)
H 12	13.6 (3.3)	10.8 (2.6)	26.8 (6.7)
H18	11.6 (2.8)	10.1 (1.5)	27.9 (5.9)
Competition			
	A	A	B
PRE	15.1 (5.1)	13.5 (4.7) &...	22.8 (7.8)
H6	16.7 (5.3)*...	13.2 (4.4) &...	23.5 (6.6)
H 12	15.2 (4.4)	12.5 (3.8)	23.6 (5.8)
H18	14.2 (3.3)	10.9 (2.4)	24.1 (8.3)

Relationships between psychophysiological parameters

5.5.3 Correlation of psychophysiological measures

To examine the relationship amongst the CSAI-2 subscales, Pearson product-moment correlation coefficients were calculated for the four measurement times in competition and practice. Intra-correlations between cognitive, somatic anxiety and self-confidence are shown in Table 5.2. The subscales generally showed stronger correlations with each other in competition compared to practice. Somatic anxiety and self-confidence were strongly correlated at the four measurement times in competition (PRE, $p < .001$; H6, $p < .05$; H12, $p < .001$ and H18, $p < .01$). Cognitive and somatic anxiety were significantly correlated with each other in competition, except at the postgame measure (PRE, $p < .001$; H6, $p < .05$ and H12, $p < .05$). The relationship between physiological parameters in competition were not further analysed because the ANOVAs for cortisol and heart rate did not reveal a significant effect for game. The low and generally non-significant correlations between somatic anxiety and physiological parameters, and between cognitive anxiety and cortisol are shown in Table 5.3. A positive correlation was found between cortisol and somatic anxiety at postgame (H18) in competition ($p < .01$).

Psychophysiological parameters and performance score

To examine the influence of game condition on 18 hole golf scores, a repeated measures ANOVA was used to analyse each golfers' competition and practice scores based on standardised 6 hole average scores. Performance scores in competition were not significantly different to practice games ($F(1,18) = 2.82$, $p = .11$).

Table 5.2 Intercorrelations (r) amongst CSAI-2 cognitive and somatic anxiety and self-confidence scores at pregame (PRE), hole 6 (H6), hole 12 (H12) and postgame (H18) for $n=19$ REC golfers during competition and practice.

	CSAI-cog and CSAI-som r	CSAI-cog and Self Conf. r	CSAI-som and Self Conf. r
Practice			
PRE	.59 _b	-.31	-.23
H6	.50 _a	-.10	-.58 _b
H 12	.59 _b	-.36	-.71 _c
H18	.10	-.17	-.78 _c
Competition			
PRE	.75 _c	-.75 _c	-.77 _c
H6	.50 _a	-.71 _c	-.56 _a
H 12	.55 _a	-.38	-.73 _c
H18	.18	-.39	-.62 _b

a, $p < .05$; b, $p < .01$; c $p < .001$

Table 5.3 Correlation coefficients (r) between somatic anxiety and physiological parameters cortisol and heart rate; with cortisol measured pregame (PRE), after 6 holes (H6), 12 holes (H12) and postgame (H18), and heart rates averaged for consecutive 6 hole periods for $n=19$ REC golfers during competition and practice.

	CSAI-som and Cortisol	CSAI-som and Heart rate
	r	r
Practice		
PRE	-.26	#
H6	.02	-.21
H 12	.35	-.05
H18	.44	.06
Competition		
PRE	.12	#
H6	.26	.07
H 12	-.16	.19
H18	.63 _b	.14

a, $p<.05$; b, $p<.01$

5.5.4 Anxiety and Performance

To examine the relationship between state anxiety and golf performance in competition and practice, Pearson product-moment correlation coefficients and multiple regression analyses were used to analyse the data. Analyses were within-subjects, and all scores were standardised by adjusting for seasonal handicap.

To examine whether anxiety and state self-confidence influenced competition performance or whether performance score is an antecedent of CSAI-2 anxiety subscales, correlations were conducted as described in Section (4.5.6). The correlation coefficients presented in Table 5.4 (a, b, and c) show that there was not a strong and consistent patterns of correlation between pregame or midgame CSAI-2 subscale measures in competition and performance scores. Only state self-confidence (H6) correlated with golfer's performance in the preceding holes (SC1-6; $p < .05$). However, there was a tendency for golf scores over the final six holes of play, SC13-18, to correlate with postgame CSAI-2 measures. Post-competition cognitive anxiety and SC13-18 were significantly correlated ($r = .6$, $p < .01$). Both somatic anxiety (H18) and self-confidence (H18) just failed to correlate significantly with SC13-18 ($r = .48$ and $r = -.44$, somatic anxiety and self-confidence with SC13-18, respectively). Performance score correlated positively with cognitive and somatic anxiety, indicating that higher levels of cognitive anxiety are associated with worse performance score. Self-confidence showed a negative relationship with performance, that is, low self-confidence relates to worse performance. These are in accordance with the direction of the anxiety-performance relationships proposed by Martens et al., (1990). In practice, higher state self-confidence (H18) related to better performance for SC13-18 ($p < .05$), and for the 18 holes (SC18; $p < .01$).

Table 5.4a Correlation coefficients (r) between CSAI-cognitive anxiety and standardised performance scores; including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for n=15 PRO golfers during competition and practice.

CSAI-cognitive				
	pre r	hole6 r	hole12 r	hole18 r
Practice				
SC18	.02			-.12
SC 1-6	.01	-.13		
SC 7-12		.03	.09	
SC 13-18	.04		-.14	-.08
Competition				
SC18	-.10			.54 _a
SC 1-6	.03	.33		
SC 7-12		-.10	.01	
SC 13-18	-.13		.37	.60 _b

_a p<.05; _b p<.01

Table 5.4b. Correlation coefficients (r) between CSAI-somatic anxiety and standardised performance scores, including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for $n=19$ REC golfers during competition and practice.

	CSAI-somatic			
	pre r	hole6 r	hole12 r	hole18 r
Practice				
SC18	-.08			.31
SC 1-6	-.04	.26		
SC 7-12		.17	.27	
SC 13-18	.16		-.01	-.27
Competition				
SC18	-.05			.29
SC 1-6	-.13	.20		
SC 7-12		.26	.10	
SC 13-18	.08		.42	.48 _a

a, $p < .05$; b, $p < .01$

Table 5.4c. Correlation coefficients (r) between CSAI-self confidence and standardised performance scores, including 18 hole score (SC18) and six hole scores (SC1-6, SC7-12, SC13-18) for $n=19$ REC golfers during competition and practice.

CSAI-self confidence				
	pre r	hole6 r	hole12 r	hole18 r
Practice				
SC18	-.37			-.63 _b
SC 1-6	-.08	-.31		
SC 7-12		-.39	-.37	
SC 13-18	-.33		-.20	-.51 _a
Competition				
SC18	.06			-.23
SC 1-6	.06	-.47 _a		
SC 7-12		-.16	-.19	
SC 13-18	-.08		-.27	-.44

a, $p < .05$; b, $p < .01$

The data was further analysed using two sets of multiple linear regression analysis. The first set of analyses examined whether CSAI-2 anxiety predicted performance score. The regression analysis used the golf scores (SC1-6, SC7-12 and SC13-18) as the dependent (criterion) variable, and the three CSAI-2 subscales collected prior to each of these periods (PRE, H6, H12, respectively) as predictor (independent) variables. Regression was also used to determine whether SC18 (dependent variable) was predicted by the three CSAI-2 subscales (independent variables) measured prior to competition, similar to McAuley (1985). The results presented in Table 5.5 show that none of the state anxiety subscales significantly predicted subsequent performance. (R square values from .01 to .15). Multiple linear regression was also used to determine whether performance score predicted CSAI-2 state anxiety. This second series used each of the three CSAI-2 subscales measured H6, H12 and H18 as the dependent variables, and the performance stage prior, that is, SC1-6, SC7-12 and SC13-18 as the independent variables. Postgame (H18) CSAI-2 subscales were also used as criterion (dependent) variables and 18 hole performance score (SC18) as the independent variable. The results are presented in Table 5.6 and show that SC13-18 significantly predicted H18 cognitive and somatic anxiety. Score for the first six holes (SC1-6) predicted self-confidence at H6, and 18 hole score (SC18) predicted post-game (H18) cognitive anxiety.

Table 5.5 Stepwise regression analysis for CSAI-2 scores for cognitive anxiety (cog), somatic anxiety (som) and state self-confidence (scon) at pregame (PRE), hole 6 (H6), and hole 12 (H12) for predicting golf performance (standardised with handicap); including scores for 18 holes (SC18), holes 1 to 6 (SC1-6), holes 7-12 (SC7-12), and holes 13 to 18 (SC13-18), in n=19 REC golfers during competition. * significant at $p < 0.05$; \$ significant at $p < .01$.

Dependent variable performance score	Variable entered	Multiple R	R ²	F	p
SC18	cog -PRE	.11	.01	.19	.66
	som -PRE	.12	.01	.12	.90
	scon -PRE	.12	.01	.07	.98
SC 1-6	som - PRE	.13	.02	.27	.60
	cog - PRE	.22	.05	.42	.66
	scon -PRE	.22	.05	.26	.85
SC 7-12	som -H6	.04	.00	.02	.88
	cog - H6	.26	.07	.57	.56
	scon -H6	.29	.08	.46	.71
SC 13-18	cog - H12	.13	.07	.29	.60
	som -H12	.31	.09	.82	.46
	scon -H12	.33	.15	.65	.60

Table 5.6 Linear regression for golf score (standardised with handicap) for 18 holes (SC18), holes 1 to 6 (SC1-6), holes 7-12 (SC7-12), and holes 13 to 18 (SC13-18), as a predictor of CSAI-2 scores for cognitive (cog) and somatic anxiety (som) and state self-confidence (scon) at hole 6 (H6), hole 12 (H12) and hole 18 (H18) for n=19 REC golfers during competition. * significant at $p < 0.05$; \$ significant at $p < .01$.

Performance Score	Dependent Variable CSAI-2 score	Beta	R ²	F	p
SC18	cog - H18	.279	.287	6.85*	.02
	som -H18	.111	.085	1.57	.23
	scon -H18	-.297	.052	0.93	.35
SC 1-6	cog - H6	.502	.106	2.01	.17
	som -H6	.266	.041	0.74	.40
	scon -H6	-.901	.220	4.78*	.04
SC 7-12	cog - H12	.007	.000	.00	.99
	som -H12	.182	.010	.18	.68
	scon -H12	-.534	.038	.68	.42
SC 13-18	cog - H18	.689	.319	7.97\$.01
	som -H18	.433	.236	5.25*	.04
	scon -H18	-.136	.199	4.25	.06

5.6 Discussion

This study examined the influence of an ecologically valid club-level golf competition on psychophysiological stress responses in nineteen male recreational golfers. Each golfers psychophysiological responses measured prior to, during and at the completion of a club competition round were compared with their responses to a practice round on the same golf course. Salivary cortisol responses and heart rates were not influenced by game condition, however golfers reported higher cognitive and somatic anxiety and lower self-confidence during competition compared to practice. The state anxiety components showed temporal changes, with both cognitive and somatic anxiety at hole 6 being higher than post-competition (H18). Additionally, pregame somatic anxiety was greater than postcompetition measures. The moderate to strong correlations between CSAI-2 components lend support for the independence of cognitive and somatic anxiety and self-confidence subscales, however there was no evidence for elevated state anxiety or state self-confidence influencing performance. Instead, performance score over the final six holes of competition predicted postgame cognitive and somatic anxiety responses. Also, better competition performances during the first six holes correlated with higher self-confidence at hole 6. There was no correlations between the psychophysiological stress parameters measured. The main finding of this study is that recreational golfers appear to manifest a definite increase in competitive anxiety in competition compared to practice, but these changes are not necessarily accompanied by elevated physiological stress responses. State anxiety measured by the CSAI-2 is not a strong antecedent of golf performance, rather golf performance toward the conclusion of a competition round may influence state anxiety responses.

Psychophysiological stress responses to competition

The changes in HPA and cardiac activity in response to golf competitions have been observed previously in elite golfers during tournaments (McKay et al., 1997). However in the present study, recreational golfers' physiological state remained relatively unchanged when comparing competition to practice rounds. After correcting for diurnal (baseline) cortisol concentrations (Cook et al., 1987), the cortisol responses to competition and practice were low, indicating that neither game condition was perceived as particularly stressful or arousing for these players. The absence of a strong increase in salivary cortisol prior to the golf games further supports the lack of psychological stimulation of the HPA axis. Anticipation is a common psychological antecedent of HPA activity (Bassett et al., 1987) and small elevations in cortisol have often been measured prior to psychologically stressful events, including golf competition (McKay et al., 1997) and other sporting activities (Brooke and Long, 1987; Cook et al., 1987). The cortisol findings in the current study, which pertain to golf competition being relatively non-stressful, are supported by the heart rate findings.

Heart rate responses in recreational golfers were not influenced by game condition, with only a $3 \text{ b}\cdot\text{min}^{-1}$ difference between 18 hole competition and practice averages. Emotional and physical influences on cardiovascular activity in competition would appear to be similar to practice, given that extraneous influences on heart rates can be accounted for. Intra-individual analysis would assist in controlling for the large differences in age and ability levels amongst the group, however players took longer to complete competition compared to practice rounds. The reason may be due to players taking more time to play each shot in competition, because the total number of shots played by each golfer was similar during both rounds. The faster pace of play in practice could theoretically elevate heart rates compared to competition, although this influence was not obvious from the data. There was trend for average heart rates to increase slightly from the beginning to the end of each

round, possibly due to physiological factors such as fatigue and rises in core body temperature.

The heart rate findings in the current study do not confer with those of Molander and Backman (1994), who found heart rate increased in middle-aged players during tournament as opposed to practice mini-golf settings. Both studies used ecologically valid tasks and environments and golfers of similar ages, however the type and frequency of the heart rate data collected may have contributed to the discrepant findings. For example, Molander and Backman (1994) measured heart rates for a 30 second period three times during the 18 hole mini-golf round by attaching an earlobe pulse monitor. The current study averaged fifteen second heart rate data for each hole played over a four hour duration. It is feasible that the act of attaching and detaching a heart rate monitor during competition may have been itself stress-evoking. Although such sampling confounds would be less likely in the current study by continuous measurement, the mini-golf tournament may have been more stress-evoking than the competition environment in the current study. Nonetheless, middle aged golfers do not always experience elevated heart rates in competition compared to practice. Indeed, the average heart rates in practice rounds in these recreational players was around $100 \text{ b} \cdot \text{min}^{-1}$ and concur with similar ability golfers in Murase et al.'s (1989) study who found average of heart rates in five middle aged golfers to be $108 \text{ b} \cdot \text{min}^{-1}$. Competition heart rates in recreational golfers was also around $100 \text{ b} \cdot \text{min}^{-1}$. This study would indicate therefore, that club competition does not necessarily provoke cardiac responses greater than those experienced during practice. In a non-competitive setting, Murase et al. (1989) concluded that golf is an appropriate exercise for older players to experience the cardiovascular benefits consistent with exercise of low to moderate intensity. The current study is able to extend these findings to include golf club-level competitions.

Whilst the physiological data concur with recreational golf being relatively non stressful, the state anxiety responses suggest that this is not entirely true. Recreational golfers reported higher levels of cognitive worry and somatic anxiety in the competition setting as opposed to practice, and lower levels of self-confidence. However, the intensity of perceived physiological arousal measured by somatic A-state was generally low. The psychophysiological responses to competition stress in this study, would suggest that recreational golfers manifest competitive stress more so as psychological worry pertaining to performance, than as perceived and actual physiological arousal. As a consequence, the current study provides no further evidence for a direct relationship between psychophysiological indicators of stress or arousal, in this instance, heart rate and HPA activity with state anxiety responses in golfers. State anxiety and physiological measures in this case, may respond to different antecedents in competition, or have different thresholds to evoke a response. The reason for these findings cannot be fully explained and serves to highlight the complex relationship between psychophysiological parameters of stress.

CSAI-2 state anxiety and performance in golfers

In the current study, there were moderate and positive correlations between cognitive and somatic anxiety in golfers, as well as moderate and negative correlations between cognitive anxiety and self-confidence and between somatic anxiety and self-confidence. These findings support the partial independence of the CSAI-2 subscales, similar to Caruso et al., (1990) who found the CSAI-2 to be a valid multidimensional measure of state anxiety in a competitive setting. Different temporal patterns for cognitive and somatic anxiety subscales when comparing pregame, midgame and postgame measures further supports the independent nature of the sub-scales, because it indicates they respond to different antecedents (Martens et al., 1990). Temporal changes will be discussed further below.

Emotional anxiety responses to competition are important to monitor as they have been proposed to predict performance in athletes. Martens et al.'s (1990) hypothesised that high levels of cognitive anxiety are associated with worse performance in competition, and based on their respective performance antecedents, cognitive A-state should show a stronger relationship with performance compared to somatic anxiety. Martens et al., (1990) employed the CSAI-2 to measure competitive anxiety in forty-nine collegiate golfers. They found temporal patterns for the CSAI-2 subcomponents were in accordance with their predictions. Cognitive anxiety increased from precompetition to midcompetition, whilst somatic anxiety and state self-confidence decreased across the same period. In the current study, temporal changes were also evident for cognitive and somatic subscales, but only partially support Martens et al. (1990) predictions. Cognitive anxiety was significantly higher at a mid-competition measure (H6), compared to after the round (H18). Cognitive anxiety at hole 6 could reflect performance expectations arising from performance feedback during these initial golf holes, whereas performance expectations would not be expected to change further after golfers have completed their round. However, PRE and H12 cognitive anxiety were similar to H6, which indicates that either performance expectations did not change from pregame to during the game, or else the CSAI-2 is not sensitive to measuring subtle changes in performance expectations in these players. Similarly, somatic anxiety prior to the game remained elevated at hole 6, and declined once competition was complete. Somatic anxiety was expected to dissipate with the start of competition, where attention is focused on task relevant cues.

The differences between Martens et al. (1990)'s findings and those in the current study, may be partly methodological. Firstly, Martens et al. (1990) were unable to employ the CSAI-2 mid-game, and relied on golfers' retrospective reports of state anxiety. The validity of retrospective reporting methods is questionable, as the influence of post-round anxiety on mid-game reflections cannot be accounted for. Secondly, Martens et al. (1990) compared

the average group anxiety responses, when Sonstroem and Bernardo (1982) had shown individual comparisons to be more sensitive. The current study employed intra-individual comparisons for REC golfers and two mid-game CSAI-2 measures. The golfer's in Martens et al. (1990) study were younger on average than the REC golfers, and the sample size was almost twice that of the current study. These factors together may conceivably result in the differences found.

Martens et al., (1990) predicted that precompetition CSAI-2 scores would relate to golf score on the first nine holes, since these two measures were temporally closer, but found the opposite. They were unable to explain why precompetition cognitive A-state correlated with performance on the second nine holes, but advocated that measuring cognitive state anxiety during performance would strengthen the cognitive anxiety-performance relationship. Having addressed this methodological concern, there was no evidence for cognitive anxiety predicting performance in recreational golfers. Cognitive A-state was highest in REC golfers at hole 6, but this did not correlate with performance score over the subsequent six holes (SC7-12). Likewise, pregame cognitive A-state did not relate to score for the first six holes (SC1-6), nor did H12 cognitive anxiety influence performance during the concluding six holes of competition play (SC12-18). In this study, the methodological approach recommended by Martens et al. (1990) and McAuley (1985) did not appear to strengthen the predicted relationship between anxiety and performance in golf.

Rather than state anxiety being an antecedent to golf performance, this study found that cognitive and somatic anxiety postgame (H18) were able to predict some of the performance variance over the concluding golf holes (SC13-18). Despite these post-game measures representing the lowest intensities of state anxiety measured for the competition game, the direction of anxiety supported Martens et al.'s (1990) predictions, that is, higher anxiety was associated with worse golf performance. These findings confer somewhat

with a study by McAuley (1985), who measured pregame and postgame state anxiety and state self-confidence using the CSAI-2 in seven women golfers across ten golf rounds. McAuley (1985) used regression analysis and found no relationship between pregame CSAI-2 scores and performance score, rather golf performance (score) was a significant predictor of cognitive state anxiety and self-confidence. Whilst postcompetition (H18) cognitive A-state correlated with 18 hole performance score, the mid-game measures used in the current study extend these findings by indicating that score over the final holes of play (SC12-18) predicted postgame state anxiety. This study confers with McAuley's (1985) conclusion that performance was an antecedent of state anxiety, and not the other way around. The paradox however, is that the intensity of cognitive anxiety for the round was lowest postgame. Similar patterns for performance influencing state anxiety was not evident in the early part of the competition game where cognitive anxiety was higher, for example, SC1-6 did not correlate with cognitive anxiety at hole 6. Performance score may not be a strong antecedent of cognitive A-state, rather a reflection of how recreational golfers feel about their performance at the end of a competition round.

The relationship between state self-confidence measured by the CSAI-2 and sport performance is largely unclear. In competition, self-confidence at H6 correlated positively with performance scores over the preceding six holes (SC1-6), indicating that self-confidence increased after better performance in the opening golf holes. Self-confidence was otherwise not strongly and consistently related to performance score before, during or after the round. Burton (1988) found that higher precompetition self-confidence was a significant predictor of performance in three swim meets. In golfers, McAuley (1985) found some support for performance influencing golfer's self-confidence, as did Martens et al. (1990) who found midgame self-confidence measures correlated with performance scores on the first and second nine holes. The golfers used in both these studies were

considered higher in ability golfers compared to those in the current study, which may have contributed to the discrepant findings.

In conclusion, this study found that recreational golfers respond to stress in competition situations with heightened emotional anxiety. Elevated anxiety however, was not associated with discernible changes in heart rate, HPA activity or differences in golf performance compared to practice. The implications for middle-aged, moderate ability golfers, is that competition performance is not directly influenced by heightened perceptions of emotional state anxiety. An indirect implication of these findings, is that club-level competition should provide the benefits associated with moderate levels of exercise and energy expenditure, without the undue risk of stress-related cardiovascular responses which might compromise golf for rehabilitation. In terms of psychophysiological relationships, this indicates that psychological anxiety and physiological responses may have different competition antecedents, and therefore may be independent measures of stress. Competitive state anxiety did not predict recreational golfers score, rather it reflected how they felt about their performance over the concluding holes played.

Chapter 6

AEROBIC FITNESS AND PSYCHO- PHYSIOLOGICAL STRESS RESPONSES TO COMPETITION IN ELITE AMATEUR GOLFERS

6.1 Overview

Competition evokes changes to golfers' psychophysiological states compared to practice (Chapter 4 and 5). By using a similar protocol for measuring psychophysiological stress, the current study proposes to examine whether enhanced aerobic fitness modifies psychological responses to competition stress in a low aerobically demanding sport, namely golf. This issue has seldom been investigated using aerobic training interventions in competitive sport settings, and may have implications for modifying stress responses in golfers.

6.2 Abstract

The influence of enhanced aerobic condition on psychophysiological stress responses to competition were examined in fifteen Australian Institute of Sport (AIS) (elite) golfers. Golfers underwent an incremental treadmill test using a walking (Bruce) protocol to determine their maximal aerobic power (VO_{2max}) and anaerobic threshold (AnT). One week later, golfers competed in an AIS competition. The competition format involved

players either winning or forfeiting money according to their handicap adjusted performance score at the end of the round. Salivary cortisol and state anxiety (Competitive State Anxiety Inventory; CSAI-2) were measured before the start of competition (PRE) after hole 6, 12 and upon completing the 18 holes (H6, H12 and H18 respectively). Heart rate was recorded at 15 second intervals from holes 1 to 18 by a heart rate monitor (PE3000) and averaged for each hole played. Players underwent an 8 week personalised aerobic training program based on heart rates at 70% of their pre-training anaerobic threshold (AT_{pre}). A second (post-training) VO₂max was completed before golfers played a second competition golf round, on the same course and time of day as the pre-training game. The results showed that despite a significant ($9.6\% \pm 2.6$; mean \pm SEM) increase in the groups mean VO₂max, there was no significant difference in heart rate, salivary cortisol or state anxiety during the post-training compared to the pre-training competition games. There was some evidence from regression analysis that combinations of the psychophysiological parameters could predict some of the performance variance. Aerobic training in this study did not influence psychophysiological responses in elite golfers to competition.

6.3 Introduction

Sport research has focused on the treatment and prevention of stress in athletic competition. Psychological intervention programs, including relaxation and positive imagery, have been employed to modulate athletes' psychophysiological state and enhance performance (Prapavessis et al., 1992; Ziegler et al., 1982). Whilst physical (aerobic) fitness is beneficial for general health and well-being (Petruzzello et al., 1991; Roth and Holmes, 1985), recent evidence suggests a more direct relationship between aerobic fitness-mediated adaptations in physiological systems and reduced psychophysiological responses to psychological stress (Crews and Landers, 1987).

Modulations in stress reactivity, including cardiovascular and neurohormonal responses, are associated with an increased ability to cope with stress (Rostad and Long, 1996). Laboratory studies comparing groups of unfit to fit individuals, have found the latter to have lower heart rates during psychological stressors (Holmes and Roth, 1985), and faster heart rate and state anxiety recovery post-stressor (Sinyor et al., 1983; Keller and Seraganian, 1984), although these findings have not always been consistent (Light et al., 1987; Cantor et al. 1978). Physical training which enhances aerobic power attenuates the pituitary-adrenal responses to exercise stress when comparing individuals at the same relative submaximal exercise workloads (Buona et al., 1987; White et al. 1976; Luger et al., 1987). However, Sinyor et al. (1983) was unable to find a change in the plasma cortisol response during a series of psychologically stressful cognitive laboratory tasks, which may have been due to baseline confounds.

Others have raised concerns regarding the relevance of laboratory responses to real-life situations (Myrtek and Spital, 1986). Brooke and Long (1987) compared a high and low-fit group of novice individuals before and after a 15 minute rappelling manoeuvre. Pre-task cortisol, heart rate, state anxiety and epinephrine were elevated in both groups, but fit individuals had lower absolute heart rates and showed faster recovery (state anxiety and epinephrine). There was no evidence for cortisol modulation, however the rappelling manoeuvre was task was highly threatening and novel, and could not be considered typical of stressors encountered in competitive golf environments. The time course of adrenocortical changes during the 15 minute rappel was not measured and furthermore, the short duration and highly potent nature of the stressor would mean that cortisol concentration would persist in the blood given the relatively long half-life of the hormone. Cross-sectional study designs do not indicate causality of aerobic fitness in modulating

psychosocial stress responses, so researchers have used training intervention studies but with equivocal results (Blumenthal et al. 1990; de Geus et al., 1990).

The stress-reducing benefits of aerobic exercise in many sporting contexts is somewhat of an anomaly, because the majority of sports require a degree of aerobic fitness training to compete effectively. However, it may have an important practical application in reducing stress responses during competition, which is considered a psychosocial stress paradigm (Herbert, 1987), in low aerobically demanding sports such as golf. A potential benefits for elite golfers experiencing reduced psychophysiological responses to competition, may include reduced fatigue especially over several days of a tournament. Crews (1994) suggested low fit golfers may be distracted during putting by heavy respirations and elevated heart rates, suggesting aerobic fitness may play a role in task-orientated attention. Improving all aspects of performance is important for elite athletes to compete successfully, therefore this study proposes to examine whether aerobic fitness reduces psychophysiological stress responses in elite golfers to competition.

Purpose:

The purpose of this study was to examine the effect of enhanced aerobic fitness on psychophysiological stress prior to, during and at the completion of competition golf play, and its influence on performance in elite male amateur golfers.

Hypothesis:

1. Increased aerobic fitness lowers heart rate, cortisol and cognitive and somatic anxiety responses to golf competition

6.4 Methods

6.4.1. Participants

Eight healthy male elite golfers (age 22.1 ± 2.2 years; height 180.3 ± 1.5 cm; weight 76.2 ± 3.2 kg; handicap 1.9 ± 0.4 strokes; mean \pm SEM) participated in the study. All participants were completing a one year Australian Institute of Sport (AIS) scholarship. AIS scholarships are awarded to the top ranking amateur male and female players in Australia to prepare them for professional golf. At the time of study, the golfers were participating in a weight development program but were not receiving aerobic training in addition to playing three to four golf rounds per week. The AIS squad was selected for this study because they represent an elite group of golfers, with the time available to incorporate an 8 week, fully supervised intensive fitness program into their schedule. There was no initial assessment to determine whether these golfers were predisposed to stress.

6.4.2 Design

To determine initial levels of physical fitness, each golfer's maximal aerobic power (VO_{2max}), heart rate and heart rhythm was measured using a graded walking treadmill (Bruce) protocol (Heywood, 1984). The following week, golfers competed in an organised AIS competition comprising 18 holes of stroke play, where saliva cortisol concentration, heart rates and sport specific anxiety (CSAI-2) was measured at pre (PRE), hole 6 (H6), hole 12 (H12) and at the completion of the round (H18). (See Chapter 3.3). Each golfer then completed three aerobic training sessions per week for eight weeks. Training intensity started with each golfers' heart rate equivalent of 70% of their anaerobic threshold determined from the initial VO_{2max} test. Training sessions were supervised by a qualified volunteer, to ensure the time and intensity of training were achieved. At the completion of the eight weeks, the golfers' underwent a second VO_{2max} test to determine the efficacy of the training program. A second competition golf round was played using the same golf

course, competition format tee off time as the original 18 hole round. In addition, golfers were required to complete two separate basal days, where saliva was collected on a day with minimal physical exertion.

6.4.3 Exercise protocols and collection of metabolic data

Protocol for determining aerobic power

A motorised treadmill (RepcO, Australia) was used to conduct an incremental walking protocol (Bruce Protocol, 1973), to assess each golfer's VO_2max . The exercise test is a multi-staged treadmill protocol to volitional exhaustion, and was selected because walking exercise is specific to golf. Workloads in the Bruce Protocol are increased by changing the speed and gradient of the treadmill, as shown in Table 6.1. The criteria for termination was volitional fatigue, manifested by one or more of the following: attainment of heart rate to 95% of predicted maximal heart rate, respiratory exchange ratio (RER) greater than 1.1, a plateau in oxygen consumption or an unwillingness to continue.

Determination of VO_2max

Golfers were familiarised with the apparatus and procedures prior to testing. On the day of testing, each golfer was requested to arrive at the laboratory one hour before testing commenced. During the next 15 minutes, golfers were informed as to the laboratory and safety procedures involved in VO_2max determination, completed a ten-minute stretching and warm-up routine.

Height and weight measurements for each individual was entered into the computer (Turbofit) software, which recorded and displayed metabolic measurements (RER, VO_2 , CO_2) every 30 seconds. A 6-lead ECG was then attached to the individual and heart rate traces were printed each per minute for the duration of the exercise test. The metabolic data (VO_2max) was measured by open circuit analysis of expired air. The expired air was

Table 6.1 Bruce Protocol used in treadmill VO_2max . testing for n=8 AMA golfers (Bruce et al. 1973 in Heyward, 1984).

Time	Treadmill		Time at
(min)	speed	grade	w/load
	(km.hr⁻¹)	(%)	(min)
1 to 3	0.0	0	resting data
3	4.0	0	1
4	4.0	10	2
6	4.0	12	3
9	5.4	14	3
12	6.7	16	3
15	8.0	18	3

measured as the subject breathed through two-way (Hans-Rudolph) valve, which was connected to a ventilometer (Pneumoscan) with a turbine flow transducer (Mark 2). Gases were analysed for the fractions of O_2 and CO_2 by Applied Electrochemistry analysers S-3A; (O_2) and CD-3A (CO_2). The ventilometer was calibrated at the start and end of the first test, and after every third subject tested, using a 3 litre calibrated syringe. The analysers were calibrated pre and post tests using alpha-standard calibration gases (CIG, Melbourne). A computer (IBM) provided direct calculations of metabolic data every 15 seconds.

Before entering the treadmill, subjects were requested to relax (in standing position). Three minutes of resting data was collected as well as a resting ECG at the start of the third minute. The treadmill was started and the player stepped on and commenced walking at minute 4. Hand-signals learned before the test were used to communicate with the golfer during the test. At the completion of testing, subjects were required to walk for 3 minutes to allow heart rate to recover, however no data was collected during this post-exercise period. Ice was applied to the calf muscles to aid in reducing stiffness.

Anaerobic Threshold Calculation

The metabolic data was downloaded from the Turbofit software. For each subject, maximal oxygen consumption was determined as the highest value measured. Heart rate corresponding to anaerobic threshold was obtained from the first treadmill test. Anaerobic threshold was determined by plotting each golfers' VO_2 against VCO_2 and Ve , using the V-slope method (Wasserman et al. 1987). The second break point from linear trends was defined as anaerobic threshold (AT), and used as the initial training intensity in the aerobic training program.

6.4.4 Aerobic Training Program

The eight week training program including the intensity, duration and frequency of exercise shown in Table 6.2. The program was designed to progressively increase the heart rates during exercise, as well as the duration and frequency of training over the eight week period. This protocol complies with recommendations for enhancing aerobic fitness (Petruzello et al., 1991; Rostad and Long, 1996).

The three components of the training load were incremented and staggered. The training heart rate in weeks 7 and 8 were close to the original anaerobic threshold. However the improvement in each golfers' anaerobic training potential over the course of the exercise program, meant that these heart rates would be well tolerated. The exercise training comprised aerobic exercise, including cycle ergometer and treadmill walking/running during a compulsory gymnasium session three times per week. Each golfer was presented with their target steady-state heart rate at the start of each training session, and subsequently monitored their heart rate by either palpation methods or by heart rate feedback from a heart rate monitor (Polar Sport Tester). A qualified physical trainer supervised each training session and recorded exercise details and attendance. At the completion of eight weeks, a second $VO_2\text{max}$ test (following procedures described) was performed to determine the change in aerobic power. Enhanced aerobic power corresponded to increases in $VO_2\text{max}$, while enhanced aerobic power was identified as lower heart rate for given oxygen consumption.

Table 6.2 Aerobic training program showing progression in intensity, duration and frequency to enhance aerobic power in n=8 AMA golfers over an 8 week period.

Week	Training HR (% of HR at A.T#)	Duration at training HR* (min)	Frequency (sessions/wk)
1	80%	15	3
2	80%	20	3
3	85%	20	3
4	85%	25	3
5	90%	25	4
6	90%	30	4
7	95%	30	4
8	95%	35	4

expressed as a percentage of heart rate (HR) at anaerobic training threshold (A.T) determined at VO₂max.test

* training at given heart rate (training sessions per week)

6.4.5 Psychophysiological parameters and golf round measures

Salivary cortisol, heart rate and CSAI-2 were measured as detailed in Methods (Chapter 3.3.2, 3.3.3 and 3.3.4 respectively). Single 200 μ l cortisol samples were analysed. Details for golf round data collection are included in Section 3.5 and performance scores in Section 3.5.1).

6.4.6 Treatments

Familiarisation, competition conditions and study controls

Familiarisation procedures prior to the golf round testing is detailed in Methods (Chapter 3.6.2). Competition rounds comprised two 18 hole stroke play events, conducted on a Melbourne metropolitan golf course (The Commonwealth Golf Club). The competition round was organised by the AIS coach, and comprised a format commonly used for tournament preparation. The 18 hole stroke competition comprised the eight male players and five female AIS players. The winner was the person with the lowest score at the end of the round. The other twelve golfers paid the winner one dollar for each shot over their handicap at the finish of the event. This format is used because it maintains the pressure on the players, not only to win but to maintain a low score and reduce the amount of money forfeited. The players are scholarship holders, and do not earn an income. In this study, it was impractical to use actual tournaments settings for several reasons. Firstly, scheduling testing between two suitable tournament events with at least an 8 week training period was not possible. Secondly, only by using the AIS competition format could re-testing occur on the same golf course and time of day. This was important for internal consistency and to reduce potential confounds on psychophysiological measures.

Jasnoski et al. (1981) stated that aerobic training studies should use a group which controls for personality types or enhanced self-efficacy resulting from participating in a group

program. Such factors may confound findings attributed to aerobic fitness changes. In this study, the AIS students participated in many activities as a group, including attending lectures, playing practices and golf training sessions. This would be expected to minimise such group influences, hence a control group was not used in the current study.

6.5 Results

6.5.1 Metabolic Data

To examine the effect of the 8 week training program on golfers' aerobic power, T-tests were used to analyse the metabolic data. The pre and post training VO_2max results for the eight male golfers in the study are shown below.

Table 6.3 Training variables (mean \pm SEM) comparing pre and post training and % change in VO_2 , anaerobic threshold (AT) and mass for n=8 AMA golfers.

Variable	Pre Training mean \pm SEM	Post Training mean \pm SEM	% change mean \pm SEM	p
VO_2 (ml.kg ⁻¹ .min ⁻¹)	54.9 \pm 2.7	59.7 \pm 2.9	9.6 \pm 2.6%	**
AT	43.3 \pm 2.2	50.3 \pm 3.2	17.7 \pm 2.6%	**
Mass (kg)	76.2 \pm 3.2	76.4 \pm 2.8		

** p< 0.01

Mean heart rate responses (b.min⁻¹) at each workload for n=8 golfers during VO_2max (pre and post) testing are illustrated in Figure 6.1.

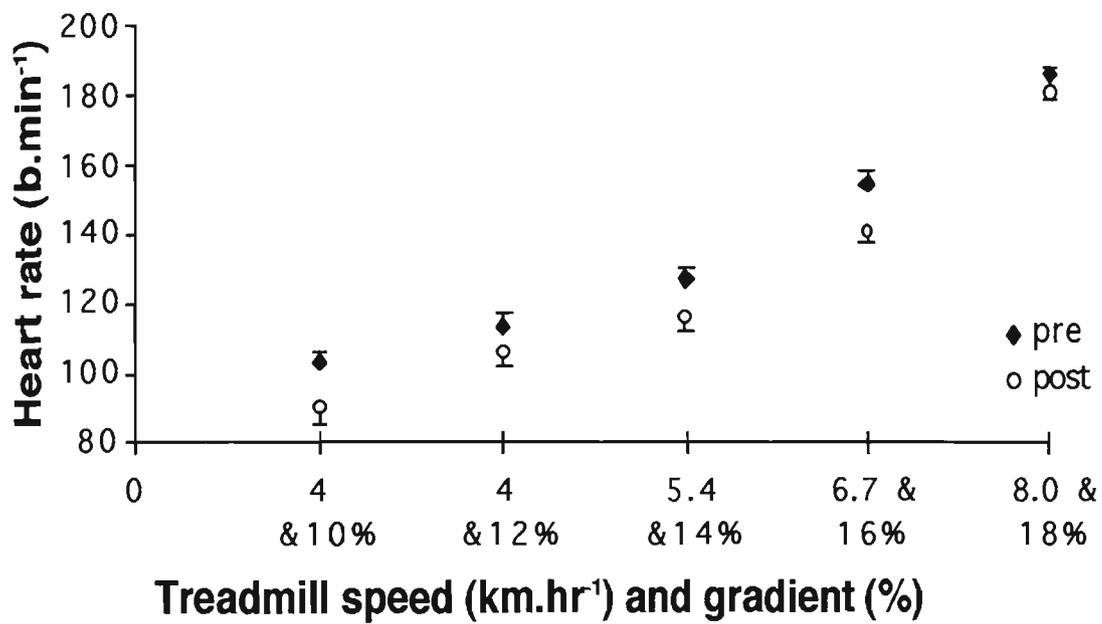


Fig 6.1 Mean heart rate responses (b.min⁻¹) during VO₂max testing for n=8 AMA golfers, before (closed diamond) and after (open circle) an 8 week aerobic training intervention.

6.5.2 Psychophysiological parameters

To examine the effects of aerobic training condition and time on the physiological parameters, intra-individual cortisol responses and heart rates were analysed before, during and after the golf games. Means \pm SEM are reported.

Cortisol

The mean cortisol responses for $n=8$ male golfers are illustrated in Figure 6.2. Salivary cortisol responses analysed by a Game x Hole (2 x 4) two-way repeated measures ANOVA revealed cortisol responses were similar in the pre-training compared to the post-training condition for both competition rounds ($2.5 \pm .22$ and $2.1 \pm .78$ nmol.l⁻¹, respectively; $F(1,7)=.53$, $p=.50$). There was no time effect for cortisol ($F(1,7) = 1.94$, $p<.15$), but there was an interaction between training condition and time ($F(3,21)=4.01$, $p<.02$). Tukey's post-hoc analysis indicated that post-training(H18) and pre-training(PRE) cortisol, were significantly higher than post-training(H12). Also, post-training(H18) was higher than post-training(H6).

Heart rate

To examine the effect of aerobic training and time on golfers heart rates, a Game x Hole (2 x 4) two-way repeated measures ANOVA was conducted on heart rates for each hole. The heart rate responses are illustrated in Figure 6.3. The ANOVA revealed that aerobic condition did not influence heart rates during competition golf, as the heart rates in the pre-training round were similar to those in the post-training competition (105 ± 2.7 and 108 ± 2.7 b.min⁻¹, respectively; $F(1,7) = 2.2$, $p = 0.18$). There was a significant effect for time ($F(17,119) = 3.29$, $p<0.001$) and a significant interaction ($F(17,119) = 1.91$, $p<0.02$). Golfers took longer to complete the pre-training round compare to the post-training round (248.5 ± 2.7 and 222.8 ± 8.7 min, respectively; $t(7) = 3.23$, $p< 0.014$).

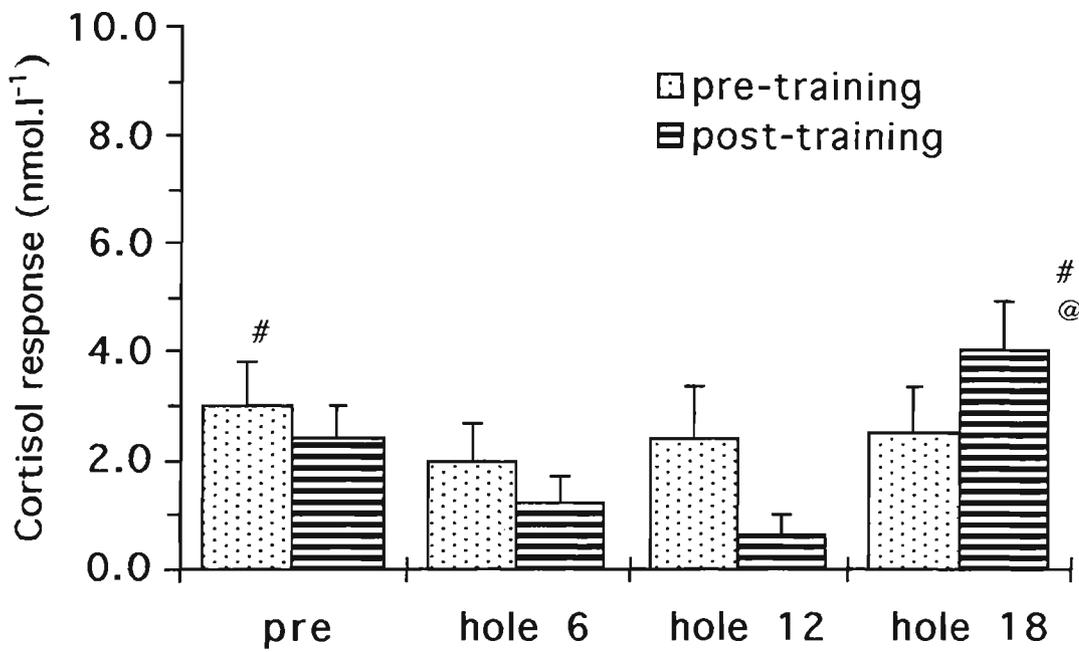


Fig 6.2 Cortisol responses (nmol.l⁻¹) for n=8 AMA golfers at pregame (pre), hole 6, hole 12 and hole 18 during a pre-training and post-training competition round. Values are mean \pm SEM. # different from post-training(H12) ($p < 0.05$); @ different from post-training (H6).

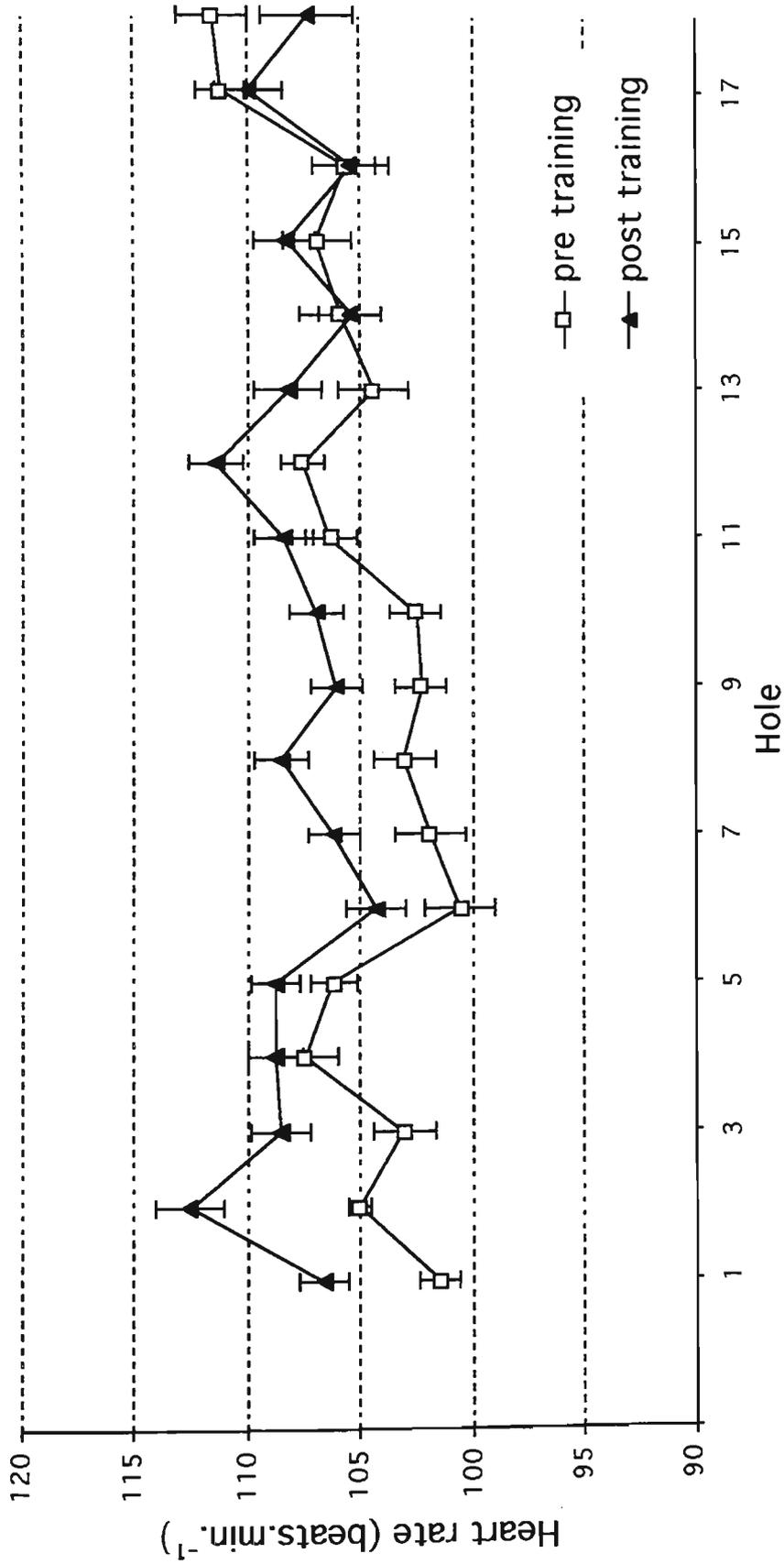


Fig 6.3 Average heart rate responses for holes 1 to 18 for n=8 AMA golfers during pre training and post training competition golf rounds. Values are mean \pm SEM. No difference between game conditions ($p<0.05$).

CSAI-2

The CSAI-2 scores (mean \pm SD) during the pre and post training golf games are shown in Table 6.4. The relationship between aerobic training condition and time on state anxiety and self-confidence was examined. Individual repeated measures ANOVAs were used to analyse the separate CSAI-2 subscales due to the sample size of the group. There was no significant effect on cognitive anxiety for the aerobic training condition ($F(1,7) = 3.66$, $p=.09$), or interaction between training condition and time ($F(3,21) = 1.56$, $p=.23$). There was a significant time effect ($F(3,23) = 3.58$, $p<.03$). For somatic anxiety and self-confidence in competition, there was no significant difference between the training condition ($F(1,7)=2.69$, $p=.15$ and $F(1,7)=.9$, $p=.37$; respectively), no effect for time ($F(3,21)=.62$, $p=.6$ and $F(3,21)=.54$, $p=.67$; respectively), or interaction between training condition and time ($F(3,21)=1.11$, $p=.37$ and $F(3,21)=1.11$, $p=.36$; respectively). Tukey's post-hoc tests used to analyse the effect of time on cognitive anxiety, revealed that cognitive anxiety for the pre-training game (PRE and H6) and the post-training game (PRE), were significantly higher than cognitive anxiety at H12 in the post-training game.

Correlations between CSAI-2 subcomponents

To examine whether the CSAI-2 subscales are moderately correlated and therefore showing a partial independence, intra-correlations (r) were calculated for cognitive anxiety, somatic anxiety and self-confidence subscales at PRE, H6, H12 and H18. The results presented in Table 6.5, and indicate moderate to high correlations between the subscales and therefore some independence.

6.5.3 Performance Measures

Intra-individual comparisons using a two-way ANOVA with repeated measures (training condition \times hole) for six hole average performance scores, revealed that performance in the pre-training game was not significantly different to the post-training game (79.3 ± 0.8 and

Table 6.4 CSAI-2 cognitive and somatic anxiety and self-confidence scores (mean \pm SD) for a pre-training and post-(aerobic)training competition golf round at pregame (PRE), hole 6 (H6), hole 12 (H12) and post round (H18) in n=8 AMA golfers.

Competition round	<u>CSAI-cog</u>	<u>CSAI-som</u>	<u>Self-conf.</u>
	M (SD)	M (SD)	M (SD)
Pre-training			
PRE	15.1 (3.5) * ..	12.8 (4.0)	28.9 (4.5)
H6	15.0 (3.6) * ...	10.8 (1.6)	28.5 (5.4)
H 12	14.6 (3.7)	12.0 (3.3)	28.6 (5.7)
H18	14.1 (4.9)	10.8 (3.6)	28.4 (6.9)
Post-training			
	NS	NS	NS
PRE	15.0 (5.3) ..*....	10.4 (2.0)	30.0 (7.9)
H6	12.8 (3.9)	10.5 (3.1)	30.9 (6.6)
H 12	10.9 (3.2)	10.0 (1.6)	31.1 (6.8)
H18	11.4 (2.7)	10.4 (1.8)	32.1 (5.5)

* different from CSAI-cog (H12) in post-training ($p < 0.05$); NS is not significant ($p < 0.05$)

Table 6.5 Intercorrelations (r) among CSAI-2 cognitive and somatic anxiety and self-confidence) measured during a pre-training and post-training competition at pregame (PRE), after 6 holes (H6), 12 holes (H12) and postgame (H18) for $n=8$ AMA golfers.

	CSAI-cog and CSAI-som r	CSAI-cog and Self Conf. r	CSAI-som and Self Conf. r
Pre-training			
PRE	.43	-.51	-.75 _b
H6	.48	-.59 _a	-.80 _b
H 12	.52	-.53	-.81 _b
H18	.38	-.51	-.76 _b
Post-training			
PRE	.52	-.62 _a	-.80 _c
H6	.52	-.49	-.94 _c
H 12	.53	-.72 _a	-.60 _a
H18	.57 _a	-.67 _a	-.76 _a

a, $p < .05$; b, $p < .01$; c $p < .001$

77.0 ± 0.9 strokes, respectively; $F(1,7)=1.69$, $p=.23$; mean ± SEM). Correlations between cortisol and performance at H6, H12 and H18, revealed that in the pre-training game, cortisol at H6 correlated significantly with performance scores over the first six holes (SC1-6; $r=.72$, $p=.045$). Higher cortisol related to worse performance score.

Multiple quadratic regression analysis was used to examine the ability for CSAI-2 components, cortisol and heart rate to predict performance. The criterion variable was the performance measure (either SC18 of SC1-6, SC7-12, or SC13-18). Predictor variables in the multiple regression analysis included CSAI-2 and cortisol measures at pre, H6, H12, H18 and heart rates for holes 1-6, 7-12, and 13-18. The results showed that 18 hole handicap adjusted score could be predicted by some, but not all of the dependent variables (Multiple R =.365; $F(5,108) = 3.32$, $p<.007$).

6.6 Discussion

This study examined the influence of aerobic fitness on psychophysiological stress responses to competition in eight male elite golfers. Despite significant improvements in aerobic power after an eight week training program, intra-individual comparisons revealed that salivary cortisol, heart rate, and state anxiety measured by the CSAI-2 were similar in both competitions. Interactions were found between aerobic condition and time of the competition round (pregame, hole 6, hole 12 and postgame) for both physiological measures. Only cortisol responses at H12 after training were significantly lower than a cortisol response measured prior to the training, and that was at pregame (PRE). Hence, there is no consistent support for enhanced aerobic fitness in modifying HPA activity to a psychological stressor. Golfer's performance scores were similar in both competition games, however regression analysis revealed standardised golf performance scores were predicted by some combinations of the psychophysiological variables. In general, this field

study provides little support for enhanced aerobic fitness influencing psychophysiological stress responses or performance to a psychosocial stressor, namely golf competition.

Golfers' salivary cortisol responses in both competition games were low (averaging 2nmol.l^{-1}), and similar in the pre-trained compared to the post-trained state. Intra-individual analysis confirmed that, despite a mean group increase in aerobic power of just under 10%, the adrenocortical response to golf competition was not effected. Physical (aerobic) training has been found to modulate the ACTH and cortisol response during submaximal exercise loads. For example in a study of ten males, Buono et al. (1987) found a similar mean group increase in VO_2max to the current study. They found reduced ACTH responses after training when comparing individuals for the same relative exercise workloads. Such studies provide evidence for physiological adaptations in adrenocortical responses to exercise stress, although the psychological influences on HPA activity during these studies cannot be accounted for. However, there are marked differences between such studies and the current studies in golfers. Firstly, these training studies were performed in laboratory controlled environments and generally involved higher exercise intensities than golf play. White et al. (1976) used low intensity exercise of around 50% VO_2max , which is still greater than the average 30% VO_2max of golf activity (Murase et al., 1989). Furthermore, treadmills or ergometers are used to achieve steady-states at these exercise intensities (Hartley et al., 1972; White et al., 1976) whereas golf activity is intermittent, ranging between walking, standing and shot-making. If modulations in HPA function had occurred in golfers as a result of enhanced aerobic power, the low intensity, intermittent nature of golf exercise may have masked their detection.

In contrast to the prediction that cortisol responses may be attenuated with enhanced aerobic condition, there was only one instance where a pre-training cortisol response was greater than a post-training response. Pregame cortisol responses before training were higher than

a mid-game measure (H12) in the post-trained state. Otherwise, cortisol responses measured after competition in the post-training condition (hole 18) were greater than those measured at the two previous mid-game sampling sites (H12 and H6). A field study by Brooke and Long (1987) measured psychophysiological responses in high fit and low fit novices to a 15 minute rappel. The high fit group had similar average VO_2max 's to the golfers in the current study after training. They found cortisol, heart rate, state anxiety and epinephrine (E) increased similarly in all participants from the pre to post-stressor period. Based on faster recovery rates (return to baselines) for E and heart rate in fit individuals, they concluded that these people coped better physiologically and psychologically to the stressor. Cortisol, they believed, remained elevated in the 30 minute post-stressor measurement period because of the long half-life of the hormone. Compared to these rappellers, the golfers in the present study were not exposed to the extreme threat induced by the potential danger in rappelling, nor were they novices to stress-inducing task. In addition, reactivity to venepuncture which could not be controlled for in rappellers can be discounted in golfers. Nonetheless, rappelling could be considered a potent psychophysical stressor, evident from the reactivity in the psychophysiological parameters, whereas the lack of reactivity of psychophysiological parameters in these golfers suggests that competition was not sufficiently stressful or arousing. Hence, the efficacy of golf competition as a psychological stressor in this study may have been a major confound. Fillingham and Blumenthal (1992) stated that the stressor must elicit a robust psychophysiological response pattern, large enough that modifications may be measured. Another explanation for the findings in the current study therefore was that greater provocation, such as a more stressful competition setting, may have been required to measure subtle changes resulting from aerobic training. Further studies are required to test this hypothesis.

In another cross-sectional study design, Sinyor et al.(1983) found that fit and low fit groups showed elevated heart rates and state anxiety to a series of psychologically stressful laboratory tasks, but that cortisol concentrations were not influenced. The current study provided no indication that elite golfers heart rates and state anxiety during the pre-training competition were elevated compared to the post-training event. Rather, they tend to support the cortisol findings in that they were generally low and comparable for both competition games. Golf competition has previously been found to evoke emotional heart rate responses in elite golfers (McKay et al., 1997), being elevated by around 20 b.min⁻¹ in a competition compared to a practice setting. In another field study, where physical activity was low but not controlled, baseballers had emotional heart rate responses around 166b.min⁻¹ (Hanson, 1966). In the current study, AMA golfers heart rates in both competition rounds were similar, around 100 b.min⁻¹, and confer with those measured by Murase et al. (1989) in golfers in a non-competitive environment. This would indicate that although the AMA golfers were playing against their peers and being assessed by their coach , the nature of the competition did not appear to evoke a strong emotional heart rate response.

Heart rate responses of high and low fit individuals to psychological stressors under more strictly controlled laboratories conditions, have more often than not detected attenuated cardiovascular responses in fit group (Crews and Landers, 1987). Although heart rate reactivity to the stressor may be similar, that is the increase in heart rate from baseline, absolute heart rates tend to be lower (Brooke and Long, 1987; Holmes and Roth, 1985; Plante and Karpowitz, 1987). It is interesting in the current study that golfer's cardiac efficiency increased. This was evident from the training bradycardia for heart rate responses to incremental treadmill testing comparing the pre and post VO₂max tests (Figure 6.1). However, this effect was not reflected in the on-course heart rates.

The reason why lower heart rates were not evident on-course as opposed to the laboratory cannot be conclusively ascertained, but the inherent lack of control in environmental settings may provide some explanation. For example, players completed their post-training competition round significantly (30 minutes) faster than the pre-training round, possibly reflecting a higher average level of physiological exercise intensity. If heart rates were somewhat elevated in the post-training game compared to pre-training, this may have concealed the predicted heart rate differences. Comparing the patterns of heart rates, there was a tendency for heart rate to trend upward toward the end of the pre-training round which is not evident in the post-training round where heart rates remained relatively flat over the conclusion of play. There was a significant interaction for heart rate found (training status X time). Although speculative, factors such as fatigue may have contributed to the upward trend in the pre-training round.

A further explanation as to why heart rate attenuation was not observed despite enhanced aerobic fitness, is the high initial fitness levels in this group of golfers. The lowest $VO_2\text{max}$ was around $48 \text{ ml.kg}^{-1}.\text{min}^{-1}$ and the highest close to $68 \text{ ml.kg}^{-1}.\text{min}^{-1}$. Even before training, these golfers may have shown an efficient (trained) cardiac responses to golf activity. Further increments in fitness may only provide small and non-significant changes to heart rates beyond these. Whilst the efficacy of the training program was high, the degree of improvement in physical fitness (as the % increase in from initial fitness levels) was varied, ranging from 1 to 24%. This factor, together with the small sample size, may have led to confounds in this study.

Whilst aerobic fitness has been implicated in reducing state anxiety to psychological stressors, including cognitive and somatic anxiety (Holmes and Roth, 1985), this study provided little evidence for a causal relationship between increased fitness and reduced competitive state anxiety during competition. More specifically, there was no change in

cognitive and somatic anxiety and state self-confidence with enhanced aerobic power in AMA golfers. Cognitive and somatic anxiety responses were generally low and self-confidence high indicating these golfers were not particularly anxious or nervous about their performance, despite the performance incentive of winning or losing money. Temporal patterns for cognitive anxiety showed that golfers were more worried about their performances early in both games compared to mid-way (hole 12) through the post-training game. On account of the low intensity of state anxiety measured in the study, there is no plausible explanation for this finding.

State anxiety scores and the physiological variables did not show a strong and consistent relationship with golf performance. Although regression analysis revealed combinations of variables could predict performance, the pattern was not consistent and these findings cannot be interpreted as meaningful. Certainly, there was no effect for aerobic condition on golf performance score. In the pre-training competition, cortisol responses at hole 6 correlated with golfers' six hole average score (SC1-6), but the relationship was not evident in the post-training game. Higher cortisol was associated with worse performance. Due to the non-significant aerobic conditioning effects on psychophysiological and performance parameters, these observations could only be interpreted by further studies where competition golf paradigms evoke a greater HPA response than the current study. The psychophysiological responses together support the contention that the competition paradigm was not particularly stressful (or arousing), which leads to questions as to whether a more psychologically stress evoking competition situation would have provided data in support of hypothesis. In conclusion, however, there is no evidence from this study for enhanced aerobic fitness reducing psychophysiological stress responses before, during or after competition golf. Future studies should examine elite golfers with lower initial fitness levels than the golfers in the present study, in a more prestigious and therefore more stressful tournament.

Chapter 7

HEART RATES DURING SHOT MAKING AND PUTTING ACTIVITY

7.1 Overview

The previous three studies involving PRO, AMA and REC golfers, measured heart rates at fifteen second intervals during competition golf and averaged the data for each golf hole played. The current study proposes to examine the fifteen second heart rate responses in conjunction with specific shot types in golf to further investigate the influence of competition on heart rate in golfers. Heart rates during putting (first putt only) are examined for PRO, REC and AMA golfers, then the average heart rates for shot types (tee, fairway, approach and putting) are compared for the PRO golfers because they had previously (Chapter 4) shown a significant heart rate response to tournament play.

7.2. Abstract

This study examined heart rate responses to golf shots (in particular putting) during competition golf. Heart rates during a one minute putting phase for PRO (n=15), REC (n=19) and AMA (n=8) golfers were defined by four heart rates measured at 15 second intervals during the first putt on each hole. Two heart rate measures were prior to putt strike (PRE1, PRE2) and two after ball contact (POST1, POST2). Univariate analysis revealed an effect for putt phase in PRO golfers ($F(3,42) = 12.0, p < .001$) and Tukey's post-hoc tests found that heart rates at PRE1 and PRE2 were lower than those after putt strike (POST1 and POST2). This was suggestive of cardiac deceleration and was not evident in

REC or AMA golfers. In addition, average heart rates for tee (TEE), fairway (FWY), approach (APR), putt (PUT) and time spent on the putting green (GREEN) were determined for PRO golfers. Intra-individual univariate analysis revealed that golfers heart rates for FWY shots were higher than those for PUT, possibly due to physical rather than psychological influences. Heart rates for PUT however, were higher than heart rates averaged for the time spent on the putting green (GREEN) in competition only. Although interpretation of the data was limited by field measurement, this study provides preliminary evidence that competition conditions may influence heart rate responses for different shot types in golf, including putting, compared to practice.

7.3. Introduction

Long shots in golf, such as tee and fairway strikes require greater power and flexibility compared to putting and chipping which rely moreso on precise neuro-muscular co-ordination and timing. For the fine motor tasks in particular, elite sportspeople tend to demonstrate consistent patterns of preparatory behaviour, or pre-shot routines. These are typically found in elite golfers prior to putting and shot making (Crews and Boutcher, 1986) and are thought to assist golfers in attaining psychophysiological states which are beneficial to performance success (Tremayne et al. 1993; Crews, 1994). Pre-shot routines are thought to direct attention to task relevant cues and co-ordinate cardiorespiratory and neural activity for successful execution of the motor task (Crews and Landers, 1993).

In a controlled laboratory study, cardiac deceleration was reported in beginner and elite golfers during putting, but was particularly pronounced in elite players during the 3 to 4 cardiac cycles preceding ball strike (Boutcher and Zinsser, 1990). Lower heart rates were evident in elite pistol shooters in a 10 second period prior to trigger release, even after correcting for respiratory effects (Tremayne et al., 1993). They concluded that attentional

focus and respiratory patterns contributed to the measured responses. Whilst laboratory settings provide environments which allow precise measures of cardiac activity during motor performances, others emphasise that heart rate activity is highly dependent on the nature of the setting (Pollack, 1994). In reference to competitive stress research in golfers, Masters (1992) stated that laboratory findings are important, but cannot be considered a “perfect ecological match” to real-life settings. This raises questions as to whether heart rate decelerations during putting are evident under high stress competition conditions. The purpose of the current study is to provide a preliminary examination of intra-individual heart rate patterns during putting in competition and practice settings. Whilst the sensitivity (frequency and timing) of heart rate data is limited in the current study compared to 0.5 second intervals used by Tremayne et al. (1993), heart rate responses during putting have yet to be measured during tournament putting in elite golfers. This study also examines heart rates for different shot types (tee, fairway, approach and putting).

Purpose

The purpose of this study is to investigate the influence of competition on heart rates during putting for PRO, REC and AMA golfers, and for categories of golf shots including tee, fairway, approach and putting for PRO golfers. The specific aims are to;

- i) compare heart rates immediately before and after ball strike in putting; during competition and practice for PRO, REC golfers, and before (pre-training) and after (post-training) an aerobic training intervention during competition in AMA golfers.
- iii) compare heart rates for tee, fairway, approach shots, and putting in competition and practice for PRO golfers
- iv) compare heart rates for putting with those measured for the time spent on the putting green, in both game conditions for PRO golfers

iv) compare heart rates for putting with those measured for the time spent on the putting green, in both game conditions for PRO golfers

7.4 Methods

7.4.1 Participants and Procedures

The data analysed in this study, comprised that of PRO, REC and AMA golfers described in Chapters 4.4.1, 5.5.1 and 6.6.1, respectively.

7.4.2 Data Collection

Golf Shots and Ball strike times

Methods of golf round data collection are included in Chapter 3 (Section 3.5)

For the 18 holes played, the type of golf shot was recorded and later categorised as tee shots (TEE), fairway shots (FWY), approach shots (APR) or putts (PUT). TEE represented the first shot played from the teeing area on each golf hole, whilst FWY included all woods and iron shots played with a nine iron or lower. APR includes pitching, chipping and bunker shots. Putting included all shots played with the putter on the putting surface. First putt represents the initial putt for each player on the 18 putting greens.

Heart rates and familiarisation

Methods for heart rates are described in Chapter 3 (Section 3.4.2). Each observer was thoroughly familiarised with the information required to complete the Golf Recording Sheet. A week prior to testing, they were required to complete entries for at least one hole of golf. This was important to maintain consistency in recording events (golf shot and times) between observers during all golf rounds. Where possible, the same observer followed a golfer for both games.

7.4.3 Data Analysis

Heart rates for first putt

Heart rate was recorded at 15 second intervals throughout each round of golf. For putting, the time recorded at ball strike for the first putt on each green was located on the golf round data spreadsheet. The two 15 second heart rates preceding (PRE1 and PRE2) and following (POST1 and POST 2) the time of ball strike were analysed. Since the time of ball strike did not necessarily coincide with the beginning of a 15 second heart rate measurement period, PRE2 occurred either at, or up to 14 seconds before ball strike, with the average error being 7 seconds. This is a limitation of this study and is addressed in the discussion (Section 7.6).

Heart rates for shot type and time spent on putting green

The heart rates for shot types in PRO golfers (TEE, FWY, APR and PUT) were also determined by locating the ball strike time recorded on the golf round spreadsheet. The heart rate at TEE was represented by the 15 second heart rate recorded immediately prior to this ball strike time, for each golfer. Heart rate for FWY and APR was derived similarly, except when there was more than one shot of the same type on a given hole, in which case the heart rates were averaged. For PUT, the same method as for FWY and APR was used. It should be noted therefore, that putting in this part of the analysis reflects all putts, not just the first putt on each green. The time the PRO golfers spent on the putting green (GREEN) was calculated (Section 3.5) and the heart rates during this time were averaged. For analysis, the 15 second heart rate representing PUT was included in the average heart rates on the green. The average number of observations (n) for each shot category amongst the PRO golfers for each game condition were (competition, practice respectively); TEE (n= 18, n=18), FWY (n=15, n=13), APR (n=11, n=13) and PUT (n=33, n=31).

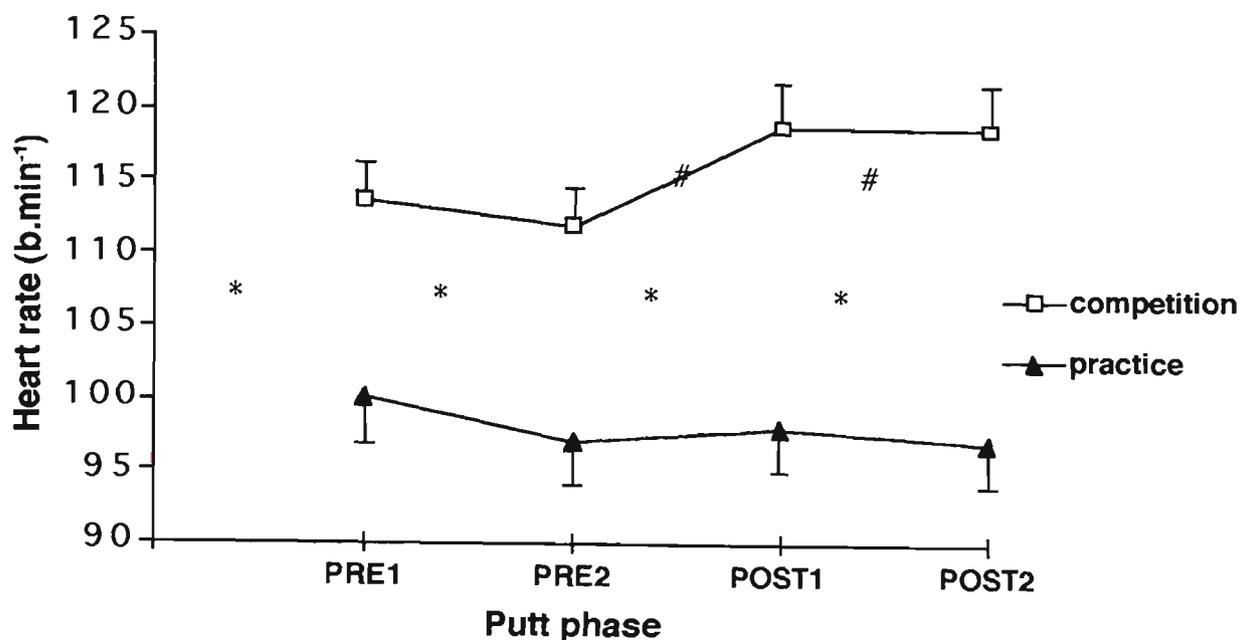
7.5 Results

7.5.1 Heart rates (during first putt) for PRO, AMA and REC

To examine the influences of game condition and putting phase on heart rates for PRO and REC golfers during first putt, separate two-way Game x Putt phase (2 x 4) repeated measures ANOVAs were used. For AMA golfers, a similar ANOVA (2 x 4, Training condition x Putt phase) was used to examine aerobic training condition on first putt heart rates. In addition to these intra-individual comparisons, a between group, two-way ANOVA with repeated measures on putt phase was used to compare changes in heart rate during the putt phase in competition for PRO, REC and AMA golfers. For AMA golfers, heart rate measurements in the pre-training competition were used. Results are presented as mean and standard errors (mean \pm SEM).

The average heart rate responses for the phases of first putts (PRE1, PRE2, POST1 and POST2) during competition and practice rounds for n=15 PRO golfers are presented in Figure 7.1(a). On average, PRE2 heart rate occurred 6.7 ± 0.4 and 6.8 ± 0.3 sec before ball strike in competition and practice games, respectively. The ANOVA revealed that putting heart rates were elevated in competition compared to practice (116 ± 2.8 and 98 ± 3.1 b.min⁻¹, respectively; $F(1,14) = 41.36$, $p < .001$). There was a significant effect for putt phase ($F(3,42) = 12.0$, $p < .001$) and an interaction between game condition and putt phase ($F(3,42) = 21.9$, $p < .001$). Tukey's post-hoc analysis confirmed that heart rates at the four putt phases in competition were greater than practice. However in competition, heart rates after putt strike (119 ± 3.1 and 119 ± 3.1 b.min⁻¹, POST1 and POST2 respectively) were significantly higher than heart rates at or preceding putt strike (113.6 ± 2.7 and 112 ± 2.6 b.min⁻¹, PRE1 and PRE2 respectively; $p < 0.05$).

(a)



(b)

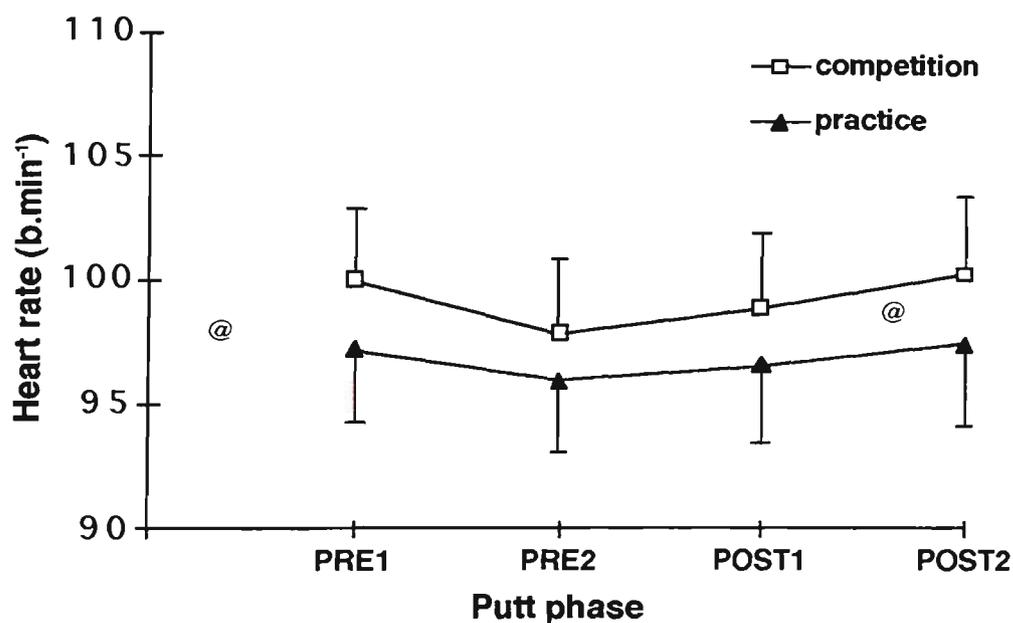


Fig 7.1 Average heart rates for (a) $n=15$ PRO and (b) $n=19$ REC golfers during four consecutive (15 second) heart rate measures; prior to putt strike (PRE 1 and PRE 2) and post putt strike (POST 1 and POST 2) in a competition and practice golf round. Values are mean \pm SEM. * denotes a difference between game conditions, Comp>Prac ($p<0.05$); # a difference from PRE1 and PRE2 in competition ($p<0.05$); @ significant difference from PRE2 and POST1 ($p<0.05$).

The REC golfers' average heart rates for putt phases PRE1, PRE2, POST1 and POST2 during competition and practice are presented in Figure 7.1(b). The time error for heart rates was 6.4 ± 0.2 and 6.6 ± 0.3 sec preceding ball strike time (for competition and practice, respectively). The ANOVA revealed that heart rates in competition and practice were not significantly different (99.3 ± 3.0 and 96.8 ± 3.1 b.min⁻¹, respectively; $F(1,18) = 1.86$, $p=.19$). There was no interaction between game condition and putt phase ($F(3,54) = 0.52$, $p=.66$), however there was a significant effect for putt phase ($F(3,54) = 3.30$, $p<.03$). Tukey's post-hoc tests revealed that competition PRE1 and POST2 heart rates (100 ± 2.9 and 100 ± 3.2 b.min⁻¹, respectively) were greater than practice PRE2 and POST1 (96 ± 2.9 and 97 ± 3.2 b.min⁻¹, respectively; $p< 0.05$).

The average heart rates for the AMA golfers during putting phase for the pre- and post-training 18 hole competition games are presented in Figure 7.1(c). The time error for heart rate was 6.5 ± 0.6 and 6.4 ± 0.5 sec prior to ball strike (pre and post-training games respectively). The data analysis revealed that there was no effect of training condition on heart rates (102 ± 2.7 and 105 ± 2.5 b.min⁻¹, pre and post-training, respectively; $F(1,7) = 2.86$, $p=.12$), nor was there an effect of putt phase on heart rates (103 ± 2.5 , 103 ± 2.8 , 104 ± 2.5 and 105 ± 2.7 b.min⁻¹, PRE1, PRE2, POST1 and POST2, respectively; $F(3,21) = 1.62$, $p=.22$). There was however a significant interaction between training condition and putt phase ($F(3,21) = 5.97$, $p<.004$). Tukey's post-hoc analysis showed that putting heart rates for the post-training condition (PRE1, PRE2, POST1 and POST2) and pre-training condition (POST2), were significantly greater than pre-training heart rates PRE1 and PRE2 ($p< 0.05$).

(c)

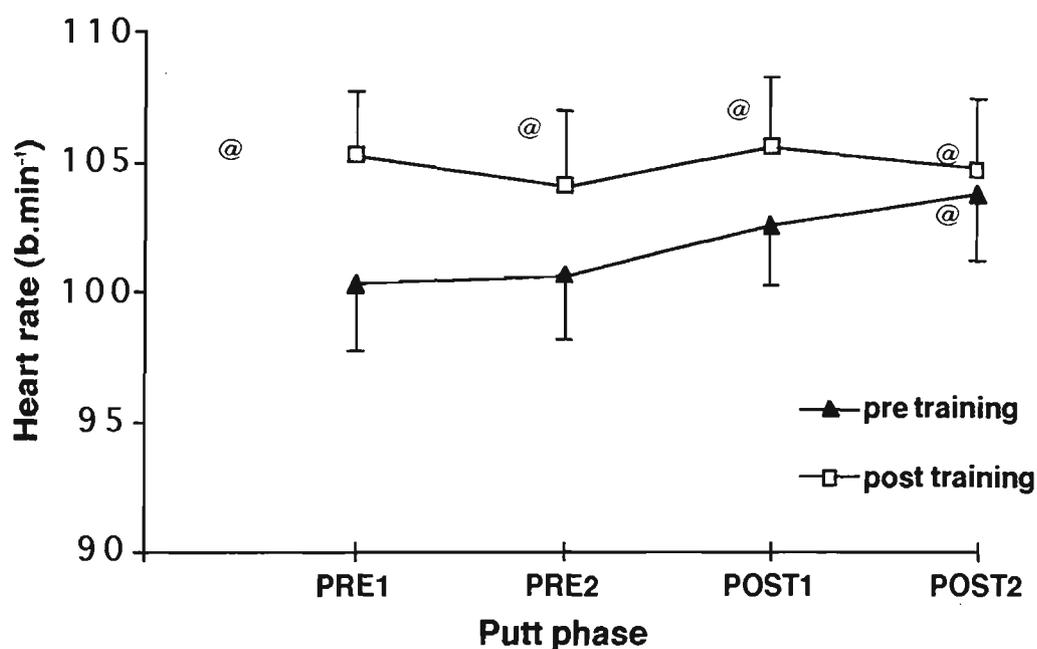


Fig 7.1 (c) Average heart rates for $n=8$ AMA golfers during four consecutive (15 second) heart rate phases, representing measures prior to putt strike (PRE 1 and PRE 2) and post (or at) putt strike (POST 1 and POST 2), during a pre-training and post-training competition round. Values are mean \pm SEM. @ denotes a difference from PRE1 and PRE2 pre-training ($p < 0.05$).

Finally, the between group ANOVA with repeated measures for putt phase indicated that for competition rounds only (pre-trained condition in AMA golfers) a significant group effect $F(2,39) = 9.33$, $p < .001$, a significant time effect ($F(3,117) = 21.14$, $p < .001$) and also an interaction between group and putt phase ($F(3,6) = 6.90$, $p < .001$) was found. Further analysis indicated that PROs (115.8 ± 2.9 b.min⁻¹) had higher heart rates in competition compared to REC and AMA (99.3 ± 3.0 and 102 ± 2.7 b.min⁻¹, respectively; $p < 0.05$).

7.5.2 Shot type and heart rates for PRO golfers

The heart rates for (TEE), fairway (FWY), approach (APR) and putting (PUT) for the (PRO) golfers are presented in Figure 7.2. To examine the effect of game condition on heart rates for different golf shots, a Game x Shot Type (2 x 4) intra-individual repeated measures ANOVA was used. The ANOVA revealed heart rates in competition were significantly higher than in practice (TEE, 121 ± 3.0 and 99 ± 3.0 b.min⁻¹; FWY, 123 ± 3.0 and 101 ± 3.0 b.min⁻¹; APR, 122 ± 3.0 and 104 ± 3.1 b.min⁻¹; and PUT, 119 ± 2.9 and 98 ± 3.1 b.min⁻¹; $F(1,14) = 49.49$, $p < .001$, respectively). There was a significant effect for shot type ($F(3,42) = 11.19$, $p < .001$) and an interaction between game and shot ($F(3,42) = 2.85$, $p < .05$). Tukey's post-hoc analysis confirmed that FWY, TEE, APR and PUT were higher in competition than practice ($p < .05$). Additionally, heart rates for FWY in competition were significantly higher than PUT in competition and that in practice APR shots evoked higher heart rates compared to TEE and PUT.

7.5.3 Heart rates for Green Activity in PRO golfers

For this section, Green Activity includes two categories: GREEN was the average heart rate for the time players spent on the putting green surface, including players' walking,

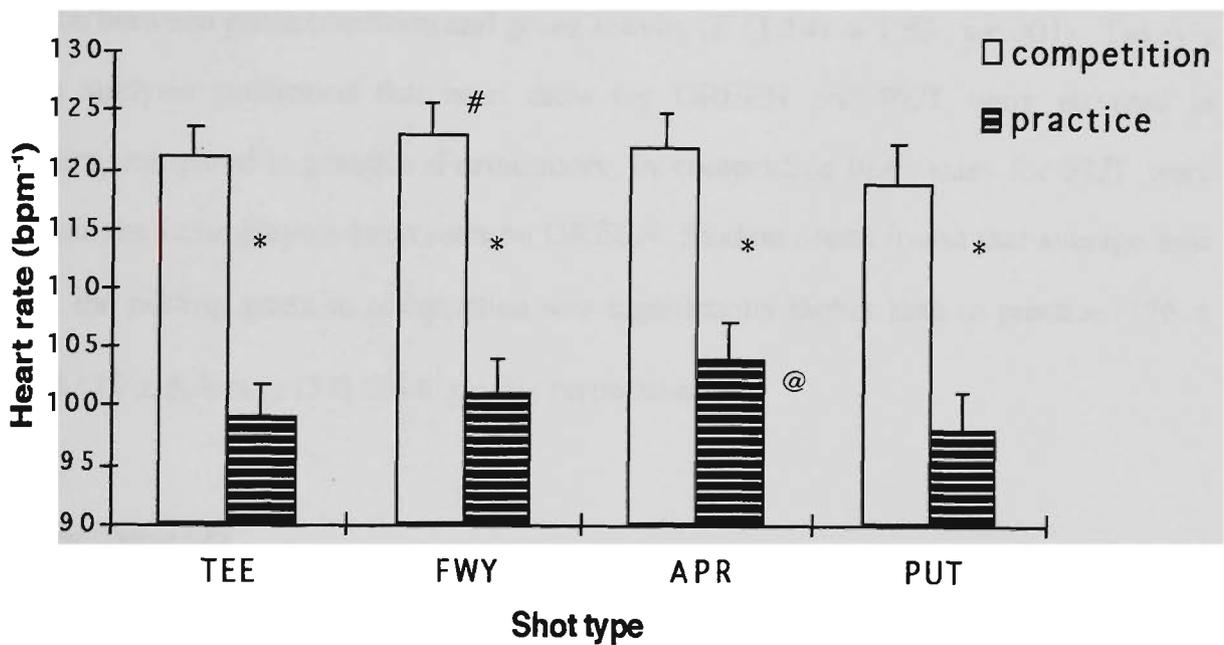


Fig 7.2 Average heart rates for shot types; tee (TEE), fairway (FWY), approach (APR) and putting (PUT) for $n=15$ PRO golfers during a competition (C) and practice (P) golf round. Values are mean \pm SEM. * denotes a difference between game conditions; C>P; # a difference from PUT in competition; @ a difference from TEE and PUTT in practice ($p<0.05$).

standing and putting activities, whilst PUT includes putting activity only. To examine the effect of game condition and green activity, an intra-individual two-way (2 x 2) Game x Green Activity repeated measures ANOVA was used. Competition heart rates for PUT and GREEN were significantly greater in competition than practice (PUT; 119 ± 2.9 and 98 ± 3.0 bmin^{-1} ; GREEN; 114 ± 2.6 and 98 ± 2.9 bmin^{-1} , $F(1,14) = 47.68$, $p < .001$, respectively; Figure 7.3). There was also a significant effect for Green Activity (106 ± 2.9 and 108.5 ± 2.9 , GREEN and PUT, respectively; $F(1,14) = 5.14$, $p < .002$) and an interaction between game condition and green activity ($F(1,14) = 1.63$, $p < .001$). Tukey's post-hoc analysis confirmed that heart rates for GREEN and PUT were elevated in competition compared to practice. Furthermore, in competition heart rates for PUT were higher than the same players heart rates on GREEN. Student t-tests found that average time spent on the putting green in competition was significantly higher than in practice (176 ± 10.2 and 110 ± 6.4 sec; $t(14) = 5.44$, $p < .01$; respectively).

7.6 Discussion

The current study examined heart rates for shot types in golf, in particular putting, during competition. In order to interpret these findings however, the limitations arising from using heart rate monitors with 15 second sampling rates are considered. The time alignment of ball strike (hr:min:sec, recorded by the observer) with the corresponding heart rate measurements before and after ball strike had an average error of seven seconds, which has implications for the data concerning shot type and putting. Therefore, it is not possible to make definite statements concerning golf swing actions such as backswing, ball strike or follow through in relation to any of these data. Furthermore, the observations regarding cardiac deceleration before putting need to be qualified in relation to this limitation. It would have been preferable to measure heart rate using a high frequency electrocardiograph and to record the exact time of ball strike with a sensing device on the face of the club, however

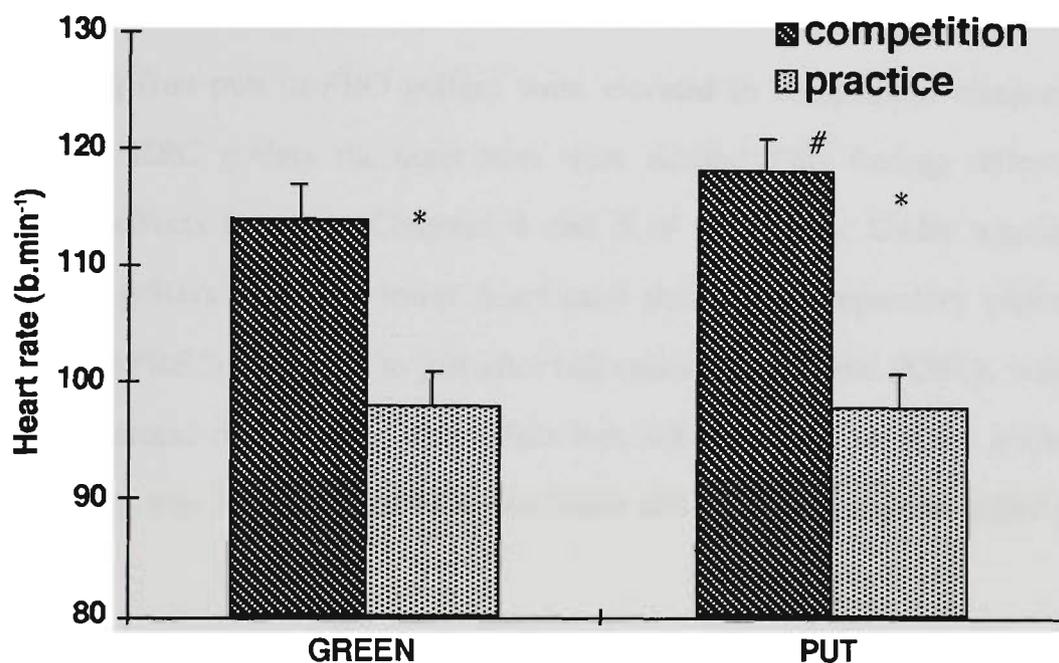


Fig 7.3 Average heart rates for green activity which includes heart rates on the green (GREEN) and heart rates during putting (PUT) for $n=15$ PRO golfers during a competition (C) and practice (P). Values are mean \pm SEM. * denotes difference between game conditions; $C>P$; # significantly greater than GREEN in competition ($p<0.05$).

this was not feasible in this study due to technical reasons and acceptance by the players and tournament organisers. A further limitation of this field study was that it was not possible to interpret the heart rate findings against shot performance. To quantify performance during tournament play for any of the shots including putting, would have been extremely difficult because each shot played varied in accuracy and distance.

Heart rates during putt phase for PRO, REC and AMA golfers.

Heart rates during first putt in PRO golfers were elevated in competition compared to practice whilst in REC golfers the heart rates were similar. This finding reflects the significant game effects found in Chapters 4 and 5 of this thesis. Under tournament conditions, PRO golfers exhibited lower heart rates during the preparatory phases of putting (PRE1 and PRE2) compared to just after ball strike (POST1 and POST), which is characteristic of cardiac deceleration. This effect was not found for the same golfers in practice games, nor was it demonstrated by the lesser ability REC golfers in either game condition.

Physiological mechanisms such as the slowing of respiration rate, or cognitive factors such as increased attention or concentration may decrease heart rate. Breath holding results in a deceleration and when exhalation occurs the heart rate will start to accelerate (Porges and Byrne, 1992). Heart rate deceleration has been found in other fine motor skill performances. Pistol shooters demonstrated this effect during the 10 seconds prior to trigger release (Tremayne et al., 1993), and both elite and beginner golfers showed heart rate deceleration during the four cardiac cycles prior to four foot and 12ft putts (Boutcher and Zinsser, 1990). The current study indicates the same may occur in elite golfers during genuine competition, although interpreting the heart rate patterns in these golfers are limited compared to Boutcher and Zinsser (1990) (discussed above). In particular, heart rate

changes in the current study cannot be attributed to cardiac deceleration in close proximity to ball strike, that is, in relation to the cardiac cycle.

One reason for the more proficient (PRO) golfers demonstrating lower heart rates prior to putting compared to the lesser ability (REC) golfers, may be associated with better adherence to pre-shot routines. Elite golfers demonstrate longer (Boutcher and Zinsser, 1990) and more consistent (Crews and Boutcher, 1986b) pre-shot routines compared to lesser ability players. However, it is interesting that the pattern of heart rates for PRO golfers during putting was not consistent across both game conditions. In practice PRO golfers heart rates were similar both before and after putt strike. It may be that the PRO golfers exhibit greater adherence to pre-shot routines in competition where the performance outcome was more important, compared to during practice. Equally, they might have experienced lower involvement in practice and contributed less effort in holing putts. Pre-shot routines were not measured in the current study and this observation awaits further study.

The AMA golfers may also be considered as elite, however there was no support for heart rate deceleration prior to putting. As discussed (Chapter 6), competition appeared to be relatively non-stressful or arousing for these players. It may be the PRO golfers established better attentional focus during putting in competition compared to AMA according to the importance of the competition, and that in less controlled field testing environment, cardiac deceleration might only be detected under higher stress conditions. In REC golfers, the heart rates approximately 30 seconds before and after putting (PRE1 and POST2) considering both game conditions together, were higher than those closer (approximately 15 seconds) to the putt strike (PRE2 and POST1). This may reflect influences from physical movement either side of putt strike.

Golf putting in general, requires minimal physical effort and body movement during the preparation and execution of the shot. The AMA golfers underwent an aerobic training program, however there is no evidence to suggest that heart rates during putting reflected a training-induced bradycardia during this short period of low physical activity.

Heart rates and shot types in PRO golfers

This study also found that elevated heart rates during the 18 hole competition game in PRO golfers were reflected by the heart rate averages for different shot types in golf, which were differentiated into TEE, FWY, APR and PUT. In competition, heart rates for FWY were elevated compared to PUT, whilst in practice APR shots were greater than TEE and PUT. Such findings possibly reflect the greater physical activity for the different types of shots, rather than emotional influences. The FWY and APR shots are usually preceded by brisk walking, whereas prior to PUT and TEE shots, the player is either standing or walking slowly.

In competition, each golfer's heart rate for PUT (on average the 7 seconds before putt strike), was higher ($5 \text{ b}\cdot\text{min}^{-1}$) than his average heart rate on the GREEN, but in practice these averages were similar. The number of putts analysed in the two games were similar (around 32 putts), however golfers spent longer on the green in competition compared to practice. This may have been due to longer shot preparation time such as lining up putts and practice swings. Interpreting these findings is difficult due to counterbalancing effects on heart rate with the different times spent on the green. For example, in practice the shorter time period for shot preparation and execution may have resulted in slight elevations in heart rates due to higher average activity levels. In relative terms, higher activity levels may not have permitted heart rates to decrease for GREEN in practice to the same extent as competition. However, attentional and emotional factors during putting in competition versus practice may certainly have influenced these data.

What is evident however, is that average heart rates whilst putting for PROs in competition is around $15 \text{ b} \cdot \text{min}^{-1}$ higher than during more relaxed practice setting. Crews (1994) cited a study by Piparo, Crews and Hart (1991) who proposed that attentional distractions manifested through strenuous walking exercise may result in worse putting performance in golfers. Whether or not a $15 \text{ b} \cdot \text{min}^{-1}$ increase in heart rate is distracting for such golfers could be considered in similar studies to the present, which can assess heart rate and putting performance in a real competition setting. An implication for PRO golfers with elevated heart rates in putting, is they would not experience similar elevated heart rates during practice putting. Maybe practicing putting for competition would best be done under higher stress evoking conditions to simulate a physiological state more consistent with actual competition. There may be advantages for golfers being fit if their heart rate recovers faster prior to putting in competition. Theoretically this may counter attentional distractions (Crews, 1994), however confounds in these studies were not able to demonstrate such an effect. Future studies could examine whether enhanced aerobic fitness reduces heart rate responses during putting in tournaments.

In conclusion, these findings indicate that elite golfers in competitive environments experience a slowing of heart rate in the period prior compared to just after putt strike. This effect has been more precisely measured in elite golfers during putting in laboratory conditions. Although these findings are difficult to interpret due to confounds present in actual game settings, and do not provide information on heart rate patterns and putting performance, it does provide a basis for further field studies. Future field studies could employ higher powered heart rate monitors which are currently available to examine heart rates during putting in elite golfers. Together with video recordings of the putting action, performance and adherence to pre-shot routines could be assessed in conjunction with more accurate heart rate data.

Chapter 8

GENERAL DISCUSSION AND CONCLUSIONS

8.1 Overview

This research measured golfers' psychophysiological stress responses to competition using field settings. The following discussion examines these findings according to two main areas. Section 8.2 examines the evidence for competitive stress in elite and recreational players and its possible implications for golfers, especially for performance. Section 8.3 focuses on the measurement of stress in golf, in particular the relationship between psychophysiological parameters of stress used in this research, and the relationship between state anxiety (CSAI-2) and performance. Whilst Section 8.3 has relevance for stress research in sport, the rationale is to explore future ways in which stress may be assessed in golfers. A summary of the main conclusions of this research are included.

8.2 Psychophysiological stress in competition golf

In the literature on golf, qualitative studies have examined competitive stress and performance in golfers (Cohn, 1990; McCaffrey and Orlick, 1989), whilst other studies have focused on the relationship between precompetition anxiety state and performance. Psychophysiological states conducive to best putting and shot performances have received some attention, but seldom has the research examined psychophysiological stress-related changes before, during and after competition rounds. In a group of elite professional trainee (PRO) golfers, competition evoked increases in physiological stress parameters, cortisol and heart rate, an increase in self-reported and cognitive and somatic state anxiety,

and a decrease in state self-confidence compared to practice (Chapter 4). Whilst recreational (REC) golfers exhibited similar directional responses to the PRO golfers on the psychometric measures, heart rate and cortisol were not influenced by competition (Chapter 5). In the second group of elite amateur golfers (AMA) who underwent aerobic training, there was no evidence that psychophysiological responses to competition were influenced by enhancing their aerobic capacity (Chapter 6).

The significance of the PRO and REC studies is that they provide general evidence for golfer's psychological and/or physiological state being different in practice as opposed to competition. McCaffrey and Orlick (1989) found that golfers reported feeling pressure during tournament play, and were also aware of the accompanying psychophysiological manifestations. The current studies found that for PRO golfers under tournament conditions, both adrenocortical and cardiac activity was elevated compared to the more relaxed conditions in practice games. Although such changes are difficult to interpret qualitatively, these changes might be due to increased anticipatory vigilance (Arthur, 1987), the threat or unpredictability of the situation (Mason, 1968), and/or general involvement in the situation (Kirschbaum and Hellhammer, 1989). Cortisol was elevated in PRO golfers prior to the golf rounds, which is similar to anticipatory responses found in pre-competitive marathon runners (Cook et al., 1987). Whilst cortisol responses were accompanied by heightened feelings of performance worry, tension and nervousness in these players, there was no indication that elevated CSAI-2 state anxiety and precompetitive cortisol responses were directly related. Lesser ability golfers also report golf stress (Thomas and Over, 1994). In this research, the lesser ability, middle-ages REC golfers also experienced competitive stress, but it was manifested differently to the PRO players. Competition stress comprised of worrying about performing poorly and perceived physiological arousal, without concomitant perturbations to their physiological state.

Although elevated competitive anxiety was evident for both PRO and REC golfers when comparing competition to practice, the intensity of the CSAI-2 subscale scores and temporal patterns of the state anxiety components in competition were different. The PRO players reported overall higher intensities of cognitive anxiety compared to REC players in competition (Figure 8.1), whereas somatic anxiety and state self-confidence responses were similar (Figure 8.2, a and b). The intensity of precompetition CSAI-2 cognitive anxiety in PRO golfers were consistent with the norms determined for 113 collegiate and high school golfers measured by Martens et al. (1990), who could be considered of similar ability (Table 8.1). In contrast to these norms, all the golfers in the current studies had lower precompetition somatic anxiety, whilst the REC golfers showed lower and the PRO golfers similar levels of precompetition state self-confidence. In general, the PRO golfers in the current study showed CSAI-2 response intensities according to their ability levels, as compared to other golf studies. With regard to temporal patterns, REC golfers reflected performance worry in the initial stages of play (hole 6), which had declined by the conclusion of the competition round. The PRO and AMA (pre-training) golfers, had similar state anxiety and self-confidence throughout competition. According to the hypothesised antecedents for cognitive anxiety, performance concerns and confidence remained consistent in these higher ability golfers.

Stress responses to competition environments arise from an interaction between the individual and their situation (Jones, 1995; McGrath, 1980). Conceivably, a variety of individual and environmental differences may have contributed to different psychophysiological responses to competition among PRO, REC and AMA golfers. Individual factors such as personality traits (Weinberg and Genuchi, 1980) and ability or skill level (Cook et al., 1983) have been found to influence golfers' responses to competition. Personality traits (trait anxiety) were not measured in these studies and so their influence remains unknown. However the PRO and REC groups comprised golfers with

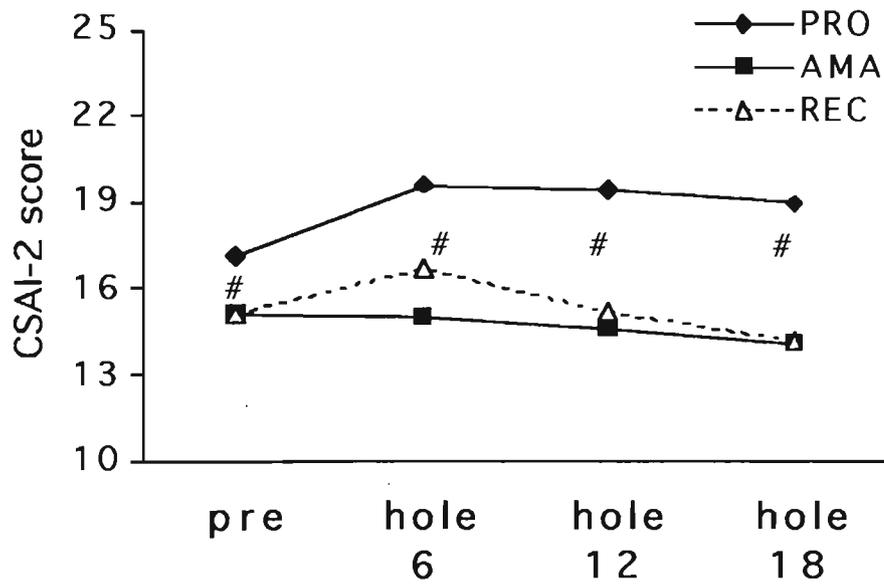
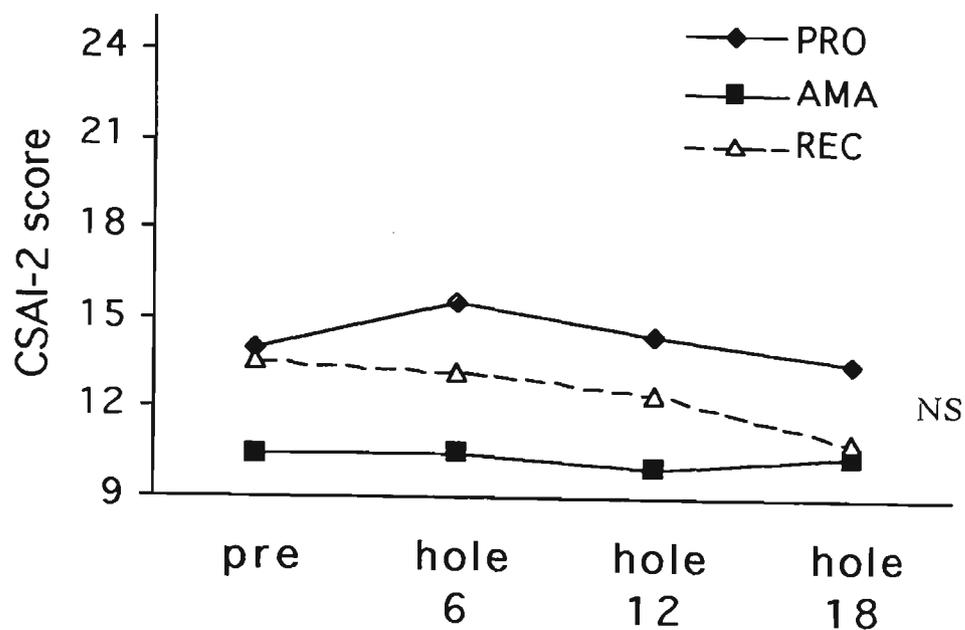


Figure 8.1a Mean CSAI-2 cognitive anxiety scores measured at pregame (pre), hole 6, 12 and postgame (hole 18) for $n=15$ PRO, $n=19$ REC and $n=8$ AMA (pre-trained) golfers in competition. # different among golfers; $PRO > AMA$ and REC ($p < 0.02$).

(b)



(c)

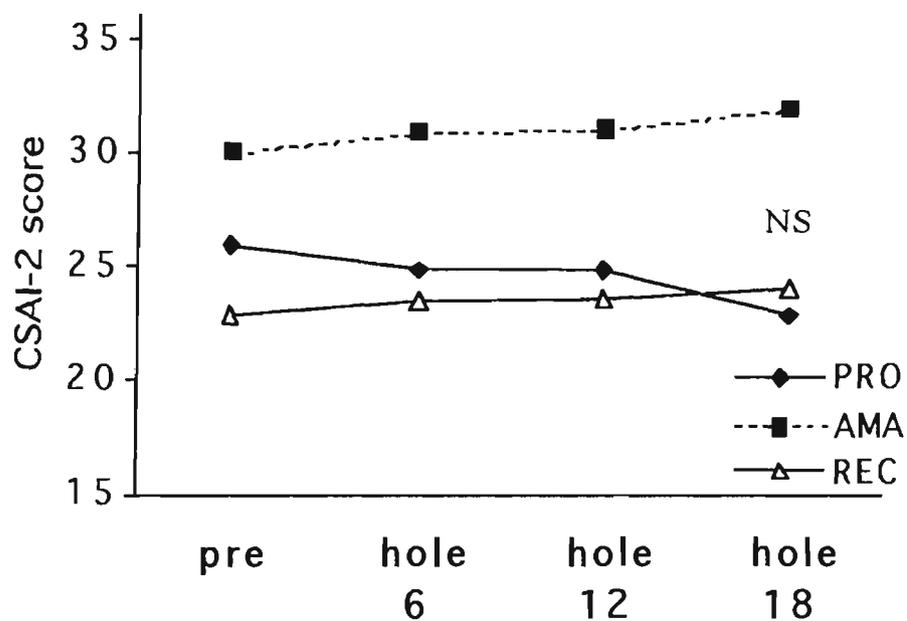


Fig 8.2 Mean CSAI-2 (a) somatic anxiety and (b) state self-confidence scores at pregame (pre), hole 6, 12 and hole 18 for $n=15$ PRO, $n=19$ REC and $n=8$ AMA (pre-trained) golfers in competition. NS between groups; somatic, $p=0.8$; self-conf, $p<.08$).

Table 8.1 Precompetition CSAI-2 scores (mean \pm SD) for cognitive, somatic anxiety and self-confidence measured in (n) PRO, REC and AMA golfers (Chapters 4, 5, and 6) compared to precompetition Norm samples in n=103 collegiate and high school golfers (Martens et al. 1990).

		n	<u>CSAI-cog</u>		<u>CSAI-som</u>		<u>CSAI-sconf.</u>	
			mean	SD	mean	SD	mean	SD
Ch.4	PRO	15	17.1	4.5	13.9	4.1	25.9	3.8
Ch.5	REC	19	15.1	5.1	13.5	4.7	22.8	7.8
Ch.6	AMA(pre)	8	15.1	3.5	12.8	4.0	28.9	4.5
Ch.6	AMA(post)	8	15.0	5.3	10.4	2.0	30.0	7.9
Martens et al. (1990)		113	16.97	5.45	15.31	3.91	26.27	5.50

very different ages and ability levels. The PRO group on average was comprised of 22 year old, high ability golfers with uniformly low handicaps (scratch to five), whereas the REC golfers were some 30 years older, and included players with a larger handicap variations (9 to 27), and can be describe as moderate ability players. The differences in ability levels were emphasised by PRO golfers averaging 10 shots per round less than REC golfers. According to Martens et al. (1990), less skilled sportspeople report higher overall levels of anxiety compared to elite competitors, because they are less capable of self-regulating thoughts and are more likely to experience worry and self-doubt. Cook et al (1983) found that low handicap (high ability, 0 to 2hcp) golfers in a prestigious tournament, had lower overall pre-competition state anxiety compared to higher handicaps (lesser ability, 3 to 9hcp). In contrast, the current studies found state anxiety responses in the higher skilled PROs were higher than those in the lesser skilled REC players. An important difference between this study and Cook et al.'s (1983), was that PRO and REC golfers were examined in separate competitions. Theoretically, direct influences of ability level, and even age (Molander and Backman, 1994) can only be examined within the same study.

Situational factors inherent in competition environments have been found to influence psychophysiological responses (Molander and Backman, 1994) and CSAI-2 subcomponents (Krane and Williams, 1987; Martens et al., 1990) in golfers. Krane and Williams (1987) argued that the level of competition influenced the CSAI-2 responses in golfers, who were assessed prior to a practice tournament round and then the actual tournament round 24 hours later. Cognitive anxiety and self-confidence were similar, however, somatic anxiety was higher prior to the actual tournament round. They concluded that the practice tournament and actual tournament were not perceived as being the same. In the current studies, the emphasis was on measuring PRO and REC golfers responses in ecologically valid competitions, which are commonly encountered at their level of the sport. However, it is unlikely their perception of their respective competitions was the same.

Whilst recreational golfers played for the honour and prestige of winning a club medal, the PRO golfers performance had implications for their career and livelihood (see Section 4.4.1). Martens (1977) stated that competition is stressful, not only because it is evaluative and ego-involving, but also when players perceive failure as being important. Although speculative, psychophysiological responses in the PRO golfers may have been elevated compared REC golfers, because they placed greater importance on playing well and as a consequence were more involved in the competitive situation, and possibly found it more stressful. The elevated cortisol responses in PRO's as compared to REC and AMA golfers in competition (Figure 8.3) and elevated heart rate responses (Figure 8.4) also suggest a higher involvement in the competition situation (Kirschbaum and Hellhammer, 1989). Different psychophysiological responses according to competitive level were also found in the sport of table tennis, where Baron et al. (1992) found that National level competition evoked greater emotional stress, as discerned by higher E but similar average heart rates and NE levels, compared to a less prestigious competition. In a contrasting situation, Karteroloitis and Gill (1987) observed low and inconsistent psychophysiological responses (state anxiety, heart rate, blood pressure) in individuals competing in a peg-board task. They stated the contrived competition setting and novel task led to participants showing little ego-involvement in the performance outcome, which consequently reduced tension levels compared to those normally observed in competitive sport settings.

The observation that the situation may have influenced psychophysiological responses in elite golfers is further supported in this thesis by the responses measured in the AMA golfers in the pre-training competition. These golfers were similar in ability and age to the PRO golfers, but showed lower cognitive anxiety, a tendency toward higher self-confidence and very low levels of somatic anxiety. Similarly, the physiological responses were generally low compared to the PROs in competition. The competition format used in the AMA group was familiar to the players, included small monetary incentives in addition

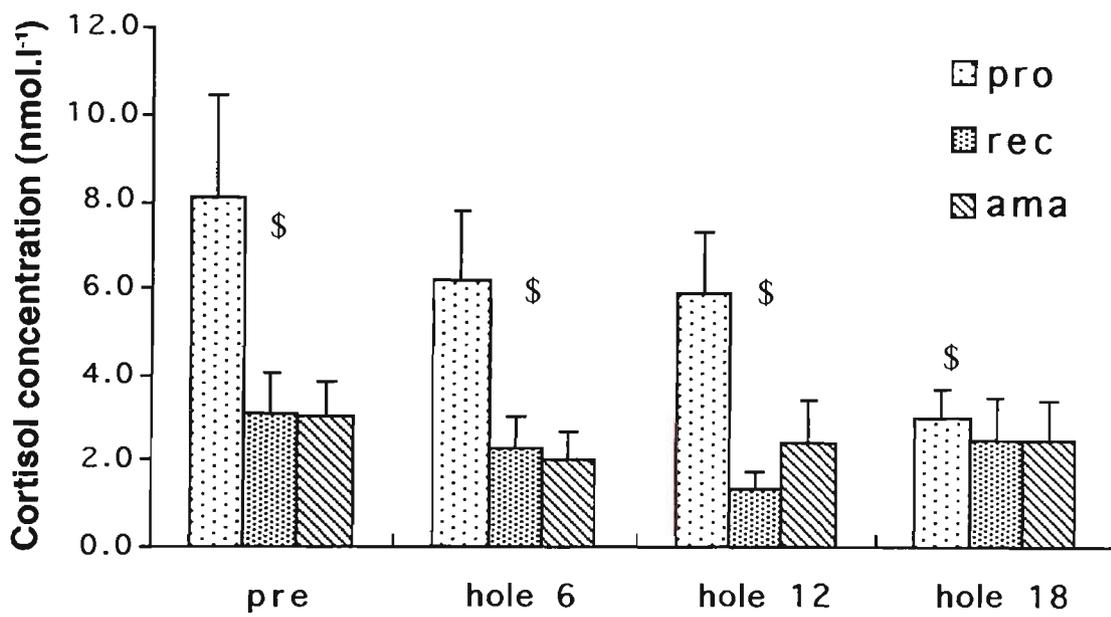


Fig 8.3 Cortisol responses (nmol.l^{-1}) measured pregame (pre), after holes 6, 12 and postgame (hole 18) for $n=15$ PRO, $n=19$ REC and $n=8$ AMA (pre-training) in competition. Values are mean \pm SEM. \$ difference between groups; PRO > REC and AMA, ($p < 0.001$).

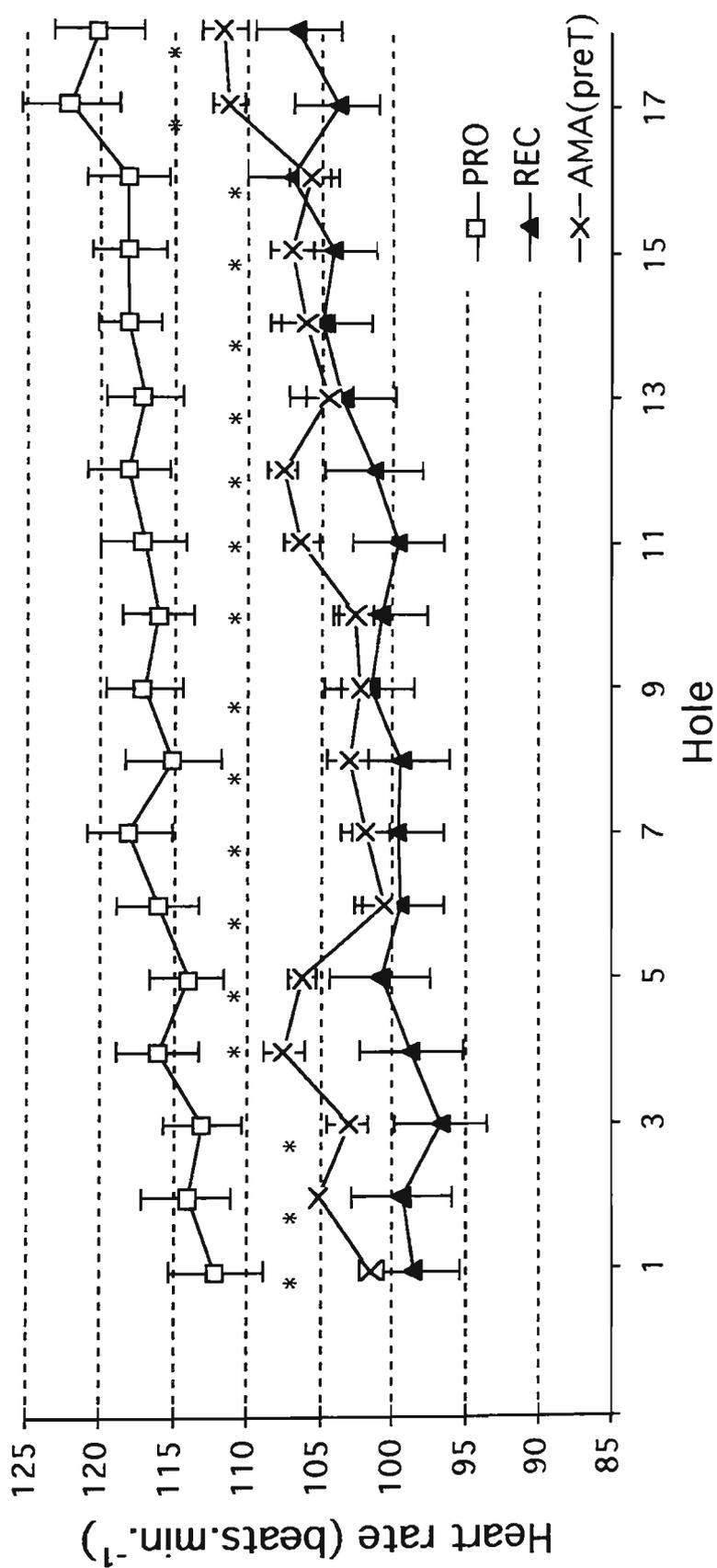


Fig 8.4 Average heart rate responses for holes 1 to 18 for n=15 PRO, n=19 REC and n=8AMA (pretraining) golfers during competition rounds. Values are mean \pm SEM. * denotes difference between groups, PRO> REC and AMA, ($p<.02$).

to the results being assessed by their coach. Nonetheless the psychophysiological responses would suggest that the competition format, based on these incentives, was not particularly involving for these players.

In conclusion, these studies have provided more detailed experimental evidence for competitive stress in golfers, manifested as changes in psychophysiological state in competition compared to practice. Differences between psychophysiological responses in elite and non-elite golfers may have resulted from differences in individual and situational factors, including age, ability or skill level, and the nature of competition including the inherent rewards. A situational context which could explore age and ability differences on state anxiety would be a PROAM event, where professional and recreational golfers compete in the same competitive situation. Future field studies in golf, should carefully consider the competition rewards involved in competitive field settings.

Psychophysiological stress and golf performance

Whilst measuring psychophysiological stress is important to better understand stress in competitive golf, an goal for such research is to determine how such perturbations relate to (competition) performance. Intra-individual analyses of performance scores in PRO golfers, showed that they shot similar 18 hole scores in competition and practice, however worse performance in competition could be predicted by high pregame cortisol and low pregame cognitive anxiety (Chapter 4). Similarly in REC golfers, 18 hole performance score was not significantly different across game condition (Chapter 5), and whilst psychophysiological variables did not predict performance, performance over holes 13 to 18 were related to players postcompetition cognitive and somatic anxiety scores. In the AMA golfers, regression analysis revealed that performance could be predicted by some combinations of the stress parameters, and that cortisol at hole 6 related to performance

averages over the initial six holes of play pre-training competition. These latter findings may be spurious given there was no indication that competition evoked much stress in these golfers (discussed in Chapter 6).

The findings from the PRO and REC studies however, do not provide evidence for a strong association between psychophysiological perturbations and performance changes, particularly a cause/effect relationship. In PRO golfers, even though pregame cortisol responses and cognitive anxiety was able to predicted their 18 hole performance score, this pattern was not consistent throughout the competition round. For example, cortisol and cognitive anxiety at H6 and H12 did not relate to subsequent performance measures (SC7-12, 13-18, respectively), even though cortisol and cognitive anxiety levels remained similar during the competition round. Therefore, high levels of cortisol and low cognitive anxiety are not considered general predictors of performance in elite golfers. There was no further evidence for cortisol influencing performance in REC golfers, because cortisol responses to competition were not found. In the REC golfers, there was no evidence that elevated state anxiety influenced their performance. On the contrary, their average scores over the concluding stages of play predicted postgame state anxiety, which coincided with the lowest levels of cognitive and somatic anxiety measured. This suggested that performance may be an antecedent of state anxiety, if only weakly so, reflecting a level of concern about their recent performance.

Performance score in golf is an important measure of performance because it ultimately decides winners and money/trophy distributions. It is advocated as being a sensitive measure of performance outcome, when compared to an individual's seasonal performance (Sonstroem and Bernardo, 1982), as found by Krane and Williams (1987) in golfers. Whilst psychophysiological stress did not appear to influence performance, as measured by standardised performance scores, psychophysiological stress may have had a more subtle

influence on other aspects of performance. For example, it may have influenced a particular shot type or the quality of fine motor skill performances, such as putting or chipping. In golfers, the quality of the golf stroke is not necessarily congruent with the shot outcome, because a poorly executed fairway shot or putt (in terms of motor performance), may find the intended target, namely the fairway or the golf hole. Weinberg and Hunt (1976) found that anxiety influenced the quality of the motor performance on a throwing task, by assessing neuromuscular performance using electromyography (EMG). A preliminary study of heart rate during a one minute putting phase (Chapter 7), found variations in heart rate patterns according to the competitive situation. Heart rate decelerations in PRO golfers prior to putt strike in competition were not evident in practice, nor was this effect evident in either game condition for REC or AMA golfers. This observation is interesting because such data has rarely been measured during genuine tournament performances in golfers, and heart rate deceleration has been previously implicated in better putting performance in elite golfers (Boutcher and Zinsser, 1990). However, the current finding is limited somewhat by the methodological concerns (Chapter 7) and because such patterns cannot be related to putting performance in these PRO golfers. Similar studies, using heart rate monitors which record R to R intervals and a measure of putting performance, could further examine these findings.

Implications of physiological stress on tournament and recreational golfers

For PRO and REC golfers, perturbations in psychophysiological state with competition did not have strong associations with golf performance, however there may be other implications associated with such changes. The current thesis provided detailed heart rate measures during golf play in competition and practice golf games, thereby extending those of Murase et al. (1989) and Getchell (1967) who quantified physiological demands of golf during non-competitive games. Irrespective of differences such as age, ability level, and golf course terrain, and other factors which may influence cardiac activity during golf play,

the average heart rates for PRO and REC golfers during practice (Figure 8.5), and REC golfers in competition (Figure 8.4) were similar. Furthermore these averages generally confer with the findings of Murase et al. (1989), that average heart rates in response to non-competitive golf situations are just over 100 b.min⁻¹. These studies indicate that competitions typically experienced at the club-level in recreational golf do not necessarily evoke additional heart rate demands compared to practice. The implication for recreational golfers is that club competition golf (in addition to social rounds), conforms with the low to moderate exercise demands (Batt, 1993), and hence may also be suitable as a rehabilitation exercise.

For PRO golfers, competition resulted in a 17 b.min⁻¹ elevation in heart rate on average across the round compared to practice. Whilst the heightened psychophysiological states found in these young PRO golfers would not be expected to have metabolic implications over a period of minutes, it may contribute to fatigue over much longer time courses, such as an 18 hole round or a four-round tournament. To extend this rationale further, factors such as poor diet and constant travel which may be common amongst touring golf professionals, could result in persistent levels of stress. These factors combined, may have deleterious metabolic (catabolic) effects on these golfers and have indirect influences on their golf performances in tournaments. The aim of the aerobic training study (Chapter 6) was to investigate whether an increase in aerobic capacity was associated with decreases in psychophysiological stress responses, including heart rate. Although the results from AMA golfers did not show a relationship between stress reduction with enhanced aerobic fitness, future studies could further explore the issue adopting the recommendations arising from experimental problems encountered in this study (see Chapter 6). In conclusion, this research has shown that alterations to psychophysiological state during competition in high and moderate ability golfers does not appear to directly influence their scoring ability, either in a positive (lower score) or negative (higher score) direction.

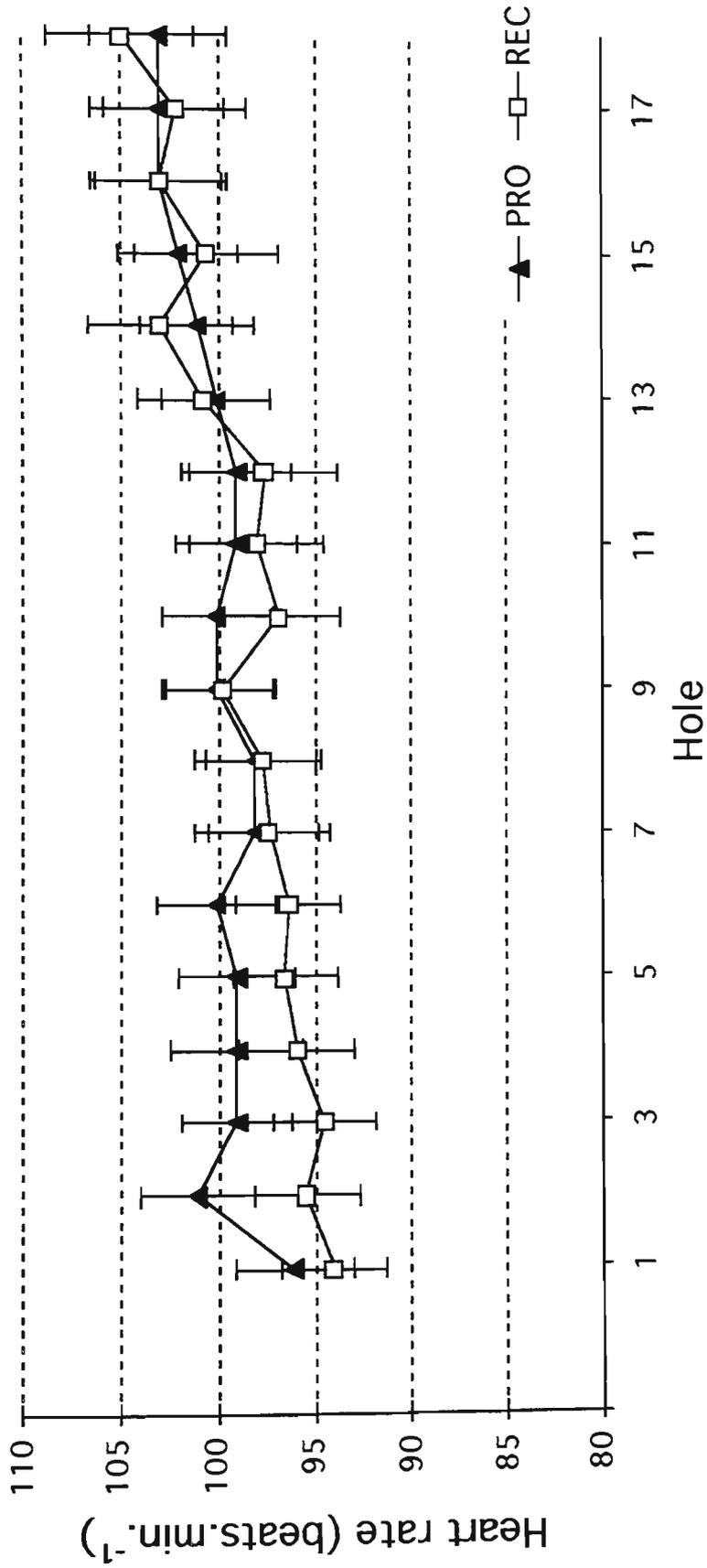


Fig 8.5 Average heart rates for holes 1 to 18 for n=15 PRO and n=19 REC golfers during practice golf rounds. Values are mean \pm SEM.

8.3 Measurement of psychophysiological stress in golf

Understanding the relationship between stress and performance in sport, relies foremost on the ability to measure stress sensitively. Cortisol is advocated as being a sensitive indicator of psychological stress (Ur, 1991; Mason, 1968). This was supported in the PRO golfers, where cortisol was elevated in competition compared to practice and supported by emotional heart rate responses. The absence of stress-related HPA activity in REC golfers was also supported by the second physiological indicator, heart rate, which also indicated low to non-existent emotional stress in competition. The CSAI-2 is considered a sensitive measure of state anxiety in sporting environments, attributed to its ability to differentiate between cognitive and somatic anxiety, in addition to measuring state self-confidence. Overall support for the independence of the CSAI-2 subscales is evident from the moderate inter-correlations among the subscales, which were generally weaker than norm values found by Martens et al. (1990; Table 8.2).

In previous CSAI-2 research, ambiguities and inconsistencies when examining psychophysiological stress and performance in sport settings, have been attributed to confounds imposed by novel and sport-irrelevant task demands (Karteroliotis and Gill, 1987), contrived as opposed to genuine competition (McCann et al., 1992), between subject comparisons rather than individual analysis of stress responses (Martens et al. 1990), performance measures failing to control for ability level (Burton, 1988), and the use of general (Caruso et al., 1990) as opposed to specific physiological indices of stress. The current thesis addressed these considerations by employing an intra-individual, psychophysiological analysis of stress responses in golf, in actual competitions. The use of minimally invasive tools to measure stress, enabled a series of psychophysiological measurements during performance over the period (hours) of stress condition, as opposed to only pre and post performance (McAuley, 1985). However, despite the sensitive

Table 8.2 Average inter-correlations (mean \pm SD) among CSAI-2 subscales (cognitive, somatic anxiety and self-confidence) measured for PRO, REC and AMA (pre and post-training (T)) golfers and norm values from a meta-analysis by Martens et al. (1990) for n=12 studies measuring precompetitive CSAI-2 inter-correlations.

	CSAI-cog & CSAI-som mean (SD)	CSAI-cog & CSAI-sconf mean(SD)	CSAI-cog & CSAI-som mean(SD)
Chap. 4 PRO	.50(.20)	-.37(.10)	-.39(.19)
Chap. 5 REC	.50(.20)	-.56(.20)	-.67(.09)
Chap. 6 AMA (preT)	.45(.06)	-.54(.03)	-.78(.03)
Chap. 7 AMA (postT)	.54(.02)	-.63(.10)	-.78(.14)
Martens et al. (1990)	.63 (.07)	-.64(1.0)	-.60(.03)

measures and methodological considerations adopted, two issues prevalent in sport research, namely the relationship between psychological and physiological stress responses, and psychophysiological stress and sport performance, could not be further elucidated

Psychophysiological relationships between stress parameters

Stress is acknowledged as a psychobiological process (Pfister and Muir, 1992), however a specific relationships between psychophysiological indices of stress, in particular physiological arousal and competitive anxiety, has received little empirical support. In marathon runners during a precompetition period, Harris et al (1989) measured parallel increases in state anxiety and salivary cortisol from rest day baselines. Preliminary data (involving only five runners) indicated that concurrent measures of state anxiety correlated with pre-run cortisol in the minutes prior to the start of the event. In other than competitive sport paradigms, studies have generally found that anxiety may be elevated in the days prior to the stressor, whereas cortisol increases when the event is imminent (Allen et al., 1985; Jones et al., 1986). Both PRO and REC golfers in the current studies showed heightened state anxiety in competition. Unlike in Harris's et al (1989) study, there was no indication that golfers' elevated state anxiety measured 10 minutes prior to competition, related to their salivary cortisol response. Similarly, there was no relationship between concurrent cortisol and state anxiety measured at latter stages of competition (after hole 6, 12 and 18). Hubert and de Jong-Meyer (1992) described the lag time between the peak hormonal (cortisol) response and the psychologically stressful period as being approximately 20 to 30 minutes. Correlation therefore, may not be the most appropriate statistical analysis between anxiety, an emotion which may change instantaneously, and an hormonal correlate, whose levels may persist over time (Neiss, 1988). Unlike the unpleasant film setting, there are no real defined onset and offset times for stress stimuli.

Competition golf is more likely to contain many and varied factors which are stress evoking for golfers.

In REC golfers, the absence of cortisol and heart rate responses to competition but the distinct elevations in state anxiety, could be explained by different competition antecedents existing for these psychophysiological parameters. In PRO golfers, concomitant psychophysiological responses might suggest common competition antecedents. The findings from these studies highlight the complex nature of competitive stress. It may be that HPA activity is stimulated when higher levels of state anxiety are perceived, similar to those found in PRO golfers. Future studies which involve a higher frequency of concomitant salivary cortisol and state anxiety measures in stressful tournament conditions may assist in elucidating a relationship.

CSAI-2 as a measure of state anxiety in golfers

The sensitivity for the CSAI-2 in measuring competitive anxiety in golfers, is based on the subcomponents having different antecedents and therefore demonstrating different temporal patterns. Martens et al. (1990) had previously examined temporal patterns in high ability (collegiate) golfers, but unlike the current study, used retrospective reporting to obtain mid-game measures. As Martens predicted, cognitive anxiety increased, and self-confidence decreased, from precompetition to midcompetition. In contrast, CSAI-2 state anxiety and self-confidence in PRO and AMA (pre-trained) golfers remained unchanged from pregame to midgame to postcompetition measures. The explanation based on multidimensional theory, is that performance expectations in these golfers remained the same throughout the game. However, Jones (1995) has suggested that this may not be the case, rather the intensity dimension of the CSAI-2 measure may be insensitive to such changes. Although temporal changes were evident for cognitive and somatic state anxiety in the REC golfers, there is only partial support for Martens et al.'s (1990) predictions. Cognitive anxiety in

REC golfers declined from a mid-game measure (H6), where performance feedback could arise over the first six holes, to postcompetition (H18), where performance feedback is unlikely to alter. The current studies therefore provide only some evidence for temporal patterns in state anxiety. These are not consistent between ability levels, nor do they provide support for the predicted changes proposed by Martens et al. (1990).

The PRO and REC studies (Chapter four and five respectively) of this thesis examined the predicted relationships between each CSAI-2 anxiety subscale and performance, according to Martens et al. (1990). The support for the CSAI-2 anxiety-performance predictions has been equivocal (Burton, 1988; Gould et al., 1987). However, one aspect of this study design in particular differed from others. Based on recommendations by Martens et al. (1990) and McAuley (1985), these studies measured state anxiety during real-life sporting contests. In particular, state anxiety before and at consecutive six hole intervals was compared with performance scores close to these measures, either the 6 holes prior or after. Martens et al. (1990) suggested the closer measures would strengthen the anxiety-performance relationship, especially when measured during the event where performance expectations would be most likely to change. Similar effects between anxiety and performance were not confirmed in the PRO golfers, therefore the overall support for this finding was not universal between groups. The inconsistent support for CSAI-2 anxiety-performance predictions may indicate that the CSAI-2 is not a consistent and strong predictor of golf performance, or the performance measure used in this thesis (golf score adjusted for handicap) may not be a sensitive enough performance measure to fully test the hypothesis. Although there was some evidence to suggest that high cortisol and low cognitive anxiety predicted better performance in PRO golfers, this association is at best tenuous.

Individual interpretations in competitive sport are important to monitor, but recent research has shown that self-report scales like the CSAI-2 might not provide an adequate reflection of anxiety state. Jones and colleagues (Jones et al., 1994; Jones et al., 1993; Swain and Jones, 1993) found that the CSAI-2 like most of its predecessors, measures only intensity of state anxiety, that is, the level experienced. They demonstrated that the frequency, that is, how often that intensity is experienced, and the direction of the anxiety, that is, whether that anxiety is perceived to be facilitating (positive) or debilitating (negative) are also important to consider. For example, in one study they found no difference between pre-competition CSAI-2 intensity scores between good and poor performing female gymnasts, but the good performers reported a significantly more facilitating interpretation of their cognitive anxiety on a direction scale (Jones et al, 1993). In another study, elite and non-elite swimmers showed no difference in somatic or cognitive intensity, but the elite group perceived both aspects of anxiety to be significantly more facilitating than the non-elite swimmers (Jones et al. 1994). In fact, Jones and Swain (1995) have now shown these differences in interpretation of the direction of anxiety states with skill levels to be based on predispositions in elite versus non-elite cricketers. Swain and Jones (1993) also showed that, while the intensity of cognitive and somatic state anxiety did not change as a competition approached, there was a large increase in the frequency of intrusive, anxiety-related thoughts in elite track and field athletes. Similarly, the present studies revealed no differences in cognitive or somatic state anxiety intensity, when comparing a measure taken just before competition, with two measures during the golf event, where such changes might be expected to be particularly manifest. Jones' work has shown that the CSAI-2 is limited in the dimension of the measure, only measuring the intensity of reported anxiety. It is possible that, while the intensity of the golfers' state anxiety remained the same, its frequency increased during competition.

In conclusion, these studies also showed that, even when physiological, biochemical, and self-report psychological indicators were used in combination, the measures did not distinguish between anxiety and performance, shortly before and at different stages during competition. Jones and colleagues have routinely found that the direction of the anxiety response may vary irrespective of the intensity of the anxiety reported. It may be that the psychophysiological relationships in this study are limited by the current form of the CSAI-2 and that direction, as opposed to intensity is important to measure. This may provide more meaningful information in future studies examining the relationship between the anxiety-performance relationship and that of psychophysiological measures such as cortisol.

Strengths and Limitations of the field approach

In sport, the use of field environments is widely advocated (Hatfield and Landers, 1983; Jones, 1996), however interpretation of the data must account for the inherent lack of controls which exist in such settings. The current research provided a more detailed insight into psychophysiological stress and performance in golfers, however problems attributed to the field environment were also encountered.

Competition rounds consistently resulted in longer 18 hole playing times compared to practice, which may be due to REC and PRO golfers taking longer times over their golf shots. The effect of faster practice rounds on players' heart rates compared to the slower, but more stressful competition rounds, cannot be determined. Theoretically, faster practice rounds may influence older (REC) players, moreso than the younger players. One benefit of the slower competition round was that it allowed adequate time for golfers to complete the CSAI-2 in its current format. Validated short-forms of state anxiety measures advocated by Jones (1995) would assist in studies measuring state anxiety more frequently during golf games.

Martens et al. (1990) found that coaches would not allow testing during National level golf events. The elite PRO golfers declined testing in their National title, and the Australian coach in study 3, was adverse to testing AIS golfers during major playing events. This is a potential problem for field research aiming to select competitive events of importance to the players. A problem encountered with the current field studies were organisational problems with testing the PRO golfers. The tournament schedules which are prone to change, did not allow us to randomise game order, while at the same time test these golfers under similar conditions (time of day and golf course). These players therefore underwent thorough familiarisation with equipment and testing procedures to reduce novelty influences, however, irrespective of this, game order is a potential confound in the PRO golfers (Chapter 4). The same problem was not met in subsequent studies because the same golf courses could be repeatedly used for all testing rounds. In accordance with Cook et al. (1987), salivary cortisol collection is a easy and non-invasive measure for examining adrenocortical responses in golfers.

8.4 Conclusions

The following summarises the main conclusions found in this research.

1. Golfers, irrespective of ability level, experience psychological and/or physiological changes during competition compared to practice.
2. Elite (PRO) golfers may experience increased HPA activity in anticipation of a tournament.
3. Heightened psychological and/or physiological stress responses in competition do not have a strong influence on performance score in golf.

4. State (CSAI-2) anxiety, heart rate and cortisol exhibit similar directional changes, but are not directly correlated.
5. Cognitive (CSAI-2) state anxiety is not strongly and consistently related to golf performance.
6. Enhanced aerobic fitness does not influence psychophysiological stress responses (state anxiety, cortisol, heart rate) to competition in elite golfers.

Chapter 9

RECOMMENDATIONS FOR FUTURE RESEARCH

The current field research has extended knowledge in the area of competitive stress in golf and performance. It has provided a better conceptualisation of the psychophysiological changes golfers experience in competition compared to practice, and that these changes do not relate strongly to performance scores. Further study is required to consolidate competitive stress research in golf, with several areas being highlighted.

1. Studies could benefit from more sensitive measures of both competitive anxiety and performance. Salivary cortisol is a valuable tool for further golf research, and given the minimal intrusion on the players, future protocols could increase the frequency of sample collection, both before and during the game. Concurrent state anxiety inventories should include direction, intensity and frequency subscales. Interpreting psychophysiological antecedents could be enhanced by additional measures including perceived exertion, personality traits (trait anxiety), and mood states, such as depression, hostility, joy. Salivary testosterone in conjunction to salivary cortisol, would provide an index of physiological catabolic/anabolic state.
2. The design and implementation of non-invasive psychophysiological protocols used in the current research, together with the above recommendations, could examine stress in other low intensity sports such as lawn bowling, pistol shooting and archery, and even intermittent sports such as baseball.

3. The stress responses found in PRO golfers during tournaments and the importance of assessing stress within individuals would justify longitudinal investigations of psychophysiological stress in golfers, for example over week-long golf tournaments or a tournament season. McAuley (1985) used longitudinal, intra-individual protocols to examine state anxiety in golfers over a ten competitive round season of golf. Such protocols could be enhanced by measuring saliva cortisol and heart rate responses. By measuring seasonal responses, golfers' psychophysiological states during individual days or tournaments could be compared with their average psychophysiological states over a golfing season.

4. In the present series of studies, heart rate was measured at 15 second intervals and these were further averaged over each of the 18 golf holes. A given heart rate measure represented some 5 to 10 minutes of data. In order to better understand the sympathetic nervous system activity in competitive golf, it would be interesting to study instantaneous heart rate (heart rate variability) during all phases of golf play. This could be contrasted with the responses of the HPA axis with its longer biological half-life. By adopting heart rate variability technology, a great deal more could be understood about cardiac deceleration that is purported to occur prior to putting.

5. A setting with potentially high competitive validity for directly comparing professional and recreational golfers would be a PROAM competition. In these events, the monetary rewards are often lucrative for the professional players, whilst the recreational players may regard these situations as challenging and potentially stressful.

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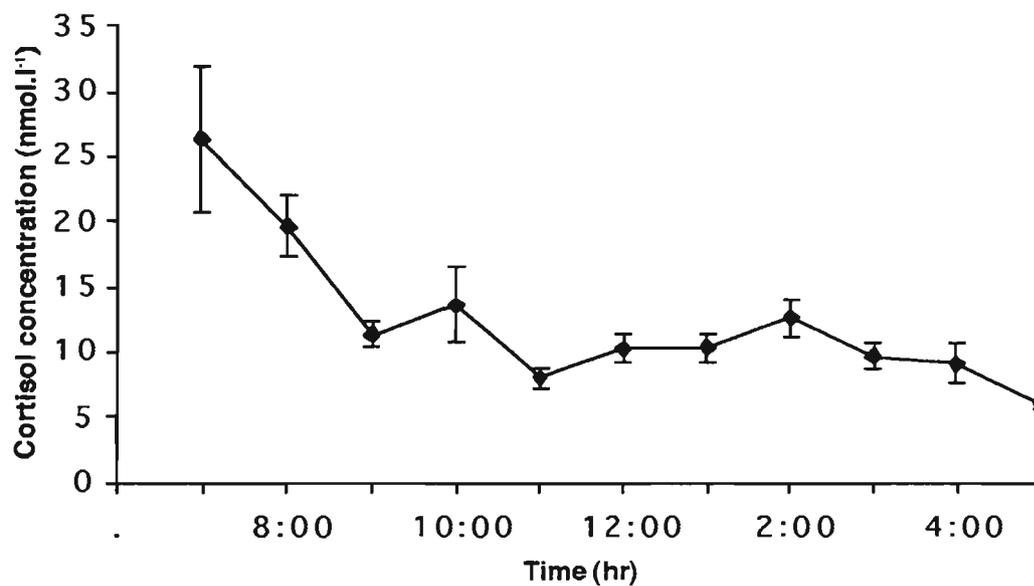
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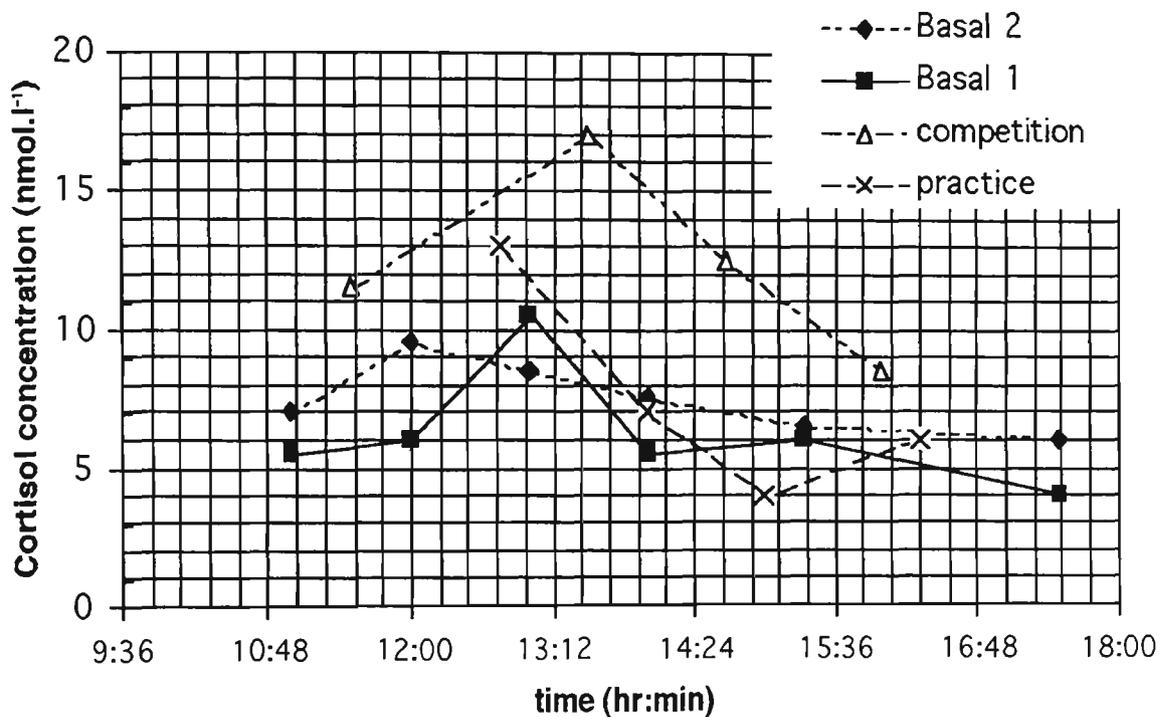
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APPENDICES



A.1 Group basal curve showing diurnal variation of salivary cortisol (nmol.l⁻¹) in (n=180) samples collected for n=15 PRO golfers on Basal days 1 and 2. Values are mean \pm SEM.



A.2 Example illustrating saliva cortisol response calculation for Player A (PRO golfer). A cortisol response (nmol.l^{-1}) in competition was the average value for Basal day 1 and 2 (closed square and triangle) subtracted from the golf round responses (open triangle), for the same time of day. Practice cortisol responses were calculated by subtracting the average basal value from the golf round cortisol concentrations measured in practice rounds (cross). Cortisol responses were a positive deviation from baseline.

A.3 Spreadsheet illustrating heart rates (15 second data; $b \cdot \text{min}^{-1}$) corresponding to the time of day (hr:min) for 18 hole golf rounds completed for $n=42$ golfers in for the two golf rounds. Golf round events shown include; time to enter and exit each hole, and putting green, shot type and ball strike (min:sec).

A.4 The Competitive State Anxiety Inventory (CSAI-2) completed at pregame, after holes 6, 12 and 18 in n=42 golfers during two golf rounds (from Martens, Burton, Vealey, Bump & Smith, 1990; Competitive Anxiety in Sport).

CSAI-2 Questionnaire

This questionnaire includes a number of statements which athletes have used to describe their feelings in competition.

1. Read each statement and then check the box according to the number which best reflects *how you feel right now*.

ie. 1 = not at all ; 2 = somewhat ; 3 = moderately so ; 4 = very much so

2. There are no right or wrong answers.

3. Do not spend too much time on any one statement, but choose the answer which describes your feelings right now.

1=Not at all; 2= Somewhat; 3= Moderately so; 4=Very much so

	1	2	3	4
1 I am concerned about this competition	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 I feel nervous	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 I feel at ease	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 I have self doubts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 I feel jittery	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 I feel comfortable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7 I am concerned that I may not do as well in this competition as I could	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8 My body feels tense	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9 I feel self-confident	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10 I am concerned about losing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11 I feel tense in my stomach	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12 I feel secure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13 I am concerned about choking under pressure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14 My body feels relaxed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15 I'm confident I can meet the challenge	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16 I'm concerned about performing poorly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17 My heart is racing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18 I'm confident about performing well	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19 I'm worried about reaching my goal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20 I feel my stomach sinking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21 I feel mentally relaxed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22 I'm concerned that others will be disappointed with my performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23 My hands are clammy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24 I'm confident because I mentally picture myself reaching my goal	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25 I'm concerned I won't be able to concentrate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26 My body feels tight	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27 I'm confident of coming through under pressure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

A.5 Golf round record sheet completed by observers following golfers 18 hole round.

Golf Record Sheet:

Date:
Course:
Comp/Prac:
Players name & hcp:

Pregame details:

Cortisol (hr:min)	(eg. 8:32)
Psych form (hr:min)	(eg 8:33)

Heart rate monitor Start time (eg. 8:14:32)
--

Hole No.

eg. 1

Hole No.	Time (at ball strike)	Club	Observations
eg. 8:36:46	eg. hr:min:sec		eg.shot result,behavioral response, weather, fluid intake etc.)
Arrive at tee	8:35:22		
Tee Off	8:38:20	D	middle of fwy
Shot #2	8:43:57	Li	left of green,
Shot #3	8:50:34	chip	good shot, near pin
Shot #4	8:53:03	putt	in
Shot #5			
Shot #6			
Shot #7			
Enter Green: (time)	8:51:10		Exit Green: 8:54:55 (time)

Club Key:		
D= driver	Mi = mid iron	C= chip
W= wood	B= bunker	P= putt
Li= long iron	Pit=pitch	Ts= trouble shot

Psychophysiological Stress in Elite Golfers during Practice and Competition

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ABSTRACT

McKay J. M., Selig S. E., Carlson J. S & Morris T. (1997). *Psychophysiological Stress in Elite Golfers during Practice and Competition. The Australian Journal of Science and Medicine in Sport* 29(2): 55-61

This study examined self-reported state anxiety (cognitive anxiety, somatic anxiety and self-confidence) measured by the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Vealey, Bump, & Smith, 1990) and physiological responses (salivary cortisol concentration and heart rate) in elite golfers prior to, during, and on completion of a tournament and practice round. The relationships between psychophysiological variables were investigated by comparing physiological and psychological responses during competition and practice to each other, and to performance. Performance was determined for each player as the difference between 18 hole score and handicap. Fifteen male Professional Golfing Association (PGA) trainees (aged 21-25 years) competed in a PGA sanctioned tournament and a practice round on the same, or similar golf course. Players completed the CSAI-2 and collected saliva for cortisol analysis on four occasions: prior to tee off, and after completing holes 6, 12 and 18. Cortisol concentration was corrected for circadian variations in cortisol secretion, using baseline cortisol measures. Within-subject analysis revealed elite golfers experienced elevated cortisol, heart rate, cognitive and somatic anxiety, and lower self-confidence during competition compared to practice. For both game conditions, the highest cortisol response was measured prior to the commencement of play, whilst state anxiety measures did not change significantly during the golf rounds. Univariate and multivariate analyses failed to reveal significant correlations between the psychophysiological variables and golf performance. In conclusion, competition and practice were clearly discriminated by the psychophysiological variables, but none of these predicted performance.

INTRODUCTION

Stress is an inherent aspect of sports competition, especially for elite athletes, whose skills are frequently tested in pressure situations. However, individuals perceive competition differently, with some responding positively to the challenge whilst others feel debilitated and performance suffers (Jones & Hardy, 1990). Stress can be regarded as a complex psychophysiological process (Pfister & Muir, 1992), often resulting in emotional, cognitive and physiological changes to the internal milieu of the sportsperson. To better understand the relationship between stress and performance in sport, researchers have investigated psychological, physiological and, less frequently, biochemical responses. Anxiety is a common emotional manifestation of stress in sport (Spielberger, 1989). Research employing multidimensional, sport-specific inventories, such as the Competitive State Anxiety Inventory (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990), has enabled more sensitive measures of state anxiety (A-state) compared to general, unidimensional scales. More specifically, the CSAI-2 differentiates between the athletes' self-reported cognitive anxiety (cognitive A-state), their perception of physiological autonomic activity, such as racing heart rate, and sweaty palms, or somatic anxiety (somatic A-state), and state self-confidence. The self-confidence subscale emerged during factor analyses. Thus it is assumed that the CSAI-2 subscales are statistically

orthogonal. As such, cognitive anxiety and self-confidence can not be parts of the same continuum; rather they are two separate constructs (Martens, Vealey, & Burton, 1990). One approach to understanding the anxiety-performance relationship has been to examine how each of the CSAI-2 components relates to performance (Gould, Petlichkoff, Simons, & Vevera, 1987; Martens, Vealey, & Burton, 1990). Whilst different antecedents affect CSAI-2 subcomponents differently in the lead up to competitive events (Gould et al., 1984; Martens et al., 1990), temporal patterns in A-state during actual performance are unclear (Caruso, Dziewaltowski, Gill, & McElroy; Karterolitis & Gill, 1987). Martens and colleagues (1990) argued that, because cognitive anxiety is related to performance evaluation, cognitive anxiety would change more than the other sub-components during performance. They proposed cognitive anxiety would show a negative linear relationship, self-confidence a positive linear relationship, and somatic anxiety a curvilinear relationship, with performance. However, support for the multidimensional anxiety-performance relationship has been equivocal (Burton, 1988; Gould et al., 1987), and furthermore, anxiety may not always be negative in affect (Parfitt & Hardy, 1993; Jones, Hanton, & Swain, 1994). Finally, the use of genuine competition, as opposed to laboratory or contrived conditions, is advocated to ensure ecologically valid environments when examining changes in A-state and performance (McCann, Murphy, & Raedeke, 1992; Weinberg & Genuchi, 1980). Self-report measures can easily be administered to athletes at sporting venues (Landers & Boutcher, 1986), however, the CSAI-2 has rarely been applied during actual competition (Martens et al., 1990; McAuley, 1985). Martens et al. (1990) administered the CSAI-2 at the end of an 18 hole golf round, but requested players to respond according to their feelings mid-round. Cognitive anxiety increased, and somatic anxiety and self-confidence decreased, from pregame to mid-game, as they predicted. Yet, this method of retrospective reporting raises doubt as to the validity of these A-state measures (Jones, 1995).

Concomitant psychological and physiological measures are advocated in competitive stress research (Hatfield & Landers, 1983; Neiss, 1988) as a broader approach to measures of self-reported anxiety alone. The physiological response to stress, or arousal, is more recently conceptualised as an individual's psychological and physiological autonomic system activation, varying on a continuum from deep sleep to extreme excitement (Gould & Krane, 1992). Heart rate, respiration, blood pressure, galvanic skin responses, muscle tension, brain activity, and hormones such as corticosteroids and catecholamines, are physiological measures of arousal state (Landers & Boutcher, 1986), yet only those which can be measured accurately, and with minimal invasiveness to the participant, are feasible sampling alternatives during serious competition. The cardiovascular response to psychological stress, indexed by heart rate (Herd, 1991), may be superimposed on the physiological response to exercise, in competitive sport (Baron et al., 1992; Hanson, 1966). Heart rate and unidimensional anxiety increase in parallel from practice to competition (Molander & Backman, 1994). There was no correlation between somatic A-state and cardiovascular responses (Karterolitis & Gill, 1987; Yan Lan & Gill, 1984), or muscle tension (Caruso et al., 1990), when participants competed in relatively novel tasks under contrived competition. Whereas heart rate responds rapidly and non-specifically to perceived threats, most neuroendocrine effectors respond to specific stimuli, often with longer time

courses. One such system is the hypothalamo-pituitary adrenal axis (HPA), which releases the steroid hormone, hydrocortisone (cortisol), from the adrenal cortex (Ur, 1991). The HPA axis is stimulated in anticipation of (Arthur, 1987; Cook, Ng, Read, Harris, & Riad-Fahmy, 1987), or in response to (Hubert & de Jong-Meyer, 1992), a wide range of psychological stressors (Kirschbaum & Hellhammer, 1989; Mason, 1968). In contrast, physical exertion of around 70% of maximal VO_2 , increases serum cortisol markedly (Cook et al., 1987; Davies & Few, 1973; Mason, 1973). Cortisol concentration exhibits similar directional patterns with unidimensional anxiety before (Benjamins, Asscheman, & Schurrs, 1992) and during stress (Hubert & de Jong-Meyer, 1992), but different temporal patterns in the period approaching a psychologically stressful event (Jones, Copolev, & Outch, 1986). Recently, development of a reliable method for determining cortisol concentration in small samples of saliva (Walker, Riad-Fahmy, & Read, 1978) has provided a relatively non-invasive parameter of serum cortisol concentration (Vining, McGinley, Maksvytis, & Ho, 1983b).

In a recent review of competitive anxiety in sport, Jones (1995) suggested that the major challenge facing researchers is the use of multidimensional protocols, including physiological parameters, in real rather than contrived competition settings. The purpose of the present study, therefore, was to use a psychophysiological approach to investigate competitive stress and its effects on performance before, during, and following a tournament golf round. Using intra-individual analysis and standardised performance scores, it was hypothesised that

1. cognitive and somatic anxiety, salivary cortisol, and heart rate measures would be higher in competition than practice;
2. somatic anxiety would be correlated with cortisol and heart rate in a positive linear relationship; and
3. cognitive anxiety would follow a negative linear relationship with performance.

METHODS

Participants and Design

Fifteen male professional golfers (handicap 3.8 ± 0.5 ; age 22.5 ± 0.4 years; height 180.1 ± 0.7 cm; body mass 82.3 ± 1.3 kg; mean \pm SE) volunteered for the study. All participants were enrolled in the three year Professional Golfers Association (PGA) Traineeship Scheme. Golfers were contacted individually to determine their interest in the study and consent to undergo testing during a competition. The trainees are a group of elite golfers, with handicaps five and below, who are preparing for a career in professional ranks. Participants were required to play in a competition and practice round of golf, where psychophysiological data, that is, CSAI-2 state anxiety, cortisol and heart rates, were collected prior to and after hole 6, 12 and 18 for each game. Two separate rest days were required to collect basal cortisol data.

MEASURES

Salivary cortisol

Cortisol is a steroid hormone, released from the adrenal cortex in response to stress related activation of the HPA axis (Ur, 1991). Plasma concentration of free hormone can be determined from saliva (Vining, McGinley & Symons, 1983a). To collect pregame, hole 6, hole 12, hole 18 and basal samples, participants allowed saliva to accumulate in the mouth for 60 seconds before expelling the sample (usually 1.5 to 2 ml) into a 5ml screw-top plastic vial. The saliva samples collected on golf or basal days were frozen overnight, then transferred the following day to freezer storage (-80°C). An advantage of saliva cortisol for field research is that it is stable for several days at room temperature (Kirschbaum & Hellhammer, 1989). Cortisol concentration was determined from duplicate 200 μl non-extracted saliva samples using Radioimmuno Assay (RIA) techniques (Clinical Assays; Gamma Coat [125- I] Cortisol Radioimmuno assay Kit, CA-1549). The saliva samples from each golfer (golf rounds plus basal samples) were

thawed several hours prior to the assay, and subsequently analysed in the same assay run. This is a common procedure to minimise any interassay variation within each participant's cortisol samples. Intra-individual measurements of cortisol concentrations (nmol.l^{-1}) were performed by correcting the levels measured during the game for the individual's normal (baseline) circadian cortisol levels recorded at the corresponding times of the day. To establish the baseline, six saliva samples were collected at hourly intervals, which spanned the four hours of the golf testing.

Cortisol concentration is reported as cortisol response, representing the positive deviation from baseline according to increased HPA activity (Kirschbaum & Hellhammer, 1989). Basal 1 and Basal 2 were used for the competition and practice rounds respectively. For each golfer, the basal cortisol concentration was determined corresponding to the time of the actual sample, for example, the basal measure corresponding to the pregame cortisol concentration. This value was then subtracted from the corresponding treatment measures, in this case, the pregame cortisol concentration for the competition round. The rationale for expressing and analysing cortisol data as a difference concentration is to control for circadian differences which arise from players completing their rounds at various times of the day and, in any case, an 18 hole round of golf takes several hours to complete.

Heart Rate

Each participant's heart rate was recorded at 15 second intervals using a Polar Sport Tester PE₃₀₀₀. The elastic chest strap (with the transmitter) was worn against the skin and the watch receiver was attached to the back of the player's waistbelt, so the heart rate display would not distract the golfer. Players reported the heart rate monitor did not interfere with their golf swing. Heart rates for each golfer were reported as the average heart rate per hole, for holes 1 to 18. The time taken to play a hole, was the time the player stepped onto the teeing area, until the time he stepped off the green. To interpret an emotional heart rate response in competition, we used the practice round as a baseline measure for physical golfing activity. The intra-individual design, whereby each player's heart rates in competition were compared to his heart rates in practice, was used to minimise individual variations in resting heart rate, fitness, height and weight. Physical exertion was not measured directly. However, for each golf round we measured the time to complete the round, and the total number of shots played. It was reasoned that significant differences in either of these measures across game condition, would indirectly indicate differences in physical exertion.

Competitive State Anxiety

Competitive state anxiety was assessed with the Competitive State Anxiety Inventory-2 (CSAI-2; Martens et al., 1990) which is a self-report psychometric inventory of A-state consisting of 27 items. At the time when this study was conceived and executed, the CSAI-2 was considered to be the most appropriate, well-validated, self-report measure of competitive state anxiety. The CSAI-2 assesses two components of state anxiety, cognitive worry and somatic anxiety, and a related construct, self-confidence, with 9 items representing each subscale. The CSAI-2 has good reliability and validity and has been widely used in research on anxiety in sport (Martens et al., 1990). Each participant completed four CSAI-2 questionnaires (PRE, H6, H12, H18) for each golf round, immediately following saliva collection. Each CSAI-2 subscale is rated on a scale from 1= "not at all" to 4 = "very much so", relating to extremes of intensity. Thus, each subscale has a range from nine to 36. Higher scores on cognitive and somatic anxiety indicate higher levels of anxiety, whereas higher scores on the self-confidence sub-scale correspond to higher levels of self-confidence.

Performance

Sonstroem and Bernardo (1982) advocate that each participant's performance measures should be standardised against their own

Figure 1. Cortisol responses (mean (SE) for competition (horizontal bars) and practice (speckled bars) golf rounds. The four pairs of data are for pregame (pre), hole 6, hole12 and 18, respectively.

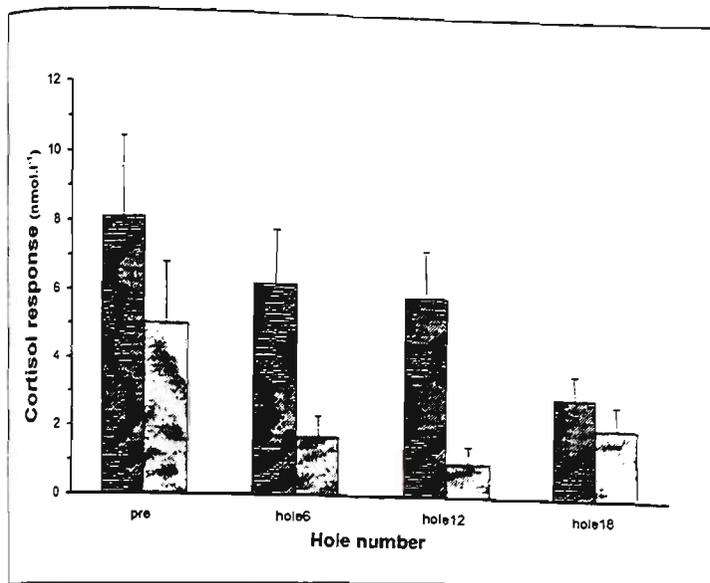
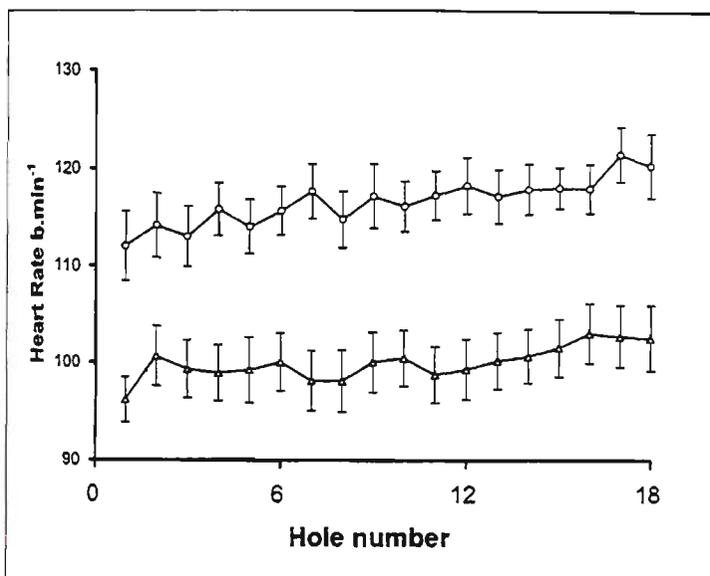


Figure 2. Heart rates for each hole (mean (SE) of competition (o) and practice (□) golf rounds.



previous performance measures. Subsequently, this intra-individual approach was followed, by using each player's handicap as a measure of previous performance standard. Two performance outcome measures were used to assess golfing performance. The first comprised of the player's 18 hole scores adjusted for current handicap. Each player's shots for the competition and practice round were totalled separately, before subtracting his corresponding handicap from the 18 hole scores. Handicaps were obtained from the PGA and represented the average performance score for the previous 6 months. A second measure, comprised each player's intra-individual performance score calculated for holes 1-6, 7-12 and 13-18, as these spanned the times between successive cortisol and anxiety sample times. One third of a player's handicap was then subtracted from the total shots played for each six holes. In this way, the player's performance for each set of six holes was compared against his own average standard for both competition and practice.

TREATMENTS

Familiarisation

Each player was thoroughly familiarised with recording equipment and sampling methods prior to being tested during golf play. Players were approached separately and the

procedures involved on the testing days explained. A week prior to the tournament, each golfer practiced golf shots (long shots, chipping and putting) whilst wearing the heart rate monitor. They completed a CSAI-2 questionnaire and collected saliva as would be required during the golf game. In each case, the familiarisation procedure lasted approximately one hour. This was an important aspect of the study, because the practical limitations of testing in pre-scheduled tournaments, prevented us from randomising game condition. The rationale was to maximise testing for each player on the same course at the same time as this would potentially affect heart rate and cortisol measures. This could only be achieved when each player's tournament round preceded his practice round. Familiarisation would assist in reducing novelty effects as a consequence of game order.

Competition

The competition round was a PGA sanctioned tournament, chosen because it is a significant sport contest where players compete for monetary rewards in addition to scores contributing to their yearly ranking. We required four golf courses to test fifteen players, due to equipment constraints. All PGA tournaments are scheduled for play on designated metropolitan Melbourne courses, six months prior to the event. From the tournament schedule, we selected four golf courses of similar length and flat terrain, to minimise extraneous responses on heart rate imposed by variable terrain. All golf round testing commenced in late winter and was completed by spring to minimise seasonal variations in temperatures which could differentially influence heart rate.

Practice

The practice round was an 18 hole stroke round played on the same course, commencing at the same time of day as the competition round. This was done to standardise task demands, advocated by Gould and Krane (1992). Eleven players were retested on the same four golf courses and at similar times of day. Two additional golf courses were required to complete practice round testing. The golf courses were of similar length (6134±41.5 metres). There was no incentive for players to score well on this occasion.

Basal

In addition to two golf testing days, each golfer collected resting cortisol samples on two other days, designated Basal 1 and Basal 2. Normal activity including standing around and walking was accepted on these days, however physical exertion (including playing or practicing golf) was not permitted before or during the sampling period. Each participant was given six tubes labelled with the sample time for saliva collection. The first time corresponded to the hour prior to their golf round hit off time. A sample was collected for each hour for the next five hours. Basal days 1 and 2 were approximately one week after the competition and practice round respectively.

PROCEDURES

As players arrived at the golf course on the competition day, a heart rate monitor was fitted, and recording commenced. Players followed their normal pre-tournament warm-up routine. Approximately 15 to 20 minutes prior to their allocated tee time, each golfer provided a saliva sample and then completed the first CSAI-2. This was the most convenient time for the golfers to complete sample collection, with minimal distraction to their golf related pre-game preparations. Each golfer was a member of a group of three players. An observer, following at a discrete distance behind play, recorded the time of day (hr:min) when the player stepped onto each tee and off the green, in addition to saliva and CSAI-2 sampling times. Basal day 1 was completed approximately one week following the competition round. Each golfer was subsequently tested on the same, or similar course when the same course was not available, within three weeks of the competition round. The same procedures were followed for the practice round as outlined for the competition round. The

Table 1: Golf scores (mean \pm SE; 6 hole total compared to each player's handicap, the latter expressed as a pro rata of the 18 hole handicap), cognitive and somatic A-state and self-confidence scores measured by CSAI-2 for competition and practice rounds of golf (left and right columns of each category, respectively). The fifth row of data (ALL) is the combined data for the four times. $^{\alpha}P < 0.001$, practice compared to competition; $^{\beta}P < 0.005$, practice compared to competition.

Hole	Score		Cognitive A-state		Somatic A-state		Self-Confidence	
	Comp	Prac	Comp	Prac	Comp	Prac	Comp	Prac
PRE	██████████		17.1 \pm 1.2	13.7 \pm 1.3	13.9 \pm 1.0	11.2 \pm 0.8	25.9 \pm 1.0	28.4 \pm 1.2
H6	0.9 \pm 0.4	0.6 \pm 0.5	19.6 \pm 1.0	13.5 \pm 1.2	15.5 \pm 1.1	10.5 \pm 0.7	24.7 \pm 1.0	28.6 \pm 1.3
H12	1.2 \pm 0.6	1.2 \pm 0.6	19.5 \pm 1.2	13.9 \pm 1.3	14.4 \pm 1.2	10.7 \pm 0.8	25.1 \pm 1.3	27.4 \pm 1.3
H18	1.5 \pm 0.5	0.4 \pm 0.5	19.0 \pm 1.4	13.3 \pm 1.3	13.5 \pm 1.3	10.3 \pm 0.7	22.8 \pm 1.6	29.7 \pm 1.3
ALL	3.6 \pm 0.9	2.2 \pm 0.9	19.0 \pm 1.0	13.8 \pm 1.2 $^{\alpha}$	14.5 \pm 0.9	10.7 \pm 0.7 $^{\alpha}$	24.6 \pm 0.9	28.2 \pm 1.1 $^{\beta}$

Table 2: Intercorrelations among CSAI-2 subscale scores, and somatic anxiety (A-state) with cortisol and heart rate.

	Cognitive worry and Somatic anxiety r	Cognitive worry and Self-confidence r	Somatic Anxiety and Self-confidence r	Somatic Anxiety and Cortisol r	Somatic Anxiety and Heart rate r
Practice					
pre	.71**	-.41	-.68**	.17	#
hole 6	.54*	-.44	-.59*	.07	.35
hole 12	.40	-.71**	-.76**	.04	.24
hole 18	.68**	-.63*	-.71**	-.28	.35
Competition					
pre	.48	-.33	-.65**	.03	#
hole 6	.38	-.48	-.27	-.22	-.07
hole 12	.31	-.42	-.22	-.38	-.23
hole 18	.83**	-.23	-.40	-.22	-.40

second basal day (Basal 2) was completed a week after the practice round, following the same procedures as Basal 1.

RESULTS

Changes in Physiological and Psychological Measures

To examine the effects of treatment and time on cortisol and heart rate, intra-individual cortisol response and heart rates were analysed (using repeated measures ANOVA), before, during and after the golf games. The mean cortisol responses for competition and practice rounds are illustrated in Figure 1. Salivary cortisol responses were analysed by a Game X Hole (2 x 4) two-way repeated-measures ANOVA which revealed a significant game effect (5.8 ± 1.6 nmol.l⁻¹ for competition and 2.4 ± 1.1 nmol.l⁻¹ for practice; mean \pm SE; $F(1,14) = 6.62$, $p < .02$), a significant hole effect ($F(3,42) = 4.14$, $p < .02$), but no significant interaction. Univariate *F* tests located the significant differences to postgame (H18; 2.6 ± 0.7 nmol.l⁻¹), compared to the other three times for competition and practice (pre, H6, H12; 4.6 ± 1.6 nmol.l⁻¹; $F(1,14) = 14.03$, $p < .002$).

To examine the effect of game and time on golfers heart rates, a Game x Hole (2 x 18) two-way repeated-measures ANOVA was conducted on heart rates for each hole. The heart rate responses are illustrated in Figure 2. The ANOVA revealed a significant game effect (117 ± 3 b.min⁻¹ for competition versus 100 ± 3 b.min⁻¹ for practice, $F(1,14) = 38.45$, $p < .001$), a significant hole effect, $F(17,238) = 3.74$, $p < .001$, but no significant interaction. Other factors which may differentially influence heart rate in competition and practice rounds, namely temperature during play ($13.1 \pm 0.5^{\circ}\text{C}$; $16.0 \pm 0.1^{\circ}\text{C}$ respectively), shots over par (7.2 ± 0.8 ; 6.0 ± 1.0 respectively), time to complete the round (267 ± 5 min; 221 ± 7 min respectively), were not significantly different.

Finally, to examine the relationship between game condition

and time on state anxiety and self-confidence, a Game x Hole (2 x 4) repeated-measures MANOVA was used on the three CSAI-2 subscale scores. The CSAI-2 scores during competition and practice golf rounds are shown in Table 1. The overall MANOVA revealed a significant game effect, $F(3,12) = 14.38$, $p < .001$, however the effect for hole just failed to reach significance. There was no interaction between game and time. Separate Univariate ANOVAs were used to locate the differences between game and time on each of the CSAI-2 components. Game x Hole (2 x 4) repeated measures ANOVAs found a significant game effect for cognitive anxiety, somatic anxiety and self-confidence, in each case. Cognitive and somatic anxiety were higher in competition compared to practice (cognitive: 19.0 ± 1.0 for competition versus 13.8 ± 1.2 for practice, $F(1,14) = 34.64$, $p < .001$; somatic: 14.5 ± 0.9 for competition versus 10.7 ± 0.7 for practice, $F(1,14) = 22.59$, $p < .001$) and self-confidence was higher in practice (28.2 ± 1.1) than competition (24.6 ± 0.9 ; $F(1,14) = 11.75$, $p < .004$). There were no significant effect of time on the CSAI-2 sub-components.

Performance Measures

We examined the ability for CSAI-2 components, cortisol and heart rate to predict performance by using multiple quadratic regression analysis. The criterion variable was the performance measure (either 18 hole score or score for hole 1-6, 7-12, 13-18). Predictor variables in the multiple regression analysis included the CSAI-2 and cortisol measures at pre, H6, H12, H18 and heart rates for holes 1-6, 7-12 and 13-18. The results showed that neither CSAI-2 or physiological measures significantly predicted performance (R values ranged from .32 to .51)

Correlation Among Measures

To examine relationships between state anxiety components, physiological and biochemical measures, and performance scores, Pearson Product Moment Correlation Coefficients were

calculated for competition and practice. Moderate correlations between CSAI-2 subcomponents are shown in Table 2. Salivary cortisol and heart rate were not significantly correlated with somatic anxiety, prior to, during or after competition or practice. The 18 hole golf score showed a moderate negative correlation with pregame cognitive anxiety, and a moderate positive correlation with pregame salivary cortisol ($r = -.5$ and $.5$, respectively). This relationship between cognitive anxiety and performance was not in the predicted direction because lower performance score relates to improved golf performance. In contrast, higher pregame cortisol related to poorer performance. There was no correlation between the other pregame, hole 6, 12 or 18, and performance in practice and competition. Neither somatic anxiety, nor self-confidence correlated with performance, in competition. In the practice game, pregame somatic anxiety and self-confidence were moderately correlated to 18 hole performance ($r = -.8$ and $.57$, respectively). Additionally, somatic anxiety and self-confidence at hole 18, showed a moderate correlation to score averaged over the last six holes of the practice round ($r = -.55$ and $.65$, respectively). This finding is qualified by the fact that very low levels of somatic anxiety were reported in practice.

DISCUSSION

The results of this study indicate that salivary cortisol, heart rate, anxiety and self-confidence responses in elite golfers were strongly influenced by competitive conditions. Only the physiological variables, heart rate and cortisol, changed over the course of the competition round. The CSAI-2 subcomponents showed moderate correlation in practice, to a greater extent than in competition. Heart rate and cortisol were not correlated to the physiological measure of arousal, somatic anxiety. There was no support for cognitive anxiety having a negative effect on performance, rather cognitive anxiety prior to competition indicated a moderate facilitative effect on 18 hole score. None of the psychophysiological parameters was able to predict performance.

Correlations Among Measures

In this study, cognitive anxiety, somatic anxiety and self-confidence were moderately correlated, corroborating the findings of Gould et al., (1984) and Martens et al., (1990) that the CSAI-2 state anxiety is a multidimensional construct. In particular, the practice condition, where only low levels of anxiety were reported, showed a stronger relationship between CSAI-2 components. This is consistent with golfers perceiving the practice game as being relatively non-threatening. Competition elevated state anxiety, with golfers reporting greater worry and experiencing bodily sensations attributed to nervousness. The fact that the relationship between CSAI-2 components did not strengthen in parallel, indicates the individual variability in reported anxiety, and further supports the multidimensional nature of CSAI-2 components.

In examining the physiological and psychological measures of arousal, there was no relationship between a commonly used index of arousal, heart rate, a more sensitive biochemical correlate of stress, salivary cortisol, and self-reported physiological arousal, somatic anxiety. Other studies found no correlation between cardiovascular parameters and somatic A-state using contrived competition and relatively novel motor tasks (Karteroliotis & Gill 1987; Yan Lan & Gill, 1984). This study supports previous findings, in a group of golfers competing in an ecologically valid setting. Furthermore, it indicates that somatic anxiety and a neuroendocrine response were not related. Cortisol had not yet been correlated with somatic A-state during tournament golf performance. Gould and Krane (1992) emphasised a persons cognitive interpretation of physiological arousal and physiological responses are conceptually distinct, but should show common variance (Hatfield & Landers, 1983; Vealey, 1990). Future research could examine somatic anxiety and more sensitive measures of heart rate, for example, heart rate variability, or beat to beat intervals (Malik, 1996).

Changes in psychological and physiological parameters and performance

The small cortisol responses found in this study, ranging from 1.0 to 8.0 nmol.l⁻¹, are in accordance other studies, employing psychological stress paradigms, such as unpleasant film stimuli (Hubert & de Jong-Meyer, 1992), academic examinations (Jones et al., 1986) and public speaking (Bassett et al., 1987). The golfers' pregame salivary cortisol was elevated shortly before the tournament, which is similar to a finding by Cook and colleagues (1987), in marathon runners about to compete in an actual marathon. They attributed this increase to anticipatory events. Evidence to support the influence of psychological HPA axis activation was that the largest cortisol response was pregame, where golfers' physical exertion was minimal. Second, golf exercise is below the threshold to elicit an exercise related HPA response (Cook et al., 1987; Mason, 1973). Third, state anxiety was higher in competition than practice, as were cortisol responses. The precise nature of the psychological influence is beyond the scope of this study, however changes in cortisol during competition do not appear to be directly related to state anxiety.

Emotional influences on heart rate may be reflected by the average heart rate in competition being 17 b.min⁻¹ higher, compared to practice. This finding coincides with higher self-reported anxiety. However, heart rate is influenced by many factors other than psychological ones (Herd, 1991). The temperature during play, the number of golf shots, and the time to complete the 18 holes did not differ between practice and competition. Although physical exertion was not measured directly, players shot a similar low score, over a similar time period, in both game conditions. Differences between individual golfers, with respect to physical fitness, resting heart rate, body weight and body adiposity and sex, were not an issue because each individual acted as his own control. Heart rate was observed to drift upwards during both rounds, maybe as a result of fatigue, wind direction and strength and terrain; the latter being controlled by using the same golf courses for practice and competition in most cases.

This study showed that, even when physiological, biochemical, and self-report psychological indicators were used in combination, the measures did not distinguish between anxiety, shortly before and at different stages during competition. Only the cortisol measures showed a significant change from pre-event to the first test during the round, and this might have reflected readiness, rather than anxiety. Individual interpretations are important to monitor, but recent research has shown that self-report scales, like in the CS AI-2, might not provide an adequate reflection of anxiety state. Jones and colleagues (Jones, Hanton, & Swain, 1994; Jones, Swain, & Hardy, 1993) noted that the CSAI-2, like most of its predecessors, measures only the level or intensity of anxiety experienced. They demonstrated that the frequency, that is, how often that intensity is experienced, and the direction of the anxiety, that is whether that anxiety is perceived to be facilitating (positive) or debilitating (negative) are also important to consider. This is especially relevant to elite performers, who are likely to interpret their anxiety as more facilitating and less debilitating than non-elite or less skilled performers (Jones, Hanton, & Swain, 1994), not only on one occasion, but routinely (Jones & Swain, 1995). Swain and Jones (1993) showed that, while the intensity of cognitive and somatic state anxiety did not change as a competition approached, there was a large increase in the frequency of intrusive, anxiety-related thoughts in elite track and field athletes. Similarly, the present study revealed no differences in cognitive or somatic state anxiety intensity, when comparing pre-competition anxiety with anxiety measures at three stages during the event, where such changes might be expected to be particularly manifest (Martens, et al., 1990). It is possible that, while the intensity of the golfers' state anxiety remained the same, its frequency increased during competition. This is suggested by the persistence of cortisol concentration during the

golf tournament. As the golfers in the present study could be regarded as elite, it is also possible that their experience of cognitive, and perhaps somatic, state anxiety was substantially facilitating, supported by pregame cognitive anxiety showing a positive relationship to 18 hole score. This might be one reason why there was no relationship of the state anxiety intensity variables with performance. It may also be true that performance score, even though it was standardised against each golfer's previous performances, was not sensitive enough to reflect subtle differences in motor performance (Weinberg & Hunt, 1976). Other reasons may include low variance in performance in this homogenous group, and these elite golfers may have learned to manage their anxiety at a facilitative level.

This study is consistent with the research on temporal patterns of state anxiety and that on the anxiety-performance relationship as a whole, in not showing clear patterns of state anxiety intensity associated with different times in relation to competition or clear relationships of state anxiety intensity to performance. While the biochemical measure of cortisol did indicate some variation during performance, the nature of the change was not indicated. It is possible that the measurement of cortisol at the same times that the intensity, frequency, and direction of cognitive and somatic state anxiety are assessed would provide a fruitful approach to examine changes in anxiety, and its relationship to performance. Additional distinctions in pre-event and during-event anxiety state might also be forthcoming from a comparison of elite performers with non-elite, using the non-intrusive, biochemical and multidimensional, self-report approaches together. Future research should explore these propositions.

Benefits and Limitations of field approach

Weinberg and Genuchi (1980) suggested enhancing the situational validity increases the potency of the response. In this study, we observed a highly significant change in psychophysiological variables with game condition which suggests the tournament was more stress evoking for the golfers than practice. A limitation arising from using actual tournaments in this study was that it prevented us from randomising the game order. The rationale for competition rounds preceding practice rounds was to maximise retesting each player on the same golf course and at the same time of day. Theoretically, order of the game conditions may influence stress parameters. However, non-invasive measures and thorough familiarisation procedures, could have assisted to minimise order effect.

The contributions of studies such as this are to provide a broader measurement approach in the study of competitive stress. Adopting psychophysiological approaches which are minimally invasive to the sportsperson will ensure that stress responses can be measured more frequently, and therefore in close proximity to performance, during competition events. A primary implication of this study is that salivary cortisol may provide a sensitive index of physiological stress for further research, together with direction, intensity and frequency state anxiety scales.

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