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Salivary Testosterone and Cortisol: Role of Athletic Setting, Game Outcome, and Game Location

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Abstract

Many studies investigating the relationship between hormones and competition have focused on athletic competition. The athletic setting enables researchers to investigate the hormone-behaviour relationship in a relatively controlled environment. However, research to date has been based on observations made from single status contests and/or weekend tournaments and as such, does not provide a clear picture of an individual's average hormonal responses to both victory and defeat.

In appreciation of this limitation, the current study tracked elite hockey players throughout a hockey season, measuring pre- and post-game salivary testosterone and cortisol as well as psychological measures. I was interested in determining whether status outcome (win vs. loss) would influence an individual's testosterone and cortisol responses to competition. Furthermore, I was also interested in assessing whether testosterone and cortisol responses were specific to the competitive environment or whether similar hormonal responses would occur during non-competitive practice sessions. Last, I was interested in whether there were any differences in pre-game hormonal and psychological states depending on where the status contest was held: home versus away.

The results indicated that game outcome moderated the testosterone responses to competition. That is, testosterone increased significantly more after a victory compared to a defeat. Furthermore, a loss of status produced significantly higher post-game cortisol levels than did an increase in status. In contrast to previous

reports, the players did not show an anticipatory rise in either cortisol or testosterone prior to competition.

In addition to the effects of status outcome on hormonal levels, it was also found that these hormonal responses were specific to competition. The athletes in the current study did not demonstrate any hormonal responses to the practice sessions. Last, there were significant differences in pre-game testosterone as well as in self-confidence, cognitive, and somatic anxiety levels depending on the location at which the status contest took place. Pre-game testosterone and self-confidence levels were significantly higher prior to games played in the home venue. In contrast, pre-game somatic and cognitive anxiety levels were significantly higher prior to games played in the away venue.

The current findings add to the developing literature on the relationship between hormones and competition. This was the first study to detect a moderating effect of status outcome on testosterone responses in a team sport. Furthermore, this was also the first study in humans to demonstrate that post-contest cortisol levels were significantly higher after a loss of status. Last, the current study also adds to the sport psychology literature by demonstrating that pre-game psychological variables differ depending on where the status contest is being held: higher self-confidence at home and higher somatic and cognitive anxiety away. Taken together, the results from the current thesis may have important practical relevance to coaches, trainers and sport psychologists who are always trying to find ways to maximize performance.

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To my parents and my brother, thank you for always supporting me and always encouraging me to succeed in anything in life. Your words of wisdom have always guided me in the right direction and I'm very thankful for having such a great family.

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Introduction

Today's young hockey players are faced with numerous challenges that may have a significant impact on their development, not only as hockey players but also as individuals. The difference between succeeding and failing at an elite level of competition can lie within a player's ability to be committed to, and to cope with, the physiological and psycho-social stress of playing at the elite level (Orlick, 1990). Furthermore, a crucial psychological variable that has been attributed to successful performance in sport competition is self-confidence (Miller, 2001). Athletes with high self-confidence are often more certain about their abilities and are more willing to take risks during competition than their otherwise less confident counterparts and this may translate into better performance.

Another area of interest in competitive sport is the relationship between anxiety and athletic performance. Does elevated anxiety lead to poor performance, or does it prepare or activate the athlete for the upcoming competition? Yerkes and Dodson (1908) first proposed the inverted-u hypothesis to explain the effects of anxiety on performance. They argued that too little or too much anxiety activation would lead to poor performance while 'just the right' amount of anxiety would lead to optimum performance.

Martens, Vealey, and Burton (1990) developed the Competitive State Anxiety Inventory in an attempt to better understand the anxiety/performance relationship in the athletic environment. This sport-specific assessment tool enables researchers to measure both cognitive and somatic state anxiety. Cognitive anxiety involves the negative expectations and concerns about an athlete's ability to compete successfully.

Martens et al. (1990) proposed that there is a negative linear relationship between performance and cognitive anxiety such that increased cognitive anxiety leads to poor performance. In contrast, somatic anxiety involves the physiological components of anxiety due to the increase in autonomic arousal and is proposed to have an inverted-u relationship with performance. Martens et al. (1990) developed this Multidimensional Theory of Anxiety in recognition of the distinct features of cognitive and somatic anxiety as they relate to athletics

Of particular interest to coaches and sport psychologists is the impact of winning and losing on the athlete's psychological and physiological states. Mazur (1985) proposed a biosocial model of status in an attempt to describe the relationship between outcome of a competitive encounter and subsequent hormonal responses. His model states that after a victory (which results in maintenance or rise in status), testosterone levels increase making it more likely that the individual will be motivated to compete assertively in future status contests (see Figure 1). One can postulate that the rise and fall of testosterone in response to status contests may be associated with the concept of a winning or losing streak in competitive sports.

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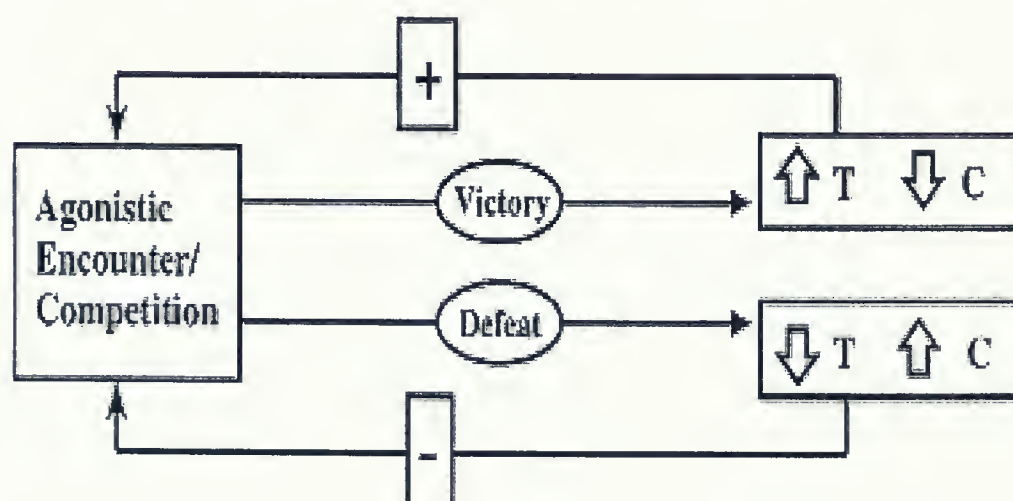


Figure 1. Biosocial model of status.

Another area that has intrigued spectators, coaches, sport commentators, and sport psychologists is the concept of the home advantage. For many years it has been found that, under a balanced home and away schedule, sport teams win more games in their home venue than in their opponents' venue (see Courneya & Carron, 1992 for review). Many explanations have been proposed to explain this phenomenon including familiarity with the facility, travel, officiating bias, and crowd support. Research now suggests that there are important pre-game psychological differences in athletes depending on game location. Furthermore, research on pre-game hormonal levels and game location may provide further insight with regard to territoriality and location of competition as testosterone has been shown to be higher prior to games played in the home venue (Neave & Wolfson, 2003).

The current thesis has been divided into six sections. The first section begins with a brief overview of the stress response. Furthermore, the first section also provides a general introduction to the hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-gonadal (HPG) axes with specific emphasis on the hormones cortisol and testosterone. The second section begins with a brief discussion on hormones and competition, followed by a description of the biosocial model of status as proposed by Mazur (1985). This section also provides a thorough review of the literature on hormones and status competitions, with an emphasis on the role of status outcome, athletic setting, and competition location. The third section focuses on the psychological aspects of status contests with an emphasis on self-confidence, cognitive anxiety, and somatic anxiety. The fourth section describes the methodology used. The fifth section presents the results. Finally, the sixth and final section

provides a discussion of the main findings along with general conclusions, limitations and possible practical implications.

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SECTION I – STEROID HORMONES

Stress Response

Competition comes at a cost to all species. Mammals engaging in status contests must allocate a great deal of physical energy during aggressive encounters, which may increase the risk of being seriously injured. Hans Selye (1956) provided the first explanation for the physiological changes that occur in the body during a physical and/or psychological stressor. When an individual is exposed to a stressor, there is a change in homeostatic balance within the body, and one way that the body attempts to restore balance is throughout the activation of two systems: (1) the autonomic nervous system (ANS), which consists of the antagonistically acting sympathetic nervous system (SNS) and parasympathetic nervous systems (PNS); and (2) and the hypothalamic-pituitary-adrenal (HPA) axis.

The main anatomical structures involved in the initiation of the stress system are located in the hypothalamus and the brain stem (Tsigos & Chrousos, 2002). The stress-response involves a series of complex interactions between neurons and hormones that work together to restore homeostatic balance. When a stressor (physical and/or psychological) is first perceived, the locus coeruleus (LC), located in the brain stem, is activated and initiates the release of excitatory neurotransmitters/neurohormones, particularly norepinephrine (NE) and epinephrine (Tsigos & Chrousos 2002). The release of NE leads to activation of the SNS and subsequent changes in the body including increased respiration, heart rate, blood pressure, glycogen conversion into glucose, and redistribution of blood supply from the skin (periphery) to the brain and working muscles (Hoffman, 2002). Upon

conclusion of the stress response, the PNS is activated enabling the body to return to a homeostatic state. From an evolutionary perspective, the bodily changes that occur during the stress response are especially useful during times of crisis, such as when fleeing a potentially dangerous predator.

The next set of more long-term adaptations to stress occurs in the hypothalamic-pituitary-adrenal (HPA) axis. First, the paraventricular nucleus (PVN) of the hypothalamus increases secretion of corticotrophin-releasing hormone (CRH), a 41 amino acid peptide first isolated by Vale, Speiss, Rivier, and Rivier (1981). CRH targets the anterior pituitary gland, which subsequently activates the release of adrenocorticotrophic hormone (ACTH). The release of ACTH into the blood stream results in the activation of the adrenal gland. At the adrenal gland, ACTH stimulates the release of glucocorticoids (cortisol in humans and corticosterone in rodents) through the adrenal cortex, which then has widespread impact on both peripheral and central processes (Sapolsky, 2005 – see Figure 2).

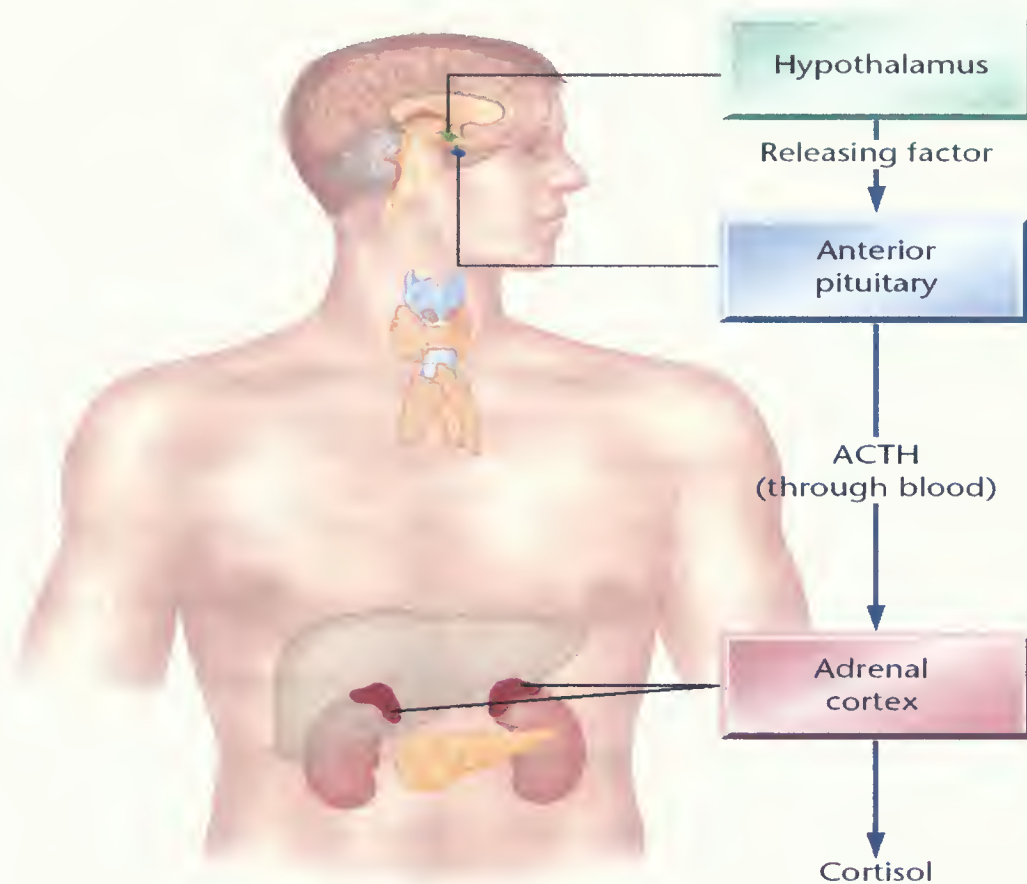


Figure 2. Hypothalamic-pituitary-adrenal (HPA) axis.

Obtained from http://cti.itc.virginia.edu/~psyc220/kalat/JK367.fig12.6.HPA_axis.jp

The HPA axis is guided by a classic feedback loop that regulates the release of cortisol through several inhibitory processes. Several structures in the brain possess glucocorticoid (GC) receptors which, when occupied, send inhibitory (hippocampus, prefrontal cortex, pituitary gland) or excitatory (amygdala) messages to the hypothalamus, which leads to a cessation or an increase in the production of CRH (van Den Eede, Van Broeckhoven, & Claes, 2005).

Cortisol

One of the hormones involved in the stress response is cortisol. Cortisol, a steroid hormone produced in the adrenal cortex, plays an important role in maintaining normal physiological function. Some of these functions include conversion of amino acids to carbohydrates, increase in proteolytic enzymes, inhibition of protein synthesis, increase in protein degradation in muscles, stimulation of gluconeogenesis, increase in blood glucose concentration, and facilitation of lipolysis (Hoffman, 2002). In addition to maintaining everyday cellular and metabolic functions, cortisol helps to regulate homeostatic balance during times of long-term physical and psychological stress.

Cortisol is synthesized from cholesterol and belongs to the steroid class of hormones. These hormones are lipid soluble and, as a result, can pass freely through the plasma membrane to exert their effects on intracellular and/or nuclear steroid receptors. Most of the cortisol released in the blood stream is 'biologically inactive' because it is bound to corticosteroid-binding globulin (CBG) and cannot pass freely through the plasma membrane to bind to intracellular receptors. A small proportion

(2%) of cortisol is found unbound to proteins and can cross the plasma membrane where it binds to intracellular receptors and can affect transcription and protein synthesis in target cells (Porterfield, 2001).

Cortisol demonstrates a circadian rhythm where levels are highest in the waking hours of the day, decrease sharply in the next few hours and then remain fairly stable in the remaining hours of the day (Aubets & Segura, 1995). Therefore, many studies evaluating salivary cortisol levels have been carefully designed in appreciation of cortisol's diurnal variation.

Despite all the reported negative consequences of stress hormones, acute stress responses have been shown to be beneficial. The obvious benefit of the stress response is its energizing capacity during times of crisis. The stress response involves increases in norepinephrine and cortisol, which work together to divert energy to the brain, heart and working muscles, producing a bodily state that increases an organism's chance of survival during a crisis. The other benefit of short-term stress activation is its role in hippocampus-dependent cognition. The stress response is believed to follow an inverted-u pattern, whereby an absence of activation or an excess of activation may be detrimental to cognitive performance (Sapolsky, 2003). A moderate amount of short-term activation, often termed 'stimulation' has been shown to facilitate cognition in both rodents and primates (Wolf, 2003).

Glucocorticoid receptors are located in the periphery and also the brain. There are two types of glucocorticoid receptors; mineralocorticoid receptors (MRs) and glucocorticoid receptors (GRs). There are GC receptors located in several important brain structures such as the hippocampus, hypothalamus, amygdala and

prefrontal cortex (see Herman, Ostrander, Mueller, & Figueiredo, 2005 for review). MRs tend to be occupied during basal levels (when cortisol levels are relatively low), while GRs tend to be occupied during stressful periods, or during times of high GC concentration (see Sapolsky, Romero, & Munck, 2000 for review). During times of physical, psychological and/or social stress, cortisol binds to low affinity receptors (GRs) in various areas of the brain, which subsequently send inhibitory or excitatory signals to the hypothalamus, which, in turn regulate the release of CRH. This mechanism enables an individual to effectively adapt during threats to internal homeostasis. In contrast, any disruptions to this system may lead to chronically elevated or reduced levels of cortisol, which have been linked to cognitive impairment (Lupien, Fiocco, Wan, Mahew, Lord, Schramek, & Thanh Tu, 2005), heart disease (Smith, Ben-Schlomo, Beswick, Yarnell, Lightman, & Elwood, 2005), depression and anxiety (see Antonijevic, 2006 for review).

Testosterone

Testosterone is the primary steroid hormone serving anabolic functions such as maintenance and growth of muscle and bone tissue. Testosterone is secreted primarily by the Leydig cells of the testes, with a relatively smaller portion (5%) secreted by the adrenal glands in both sexes (Porterfield, 2001). Testosterone has been shown to mediate sexual differentiation during gestation, to promote the appearance of secondary sex characteristics during puberty and also to mediate sexually dimorphic behaviours (Nelson, 2005). Secretion of testosterone is controlled by the hypothalamic-pituitary-gonad axis (HPG) and is characterized by the release of gonadotropin releasing hormone (GnRH) from the hypothalamus, which stimulates

the release of luteinizing hormone (LH) from the anterior pituitary. In men, LH binds to receptors on the Leydig cells of the testes and stimulates the release of testosterone (Nelson, 2005). Much like the negative feedback regulation of the HPA axis, testosterone receptors are found on the hypothalamus and anterior pituitary and upon binding to these sites, testosterone blunts or slows the release of GnRH and LH respectively (see Figure 3).

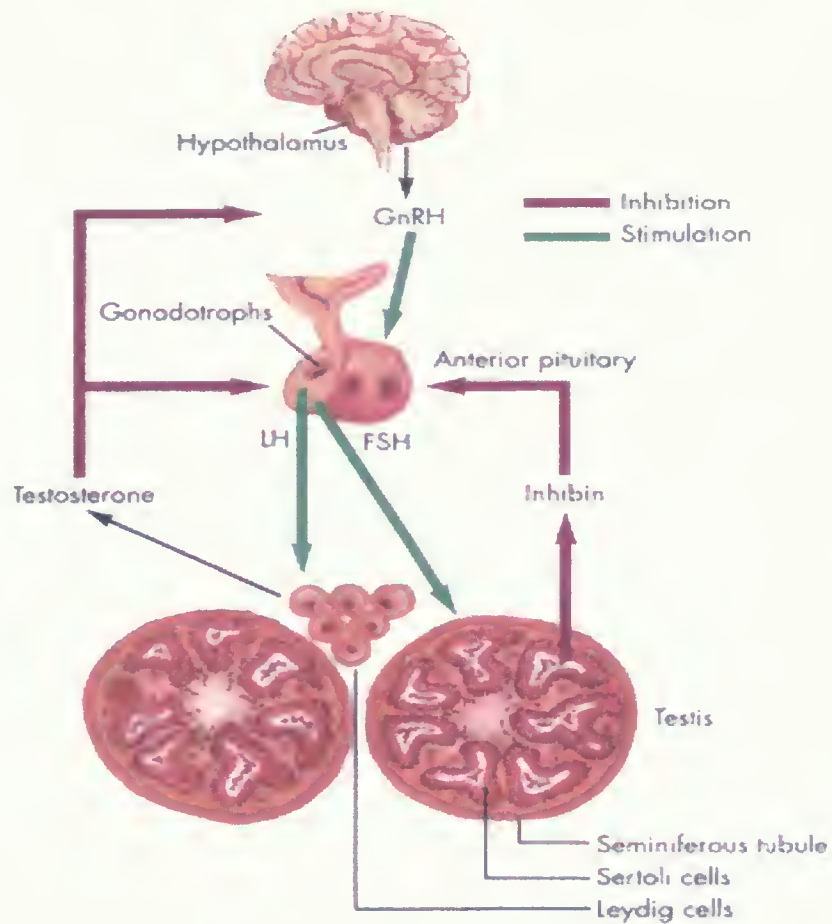


Figure 3. Hypothalamic-pituitary-gonadal (HPG) axis.

Obtained from <http://www.homefertility.com/hypothalamus.jpg>

The majority of testosterone circulating in plasma is found bound to proteins. For example, 40% is bound to sex hormone-binding globulin (SHBG) and 47% is bound to albumin and other proteins (Porterfield, 2001). Just as with cortisol, testosterone bound to a protein is not able to enter a cell and bind to its intracellular receptors, and as a result, is not considered biologically active. Testosterone measured in saliva is also known as 'bioavailable testosterone' because it is not bound to proteins and thus, represents the biologically active fraction in circulation, capable of binding to intracellular receptors in the periphery as well as the central nervous system.

Androgen receptors have been identified in bed nucleus of the stria terminalis (BNST), medial pre-optic area (MPOA), lateral septum and medial amygdala in rodents (Simon, 2002). These same neural structures have been identified as important mediators of aggressive behaviours. In humans, testosterone has been related to many behavioural characteristics including aggression, assertiveness, dominance, sensation seeking and risk taking (Kreuz & Rose, 1972; Scaramella & Brown, 1978; Dabbs, Frady, Carr, and Besch, 1987; Mazur & Booth, 1998; Archer, 2006).

Relationship between Testosterone and Cortisol

It has long been known that chronic exposure to many types of physical and psychological stress can have a suppressing effect of the hypothalamic-pituitary-gonadal (HPG) axis (Chrousos & Gold, 1992). In male humans, cortisol has been shown to have a suppressing effect on testosterone production (Cumming, Quigley, & Yen, 1983). It has been suggested that the decrease in testosterone release is

independent of LH secretion, and is mediated by a direct inhibition of testosterone production from the Leydig cells of the testes. The Leydig cells of the testes contain glucocorticoid receptors, and during physical and/or psychological stressors, cortisol can bind to receptors on the Leydig cells to inhibit the production and release of testosterone. Under normal circumstances, the Leydig cells are able to resist the elevated levels of cortisol through oxidative inactivation of cortisol by 11-beta-hydroxysteroid dehydrogenase (Hardy, Sottas, Ge, McKittrick, Tamashiro, McEwen, Haider, Markham, Blanchard, Blanchard, & Sakai, 2002). However, it has been shown that social defeat in rats, which is associated with elevated corticosterone, impairs the ability of Leydig cells to up-regulate the production of 11-beta-hydroxysteroid dehydrogenase, thereby leading to a suppression of testosterone synthesis and release (Hardy et al., 2002). In contrast, dominant male rats, that also show elevated levels of corticosterone during the formation of hierarchies, do not experience decreases in testosterone, most likely due to an up-regulation of 11-beta-hydroxysteroid in response to the high corticosterone levels (Hardy et al., 2002).

Although testosterone and cortisol have been shown to have opposing metabolic effects, research has also demonstrated that under competitive conditions, both hormones can increase simultaneously (Elias, 1981; Suay, Salvador, Gonzalez-Bono, Sanchis, Martinez, Martinez-Sanchis, Simon, & Montoro, 1999; Edwards, Wetzel, & Wyner, 2005).

In response to the interest in monitoring training among athletes, some exercise physiologists have suggested that a good marker of over-training and/or fatigue is the testosterone/cortisol ratio (anabolic/catabolic). It has been argued that a

lower testosterone and higher cortisol environment may be a negative state that disrupts normal anabolic processes such as muscle growth and reproduction (Tremblay, Copeland, & Van Helder, 2005). No current study has investigated the testosterone/cortisol ratio in relation to status outcome in competitive sports. Based on the literature on hormones and competition, it would be reasonable to hypothesize that the ratio would increase after a victory and decrease after a loss.

SECTION TWO – HORMONES AND COMPETITION

Hormones and Competition

One of the similarities that humans share with other primates is that they compete for valued prerogatives such as food, reproductive opportunities, and status. Very often humans use non-aggressive tactics during competitive encounters. Unlike the lower primates that quite often use direct physical force while competing for reproductive opportunities, humans rarely resort to aggressive means during everyday social competition. This is not to say that humans will not display aggressive acts during competitive encounters. However, these behaviours are socially unacceptable and therefore, humans normally rely on non-physical means to gain and/or maintain status during competitive encounters.

It is very difficult to study human competition when it occurs naturally, and not in a formalized competition setting like sports. Therefore, studies on social status and hormonal secretion have focused on athletic competition. The sport environment provides researchers with the ability to study human competition in a relatively controlled and ecologically valid environment. Sport competitions are unique in that they are structured and organized, have a set of well-defined rules and regulations, are socially acceptable, provide for a clear set of unambiguous winners and losers and typically have a territoriality component (home and away effect). These characteristics have led researchers to study the athletic environment while seeking answers to questions relating to the reciprocal relationship between hormones and competitive behaviour.

Sporting activities such as judo (Salvador, Suay, Gonzalez-Bono, & Serrano, 2003; Suay et al., 1999; Filaire, Maso, Sagnol, Ferrand, & Lac, 2001; Salvador, Simon, Şuay, & Llorens, 1987), wrestling (Elias, 1981), basketball (Bernhardt, Dabbs, Fielden, & Lutter, 1998; Gonzalez-Bono, Salvador, Serrano, & Ricarte, 1999), rowing (Jurimae, Maestu, Purge, Jurimae, & Soot, 2002; Kivlighan, Granger, & Booth, 2005), rugby (Bateup, Booth, Shirtcliff, & Granger, 2002), tennis (Booth, Shelley, Mazur, Tharp, & Kittok, 1989; Mazur & Lamb, 1980), field hockey (Kerr, Wilson, Bowling, & Sheahan 2004) and ice hockey (Putnam, Carré, & Kivlighan, unpublished data, Carré, Muir, Belanger, & Putnam, 2006) have been used to study athletes' hormonal and psychological responses to competition.

Biosocial Model of Status

The biosocial model of status, a theoretical model of gaining, maintaining, and losing status, has guided research on the relationship between hormones and competition. Mazur (1985) hypothesized a reciprocal relationship between testosterone levels and willingness to maintain or achieve social status by way of competition. This feedback loop is proposed to involve the following: As an individual's testosterone levels increase, he or she becomes activated and more willing to compete in an attempt to gain or maintain social status. The reciprocal component of the model suggests that when an individual is victorious in a competitive situation, this victory produces a rise in testosterone whereas losing produces a decrease in testosterone (see Figure 1). The main concept of the model is that individuals are in constant competition for status. Through various aggressive and non-aggressive means, an individual attempts to 'outstress' his or her opponent.

The winner of the status contest assumes the higher rank whereas the loser assumes the lower rank.

According to Mazur (1985), primate species differ in the degree to which they demonstrate their status. However, virtually all primate species that have been studied demonstrate consistent rank orders with respect to influence, power, and valued prerogatives (Mazur, 1985). Higher ranked individuals are very often described as being 'calm, confident and assertive' and better able to deal with stressful situations. Conversely, the lower ranked individuals are described as 'nervous, insecure and submissive' and perhaps succumb to stressful situations more readily. This calm, confident and assertive demeanor can be very important in complex social interactions. Furthermore, these traits are especially advantageous to elite athletes who engage in rank competition on a regular basis.

In addition to testosterone, the hormone cortisol also plays an important role in responses to competition. Many competitive situations, such as athletic events are stressful and thus activate the production of cortisol by way of HPA-axis activation. The model proposes that individuals of lower rank experience greater degrees of stress and thus would have more elevated levels of cortisol. Furthermore, individuals losing an athletic competition (loss of status) would experience a greater degree of stress, which would influence their post-competition cortisol levels.

As mentioned, after a victorious bout (or a rise in status), the winner's testosterone levels may rise, and this rise is hypothesized to carry on into the next competition and create a favourable snowball effect. The winners are hypothesized to be more willing to engage in competitive situations with assertiveness and

confidence, thus increasing the likelihood of another victory. After a defeat (or a drop in status), it is presumed that the individual will experience a drop in testosterone, which may lead him or her to be more nervous and insecure prior to future competitions. Therefore, research on the effects of winning and losing status contests and their relationship to hormone levels would be of great value to athletic coaches who are always looking for a way to continue their winning ways or break their dreadful losing streaks.

Rodent, Bird and Non-Human Primate Studies

In assessing Mazur's (1985) biosocial model of status, it is important to investigate hormonal responses to both winning (rise or maintenance of status) and losing (loss of status) within a competitive setting. Based on Mazur's (1985) biosocial model of status, one would expect testosterone to rise in winners and drop in losers while cortisol should rise in losers and drop in winners.

Studies on rodents, birds, and primates have provided general support for the biosocial model of status. For example, Lloyd (1971) found that male mice on the losing end of an agonistic encounter showed a general reduction in testosterone following the contest. In addition, Oyegbile and Marler (2005) studied the winner-effect in the California mouse. The authors found that, independent of improved fighting technique, winners demonstrated a significant increase in testosterone, which improved their chances of winning future agonistic encounters.

In addition to rodent studies, it has been found that successful agonistic encounters increase testosterone in birds. For example, Johnsen and Zuk (1995) looked at the relationship between competition outcome and testosterone levels in

captive male red jungle fowl. The authors report that individuals who attacked first, were also the winners, and that the victory was associated with the greatest increase in testosterone. Another study with primates provided partial support for the biosocial model of status. Beehner, Bergman, Cheney, Seyfarth, and Whitten (2006) reported that basal testosterone levels did not predict current social rank, but that male baboons that rose in rank (presumably by winning a dominance contest) had higher testosterone levels than those who dropped in rank (or lost a status contest).

In addition to the effects of status contests on testosterone, there has been partial support for Mazur's (1985) model with regard to cortisol. Research using the resident-intruder paradigm with rats has demonstrated that both members of the dyad - dominants and subordinates - will demonstrate elevated levels of corticosterone. However, the key difference is that subordinates have significantly higher corticosterone levels compared to dominants. Therefore, rodent studies suggest that competition is associated with elevated levels of corticosterone in both winners (dominants) and losers (subordinates) but subordination is associated with the highest levels of corticosterone (Blanchard, Sakai, McEwen, Weiss, & Blanchard, 1993).

Research on cortisol and primates has been more variable, with subordinates presenting with higher cortisol levels in some primate groups while dominants in other groups having higher cortisol (see Abbott, Keverne, Bercovitch, Shively, Mendoza, Saltzman, Snowdon, Ziegler, Banjevic, Garland, & Sapolsky, 2003 and Sapolsky, 2004 for reviews). Abbott and colleagues (2003) suggest that subordinates will have the highest cortisol levels if they live in an environment that is filled with physical and psychological stressors and lack a social support system. Moreover,

Sapolsky (2004) argues that the general rule is that subordinates will be exposed to the most physical and psychological stressors and thus present with chronically elevated cortisol levels, but there are exceptions to this rule that can be explained by the social contexts in which rank is allocated.

Human Studies

Investigating the biosocial model of status in humans can be problematic for several reasons. Although similar to lower primates, humans have a more complex behavioural repertoire than non-human primates. Therefore, studying humans requires a quite different approach from that used in the study of lower primates. Current research has focused on studying humans within a controlled competitive setting such as athletic contests and well-controlled laboratory experiments.

Mazur and Lamb (1980) were the first to conduct a study investigating the effect of winning and losing on subsequent testosterone levels among tennis players. The authors reported a moderating effect of contest outcome, such that winners demonstrated an increase in testosterone post-competition while losers demonstrated a decrease. Elias (1981) reported a similar effect among wrestlers, indicating greater percent testosterone changes in winners than losers. Furthermore, Elias (1981) also found that winners had significantly higher cortisol levels, which could be attributed to the 'positive' stress associated with gaining status. Booth et al. (1989) reported that testosterone levels of eventual tennis winners rose across the match while that of eventual losers declined. However, Booth et al. (1989) noted that not all winners rose in testosterone and that the athletes' subjective assessment of performance may moderate this effect. Also, the authors found no significant difference in cortisol

between winners and losers, but noted that the highest ranked players had the lowest pre-contest cortisol values suggesting that social rank within sporting competitions may play an important role in an athlete's physiological states prior to competition.

Although status contests involving physical effort may have an impact on hormonal levels, interest has begun to focus on status contests involving non-physical confrontation. This method of analysis is especially ecologically valid because humans will often engage in status contests that do not involve direct physical competition. Mazur, Booth, and Dabbs (1992) studied the effects of outcome on testosterone among a group of competitive chess players. Chess was the ideal environment in which to study hormonal effects of competition because it required no physical exertion. Mazur et al. (1992) found that winners had significantly higher testosterone levels than did losers, suggesting that physical exercise need not be present in order for hormonal changes to occur. This finding also supported the biosocial model of status in that winning, or a rise in status leads to an increase in testosterone. Bernhardt et al. (1998) studied spectators' hormonal responses to an athletic competition between their favorite football and soccer teams and a rival team. Results indicated that testosterone rose among fans of the winning team while testosterone decreased among fans of the losing team. These findings support the notion that the vicarious experience of gaining or losing status may alter hormonal levels in a similar way to the changes experienced by the individuals directly involved in the status contest. Last, in a rigged reaction time study, Gladue, Boechler, and McCaul (1989) reported that men who were labeled as winners had

significantly higher post-competition testosterone levels as compared to losers.

However, Gladue et al. (1989) also found no significant difference between winners and losers for the hormone cortisol.

Other studies have failed to find any differences between winners and losers of athletic competition. For instance, three studies have reported no moderating effect of game outcome on hormone levels (Gonzalez-Bono et al., 1999; Suay et al., 1999, Salvador et al., 1987). First, a pilot study by Salvador et al. (1987) involving 14 judo competitors found no support for a moderating role of competition outcome on testosterone and cortisol responses. This study used a between-subjects design in which the results of the competition produced 6 winners and 6 losers (1 match ended in a draw). Therefore, the final sample was relatively small and a null finding with regard to a moderating role of competition outcome is not surprising. Furthermore, this study involved collecting saliva samples between 10 a.m. and 12 p.m., a time at which testosterone values are highly variable (Dabbs, 1990; Book, Starzyk, & Quinsey, 2001). In addition to the time at which the samples were collected, post-competition saliva samples were collected 45 minutes after the contest, which may have allowed the hormone values to return to near-baseline values and thus make it very difficult to obtain a statistically significant difference between winners and losers. The second study by Gonzalez-Bono et al. (1999) involved collecting pre- and post-game saliva samples from a single status contest between two elite basketball teams. This study also employed a between-subjects design comparing testosterone and cortisol responses of winners ($n = 8$) and losers ($n = 8$). The authors report that winners showed small increases and losers showed small decreases in testosterone,

however, winners and losers did not differ significantly in their testosterone response to competition. Again, a lack of a significant interaction is not all that surprising given the small sample size. Despite the failure to detect any effect of status outcome in some studies, there is general agreement that the outcome of a competitive encounter (physical and/or non-physical) can influence subsequent hormonal levels (see Mazur & Booth, 1998; Archer, 2006; van Anders & Watson, 2006 for reviews).

Many of the studies investigating the effect of competition on hormone responses have also reported that an athlete's physiology will change prior to competition as if in anticipation of the upcoming challenge. This anticipatory response has been documented for cortisol (Suay et al., 1999; Filaire et al., 2001; Salvador et al., 2003) and testosterone (Booth et al., 1989; Mazur et al., 1992; Suay et al., 1999; Salvador et al., 2003). It has been suggested that the anticipatory hormonal response will make the individual more willing to take risks, improve coordination, cognitive performance, facilitate energy mobilization and improve concentration (see Mazur & Booth, 1998 for review).

Clearly, then, research has demonstrated that situational factors such as winning and/or losing may have an impact on testosterone and cortisol secretion. Furthermore, pre-contest hormonal levels have been shown to rise as if in anticipation of an upcoming status contest. However, can these hormonal changes simply be attributed to the physical activity involved in sporting contests or does the additional psychological stress associated with competition induce a more pronounced hormonal responses?

Athletic Setting

Exercise physiology has demonstrated that physical activity can activate the HPA-axis and thus increase cortisol secretion (Hoffman, 2002). Although it is known that non-competitive physical activity can increase cortisol levels, researchers have found that competitive physical activity has a greater effect on overall HPA responsiveness. In a study investigating hormonal changes in elite swimmers, Aubets & Segura (1995) found that, although salivary cortisol levels increased in both the non-competitive treadmill test and competition, the competitive environment produced significantly greater increases from pre- to post-testing. Furthermore, Filaire et al., (1997) found no significant difference in salivary cortisol levels during a training session among a group of female volleyball and handball players, but found significant increases in cortisol for the competition sessions. The authors suggest that the increase in salivary cortisol seen during competition is a result of additional psychological stress that occurs during athletic competition.

These results suggest that, at the elite level of athletics, individuals will only mount a hormonal stress response during competition and not during practice sessions. These results may have important implications for individuals, such as sport psychologists, who are interested in maximizing performance and preparing athletes for competition. Moreover, these findings are consistent with the idea that psychological factors may have a greater impact on the endocrine status than physical exertion itself.

Game Location

The preceding research has indicated the importance of hormonal factors in competitive situations. The following will describe one psychological factor that may be of relevance in competition, specifically, the location at which the competition is held – whether “home or away”. The ‘home advantage’ is a robust effect in that home teams in competitive sporting environments win over 50% of the games played under a balanced home and away schedule (Courneya & Carron, 1992). A considerable amount of research has focused on factors assumed to underlie this phenomenon (Courneya & Carron, 1992; see Carron, 2005 for review) and these factors are as follows: familiarity with facility, crowd density, travel, and officiating.

It has been proposed that familiarity with the facility may be advantageous to the home team. A recent study by Pollard (2002) found that the home advantage was decreased for professional athletic teams who relocated to a new home venue. Approximately 72% of National Hockey League, National Basketball Association and Major League Baseball teams that relocated experienced a decrease in their win/loss ratio at home.

It has also been proposed that crowd size and density may play an important role in the home advantage. Agnew and Carron (1994) examined several factors thought to play a role in the home advantage including absolute size of the crowd, crowd density, intra vs. inter divisional rivalry, and the time of year of the game. The authors reported that the only factor related to game outcome was crowd density. For example, as crowd density increased, so did the home advantage. In contrast, another

study found that crowd size rather than crowd density was related to the home advantage (Nevill, Newell, & Gale, 1996).

An additional area of interest that has received a considerable amount of attention is the effect of travel and the home advantage. Teams traveling to venues by airplane or bus may, in fact, be at a disadvantage when playing in their opponents' venue. Professional hockey teams (National Hockey League) crossing multiple time zones (Pace & Carron, 1992) and basketball teams traveling in excess of 200 miles (Snyder & Purdy, 1985) were more likely to lose games played in their opponents' venue than in their home venue.

Another factor thought to influence the 'home advantage' is officiating. That is, it is believed that the home team has an advantage over the opposing team because the officials or referees make decisions or calls that favour the home team. It has been suggested that the officials/referees make more calls in favor of the home team mainly due to the influence that the home crowd may have on their decision-making (Nevill & Holder, 1999).

Although these studies identified possible variables involved in the concept of the 'home advantage' fewer studies have investigated pre-contest hormonal and psychological states of athletes in the home and away venues. Recent studies have now begun to focus on the pre-competition psychological and hormonal states of athletes playing in their home and away venues. A study by Bray, Jones, and Owen (2002) found that athletes had significantly higher pre-game self-confidence and self-efficacy for games played in the home venue. They also found that athletes had significantly higher pre-game somatic and cognitive anxiety when playing in their

opponents' venue. In addition, it was found that basketball players had higher pre-game self-confidence when playing in their home venue (Thuot, Kavouras, & Kenefick, 1998). Although these studies do not explain the advantage of having higher self-confidence and lower anxiety when performing in the home venue, the results indicate that there are important psychological differences for games played at home and those played at the opponents' venues. Furthermore, despite these findings, some studies have also failed to find any difference in anxiety depending on game location (Thuot et al., 1998; Duffy & Hinwood, 1997). Therefore, the results on the psychological states of athletes prior to competition and game location remain equivocal.

In addition to research examining the relationship between pre-game psychological states of athletes and game location, a recent study (Neave & Wolfson, 2003) looked at the pre-game testosterone levels of soccer players. The results of this study revealed that athletes had significantly higher pre-game testosterone when playing in their home venue compared to playing in their opponents' venue. This finding is very important because it suggests that humans may express higher levels of testosterone when defending, or in the comfort of, their home territory. This territoriality phenomenon has been demonstrated in several primate (Cristobal-Azkarate, Chavira, Boeck, Rodriguez-Luna, & Veal, 2006) and rodent (Hume & Wynne-Edwards, 2005) studies. Wingfield, Hegner, Dufty, & Ball (1990) formulated a Challenge Hypothesis to explain the rise in testosterone associated with territorial behavior. The authors state that males will display territorial behavior during times of

competition, especially during breeding season. This territorial behavior has been associated with an increase in overt aggression as well as a rise in testosterone.

Higher testosterone levels have been associated with dominant and assertive behaviour (Mazur & Booth, 1998), vigour and activation (Dabbs, Strong, & Milun, 1997; O'Connor, Archer, Hair, & Wu, 2002), and visual-spatial ability (Janowsky, Oviatt, & Orwoll, 1994). I propose that higher testosterone levels observed prior to competition in the home venue may be related to the athlete's belief that playing in his or her home venue provides for a disproportionate advantage to the home team. Thus, playing at home may be related to a sense of higher social status for the members of the home team, leading to a heightened level of pre-game testosterone. As demonstrated, testosterone has been linked to aggressive and assertive behavior, both of which are very important in the sport of competitive ice hockey. Therefore, higher testosterone prior to games played at home may facilitate the expression of these crucial behavioural characteristics, and as such, may provide an advantage to the home team.

SECTION THREE – PSYCHOLOGY AND COMPETITION

Psychology of Sport

In addition to investigating the hormonal responses to athletic competition, it is important to consider the psychological variables that may affect the subjective experience of competition. Some researchers have focused on factors such as trait and state anxiety (Martens et al., 1990), cognitive and somatic anxiety (Gould, Petlichkoff, Simons, & Vevera, 1987), self-confidence (Feltz, 1988), and the home advantage (Neave & Wolfson, 2003). These researchers emphasize that at the elite level of athletic competition, psychological factors can play a key role in success and/or failure.

Definition of Stress

The term ‘stress’ was originally borrowed from the field of engineering and has since been refined to reflect a more psychological and physiological process. Some have referred to stress as the “process that occurs in response to events that disrupt, or threaten to disrupt, our physical or psychological functioning” (Baron, 2001, pp. 516). Other researchers have defined stress as any type of threat, either real or perceived, that requires compensatory responses for the maintenance of homeostasis (Radley & Morrison, 2005).

Trait and State Anxiety

In general, anxiety occurs when an individual doubts his or her ability to cope with a given situation (Hardy, Jones, & Gould, 1996). In addition, it is important to distinguish between trait and state anxiety. Trait anxiety, in the sport context, refers to an athlete’s “tendency to perceive competitive situations as threatening and to

respond to these situations with feelings of apprehension and tension” (Martens, 1977). Trait anxiety can be also interpreted as an individual’s general anxiety level, which is influenced by his or her personality characteristics. In contrast, state anxiety refers to a more situational form of anxiety that usually elicits a physiological response by activating the sympathetic nervous system. Therefore, a person with low trait anxiety may not necessarily have low state anxiety, and someone with high trait anxiety may not always present with high state anxiety prior to competition.

Cognitive and Somatic Anxiety

Martens et al., (1990) distinguished between two dimensions of anxiety; somatic anxiety and cognitive anxiety. Somatic anxiety “refers to the physiological and affective elements of the anxiety experience that develop directly from autonomic arousal” (Martens et al, 1990, p. 6). Therefore, an individual may subjectively experience somatic anxiety by his or her perception of an increase in heartbeat, perspiration, heavy respiration, and tense muscles. These symptoms are indicative of a physiological stress response. Cognitive anxiety can be defined as “the mental component of anxiety [that] is caused by negative expectations about success or by negative self-evaluation” (Martens et al., 1990, p. 6). One example of cognitive anxiety in elite athletes is the fear of failure or fear of disappointing their fans and teammates, which can have an impact on their performance.

Several studies have investigated the relationship between somatic and cognitive anxiety and subsequent athletic performance. These studies have primarily demonstrated a negative linear relationship between cognitive anxiety and performance. For example, Burton (1988) found a negative correlation between

performance and cognitive anxiety in two samples of athletes. Also, Gould, Petlinchhoff, and Weinberg (1984) reported a significant negative correlation between performance and cognitive anxiety in college wrestlers and high school volleyball players.

With regard to somatic anxiety, it has been suggested that there is a curvilinear relationship between this construct and athletic performance. More specifically, an inverted-u relationship has been observed in that low and high somatic anxiety were associated with poor performance, while moderate levels of pre-competition somatic anxiety have been related to optimal performance. For example, Gould et al., (1987) found an inverted-u relationship between pistol shooting performance and somatic anxiety and Burton (1988) observed a similar relationship in swimmers.

Self-Confidence

Although the term 'self-confidence' is often used by coaches, players and sport commentators, many cannot offer an operational definition of the term. Weinberg and Gould (1995) defined self-confidence as an individual's belief in being able to successfully perform a desired behaviour. Confident athletes are individuals who believe in their ability to successfully execute a task during competition. Several studies suggest that there is a significant positive correlation between athletic performance and self-confidence. For example, strong positive correlations between performance and self-confidence were seen in long distance runners (Martin & Gill, 1991), basketball players (Parfitt & Pates, 1999), cricket players (Thelwell & Maynard, 1998) and soccer players (Maynard, Hemmings, & Warwick-Evans, 1995).

There has been general agreement in the literature that self-confidence is positively related to athletic performance (see Woodman & Hardy, 2003 for a meta-analysis). Therefore, research on hormones and competition must also consider psychological factors that may have a significant impact on an individual's performance.

Summary of Literature

Current literature examining the moderating effect of competition outcome on testosterone responses in individual sports such as tennis (Mazur & Lamb, 1980; Booth et al., 1989), wrestling (Elias, 1981) and chess (Mazur, Booth, & Dabbs, 1992) have provided empirical support for the biosocial model of status with respect to testosterone. Furthermore, laboratory reaction time tasks (Gladue et al., 1989) as well as the vicarious experience of gaining and/or losing status (Bernhardt et al., 1998) have also provided support for the biosocial model of status. In contrast, other studies have failed to find significant differences between winners and losers of status contests. Moreover, no published studies involving team sports have provided support for the model as proposed by Mazur (1985).

There are several limitations to past studies that may mask a significant moderating effect of competition outcome on testosterone and cortisol responses. For example, past studies have relied primarily on data obtained from single status contests which may produce subtle, yet statistically insignificant differences between winners and losers (i.e. Gonzalez-Bono et al., 1999; Suay et al., 1999). As such, it may be more useful to collect data for several status contests over a period of time and compare average pre- and post-game samples from victories and defeats. Furthermore, previous studies with team sports have been conducted using a between-

subjects design with small sample sizes, thus making it very difficult to detect a significant difference between winner and losers.

The current study was designed with the purpose of addressing three main research questions: 1) Does game outcome moderate the relationship between pre- and post-game testosterone and cortisol throughout an athletic season?; 2) Is physical activity, on its own, sufficient to produce a testosterone and cortisol response among elite athletes?; 3) Do athletes present with a different set of pre-contest psychological and hormonal states depending on the location of the status contest? In addition to these main research questions, we were also interested in examining the relationship (if any) between testosterone, cortisol and psychological variables with individual performance.

Hypotheses

1) Status Outcome

The current literature has demonstrated a moderating effect of status outcome on the testosterone response in individual sports, and as such, I predicted that game outcome would be a significant moderator of the pre- to post-game testosterone response. More specifically, I predicted that winning would produce an increase in testosterone while losing would produce a decrease.

With regard to cortisol, human studies have produced mixed results, but most suggest that athletic competition (win or lose) will produce a significant rise in cortisol. Based on resident-intruder research in rodents (Blanchard et al., 1993), I predicted that winning and losing would be associated with cortisol increases, but that losing would produce the highest post-competition cortisol levels.

2) Athletic Setting

The second major research question was whether hormonal responses were specific to status contests or whether physical activity on its own would be sufficient to produce testosterone and cortisol responses. I predicted that athletic setting would moderate the relationship between pre- and post- levels of testosterone and cortisol. Specifically, the elite athletes in the current study would mount a cortisol and testosterone response to competition but not to practices.

In addition to investigating the different responses to competition vs. practices, I was also interested in examining whether this group of athletes would mount an anticipatory cortisol and testosterone response to competition, which has been frequently demonstrated in the literature. I predicted that the athletes would have significantly higher pre-competition testosterone and cortisol levels compared to pre-practice levels.

3) Game Location

Recent evidence suggests that there are important pre-contest psychological and hormonal differences in athletes depending on the location in which the status contest is played, home vs. away. I hypothesized that athletes would have significantly higher self-confidence and lower cognitive and somatic anxiety when playing in their home venue. Furthermore, the research of Neave and Wolfson (2003) suggests that pre-contest testosterone levels are higher when the athletes compete in their home venue. Therefore, I was interested in replicating this finding and hypothesized that testosterone would be higher when the team played in their home

venue compared to their opponent's venue. To extend the findings of Neave and Wolfson (2003) I was interested in examining possible pre-contest differences in cortisol levels depending on game location. Since playing in an opponent's venue may be more intimidating, I hypothesized that pre-contest levels would be highest in the opponent's venue compared to the home venue.

4) Individual Performance

In team sports, it is certainly possible that, despite being on the winning end of a status contest, the individual player may have performed poorly. Moreover, despite losing a game, an individual player may have had an exceptional performance. As a result, some researchers argue that individual contribution to the outcome of the game should be the primary variable of interest instead of the outcome of the status contest itself (Salvador, 2005).

Therefore, in appreciation of this position, I took a measure of individual performance (as assessed by the team's head coach) and correlated this with pre-contest testosterone and cortisol as well as with the percent change (pre- to post-game) in testosterone and cortisol. Testosterone has been associated with dominant, assertive and aggressive behaviour, and as such, I hypothesized a significant positive correlation between pre-game testosterone and individual performance. Furthermore, based on Yerkes and Dodson's (1908) inverted-u hypothesis on performance and anxiety, I hypothesized a curvilinear relationship between pre-game cortisol levels and individual performance. I also hypothesized that the percent testosterone change (pre- to post-game) would be positively correlated with individual performance,

whereas the percent cortisol change (pre- to post-game) would be negatively correlated with individual performance.

In addition to examining the relationship between hormones and individual performance, I was interested in evaluating the relationship between individual performance and pre-game self-confidence, cognitive anxiety, and somatic anxiety. First, in accordance with the literature, I hypothesized a positive correlation between individual performance and pre-game self-confidence. In addition, I hypothesized a negative correlation between cognitive anxiety and performance and a curvilinear relationship between somatic anxiety and performance.

SECTION FOUR - METHODOLOGY

Methods

Participants

The sample was composed of 17 members of an elite Jr. A hockey club located in Northern Ontario, Canada. This hockey club participated in the elite Canadian Junior Hockey League and the players ranged in age from 16-20 years ($M = 18.21$, $SD = 1.48$). The team practiced two times per week and played an average of two games per week. Three members of the team did not participate in several of the games due to injury, trade, and/or poor performance, and were eliminated from the main analyses. The final sample was composed of 14 individuals.

Procedure

The Canisius College Institutional Review Board approved the present study. In addition, formal permission to work with the team was received from the team's head coach. Prior to data collection, players provided informed written consent. On the first day, the nature of the research study was explained to participants, and they were asked to sign a letter of informed consent. Next, participants were asked to sign a form agreeing to refrain from eating heavy meals, candy, and brushing their teeth one hour prior to arriving at practices and games. Participants were given a micro vial 45 minutes prior to the practice session and asked to provide a 1 ml saliva sample by passive drool. The players were asked to provide another saliva sample 15 minutes post-practice. The micro vials were kept frozen and transported to the Brock University Hormone Laboratory and stored at -20 degrees celsius for later analysis.

For the game sessions, players were asked to complete the Competitive State Anxiety Inventory-2 (CSAI-2: Martens et al., 1990, see Appendix A). Players were instructed to answer the questions truthfully and to respond to the questions based on how they felt at the present moment.

For the game sessions, players were asked to provide a 1 ml saliva sample 45 minutes prior to the game. Players provided this pre-game sample prior to doing any physical activity, such as warming-up and stretching, eliminating the possible confounding effect of exercise on pre-game hormone values. Also, similar to the practice sessions, players provided a 1 ml sample 15 minutes after the game. In appreciation of the diurnal variation of salivary testosterone and cortisol, all saliva samples (practice and game sessions) were collected between 5:00 p.m. and 9:30 p.m.

Last, performance data evaluating subjective measures of performance were collected at the conclusion of each game. The team's head coach provided the researcher with a subjective assessment of each individual player performance at the conclusion of every game (see Appendix B).

Overall, data were collected for five games throughout the season (3 home games and 2 away games). Of the five games that were assessed, the team finished with four losses and one win. Data were collected for two practice sessions, one at the beginning of the season in October and the second near the end of the season in January. Descriptive statistics are provided in Table 1 including the date of competition/practice, game outcome, and game location.

Table 1. Descriptive statistics on date of data collection, game outcome, and game location.

| Date | Oct 6 | Oct 21 | Nov 11 | Nov 13 | Dec 2 | Dec 18 | Jan 6 |
|----------|----------|--------|--------|--------|-------|--------|----------|
| Outcome | Practice | Loss | Loss | Loss | Loss | Win | Practice |
| Location | Home | Home | Home | Away | Home | Away | Home |

Measures

Anxiety & self-confidence: To evaluate the pre-game psychological states of anxiety and self-confidence a sport-specific assessment tool was used. The multidimensional Competitive Sport Anxiety Inventory-2 (Martens et al., 1990) was used to measure each players' pre-game somatic state and cognitive state anxiety levels as well as pre-game state self-confidence levels. The CSAI-2 consists of 27 items scored on a Likert scale of 1 (not at all) to 4 (very much so). The three subscales (Cognitive Anxiety, Somatic Anxiety, and Self-Confidence) contain summed scores ranging from a low of 9 to a high of 36. The cognitive anxiety subscale was composed of items 1, 4, 7, 10, 13, 16, 19, 22, and 25. The somatic anxiety subscale was composed of items 2, 5, 8, 11, 14, 17, 20, 23, and 26. The self-confidence subscale was composed of items 3, 6, 9, 12, 15, 18, 21, 24, and 27. Higher scores on cognitive and somatic anxiety indicated a higher level of anxiety, while higher scores on the self-confidence subscale indicated a higher level of self-confidence. Martens et al. (1990) indicate that the CSAI-2 has Cronbach's alphas of 0.79 to 0.90. Furthermore, Martens et al. (1990) indicate that by comparing the CSAI-2 to eight scales that measure anxiety, it was found that "the coefficients are

highly congruent with hypothesized relationships among the CSAI-2 subscales and scales of related constructs” (Marten et al., 1990, pp.136). Cronbach alpha values for the current sample ranged from .90 to .95.

Performance: One of the major problems in assessing the relationship between performance and hormonal/psychological states is that it is very difficult to assess individual athletic performance, especially in team sports. In the game of hockey there are many different types of players - checkers, goal scorers, two-way players, special team players, and aggressors. Therefore, it becomes difficult to rate each player under the same set of objective criteria. For this reason, this study used a subjective assessment of performance, which was provided by the team’s head coach at the conclusion of each game. Player performances were rated on a 1 to 4 scale (1 = Poor, 2 = fair, 3 = good, and 4 = very good). The coach was asked to rate the player’s performance relative to his optimal performance or his performance potential. Therefore, the performance of each player was compared to his own ability and not to that of other players.

Hormone analysis: All saliva samples were stored at -20°C until assayed for cortisol and testosterone. Samples were centrifuged at 3000 rpm for 15 minutes and the supernatant assayed undiluted. All enzyme immunoassays were carried out on NUNC Maxisorb plates. Cortisol (R4866) and testosterone (R156/7) antibodies and corresponding horseradish peroxidase conjugates were obtained from C. Munro of the Clinical Endocrinology Laboratory, University of California, Davis. Steroid standards were obtained from Steraloids, Inc. Newport, Rhode Island. Plates were first coated with 50 μl of antibody stock diluted at 1:10,000 in a coating buffer (50 mmol/L

bicarbonate buffer pH 9.6) for the testosterone assay while cortisol antiserum was diluted at 1:8000 for the cortisol assay. Plates were stored for 12–14 h at 4 °C. 50 µl wash solution (0.15 mol/L NaCl solution containing 0.5 ml of Tween 20 L⁻¹) were added to each well to rinse away any unbound antibody, then 50 µl phosphate buffer per well was added. The plates were incubated at room temperature for 30 minutes for testosterone, and 2 hours for cortisol before adding standards, samples, or controls. For each hormone, two quality control samples at 30% and 70% binding (the low and high ends of the sensitive range of the standard curve) were prepared. For all assays, 50 µl testosterone, or cortisol horseradish peroxidase conjugate were added to each well, with 50 µl of standard, sample, or control for testosterone or cortisol. Testosterone plates remained incubated for 2 hours at room temperature while cortisol plates remained incubated for 1 hour. Next, the plates were washed with 50 µl wash solution and 100 µl of a substrate solution of citrate buffer, H₂O₂ and 2,2'-azino-bis [3-ethylbenzthiazoline-6-sulfonic acid] was added to each well and the plates were covered and incubated while shaking at room temperature for 30–60 minutes. Plates were then read with a single filter at 405nm on the microplate reader (Titertek multiskan MCC/340). A regression line was fit to the sensitive range of the standard curve (typically 40 – 60 % binding) and samples were interpolated into the equation to get a value in pg or ng per well. All samples were assayed in duplicate and run in the same batch. The testosterone assay has been previously validated (Muir, Vella, Pisani, & de Catanzaro, 2001). The intra- and inter- assay CVs were 6.5% and 6.8% for salivary testosterone and 7.8% and 6.5% for salivary cortisol.

SECTION V - RESULTS

Preliminary Analyses

Prior to data analysis, z-scores were computed in order to identify possible outliers. Outliers were identified as values greater or smaller than 3 standard deviations from the mean. Upon examination of the testosterone values, 2 samples were identified as outliers (3.5 and 6.5 standard deviations from the mean) and were subsequently eliminated prior to conducting the analyses. Examination of the psychological variables (cognitive/somatic anxiety and self-confidence) did not reveal any outliers. In addition, distributions were examined for violations of normality. Examination of the distributions revealed that all hormonal and psychological data were normally distributed. An alpha level of .05 was employed for all statistical analyses.

As the present study examined salivary cortisol and testosterone throughout the athletic season (mid October to mid January), paired-t tests were computed to rule out any possible circannual effects on the hormones assessed. Saliva samples were collected for practice sessions in October and January, at the same time of day as those collected for the game sessions. Paired-t tests revealed no significant differences for cortisol ($t(13) = .05, p = .96$) or testosterone ($t(13) = .54, p = .60$) values obtained during practice sessions at the beginning (October) and end (January) of data collection.

In addition, prior to data analysis, the opponents' winning percentages were computed to evaluate any possible difference in opponent quality for games played at home and those played away. The analysis revealed that games played at home

($n = 3$) were played against teams with an average winning-to-loss ratio of .64 while games played away ($n = 2$) were played against teams with an average win-to-loss ratio of .63. Therefore, any difference in pre-game physiological and/or psychological levels would not be attributed to differences in the quality of the opposing team. Furthermore, the team under investigation had an overall win-to-loss ratio (home and away) of .31. The team played a balanced home/away schedule where 50% of the games were played at home and 50% of the games were played away from their home venue. The team's win-to-loss ratio at home was .38 while their win-to-loss ratio away was .25. Of the games that the team won during the season ($n = 14$), 57% were played in the home venue. An investigation of the elite Junior A hockey league in which the team under investigation competed, revealed that overall, 59% of games were won by the home team.

1) Status Outcome

To test the main hypothesis that game outcome would moderate the testosterone and cortisol response to athletic competition, repeated measures ANOVAs were computed. Pre- and post-game testosterone and cortisol levels for the four loss sessions were averaged and compared to the single win session. Paired t-test (two-tailed) were computed when necessary, to evaluate any main effects and/or interaction effects.

A 2 (outcome: win vs. loss) by 2 (time: pre vs. post) repeated measures ANOVA was computed to evaluate the main hypothesis that game outcome would moderate the relationship between pre- and post-game *testosterone* levels. Means

(SE) of pre- and post-game testosterone values are presented in Table 2. Results (presented in Table 3) revealed a main effect of time and outcome and a time by outcome interaction. The interaction is plotted in Figure 4. Paired t-tests revealed that there was a significant increase from pre- to post-game testosterone for both win ($t(12) = 3.71, p = .003$) and loss sessions ($t(12) = 2.59, p = .02$), however, post-game testosterone was significantly higher for the win session as compared to the loss sessions ($t(12) = 5.51, p < .001$). Furthermore, additional analysis demonstrated that the percent increase in testosterone was significantly greater for the win session as compared to the loss session ($t(12) = 2.68, p = .02$).

Table 2.

Mean (SE) for pre- and post-game testosterone (pg/ml) by game outcome.

| | PRE-GAME | POST-GAME |
|------|----------------|----------------|
| WIN | 168.46 (34.68) | 338.07 (40.12) |
| LOSS | 157.17 (21.51) | 215.58 (32.32) |

Table 3.

Two (Outcome: win vs. loss) by 2 (Time: pre vs. post) Repeated Measures ANOVA for Testosterone.

| Source | SS | df | F | p | η_p^2 |
|----------------|--------|----|-------|------|------------|
| Outcome | 67044 | 1 | 14.74 | .002 | .55 |
| Time | 147871 | 1 | 14.23 | .003 | .54 |
| Outcome x Time | 40427 | 1 | 9.91 | .008 | .45 |
| Error | 48956 | 12 | | | |

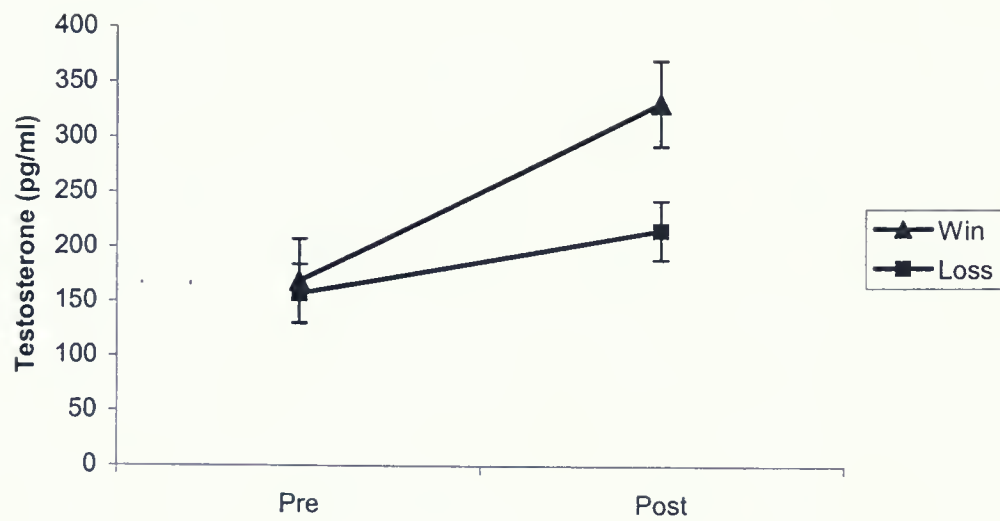


Figure 4. Mean (SE) pre- and post-game testosterone (pg/ml) by game outcome.

To test our hypothesis that post-game *cortisol* levels would be significantly higher for loss sessions, we computed a 2 (outcome: win vs. loss) by 2 (time: pre vs. post) repeated measures ANOVA. Means (SE) for pre- and post-game cortisol levels are presented in Table 4. Results (presented in Table 5) revealed main effects of outcome and time and no outcome by time interaction. The means are plotted in Figure 5. Paired t-tests revealed that cortisol levels increased significantly from pre-game values for both win ($t(13) = 2.68, p = .019$) and loss ($t(13) = 4.50, p < .001$) sessions. To evaluate whether post-game cortisol was different depending on game outcome, a paired t-test was computed. Results demonstrated that post-game cortisol was significantly higher for the loss session as compared to the win session ($t(13) = 3.01, p = .01$). However, there were no differences in percent change in cortisol between win and loss sessions ($t(13) = .89, p = .39$).

Table 4.

Mean (SE) for pre- and post-game cortisol (ng/ml) by game outcome.

| | PRE-GAME | POST-GAME |
|------|-------------|-------------|
| WIN | 2.80 (0.51) | 4.99 (0.69) |
| LOSS | 3.61 (0.37) | 6.85 (0.76) |

Table 5.

Two (Outcome: win vs. loss) by 2 (Time: pre vs. post) Repeated Measures ANOVA for Cortisol.

| <i>Source</i> | <i>SS</i> | <i>df</i> | <i>F</i> | <i>p</i> | η_p^2 |
|----------------|-----------|-----------|----------|----------|------------|
| Outcome | 24.804 | 1 | 9.94 | .008 | .43 |
| Time | 103.010 | 1 | 21.76 | .000 | .63 |
| Outcome x Time | 3.874 | 1 | 1.08 | .318 | .08 |
| Error | 46.641 | 13 | | | |

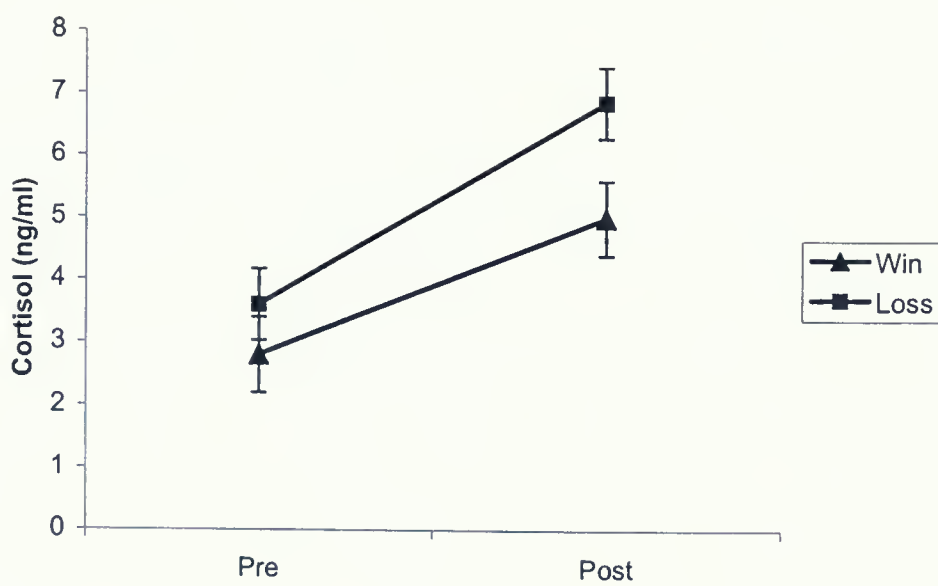


Figure 5. Mean (SE) pre- and post-game cortisol (ng/ml) levels by game outcome.

2) Athletic Setting

To test the hypothesis that athletic setting (practice vs. competition) would moderate the *testosterone* response, a 2 (setting: practice vs. game) by 2 (time: pre vs. post) repeated measures ANOVA was computed. Pre- and post-game testosterone values were averaged across the five games and compared to the average pre- and post-practice testosterone values obtained from the two practice sessions. Means (SE) of pre- and post-practice/competition testosterone values are presented in Table 6. Results (presented in Table 7) revealed a main effect of time but no effect of setting or setting by time interaction. The means are plotted in Figure 6. Although we failed to achieve a statistically significant interaction effect, our *a priori* hypotheses warranted further post-hoc analyses. As expected, paired t-tests indicated that there was a significant increase from pre- to post-*competition* in testosterone ($t(13) = 3.85, p = .002$), but not in pre- to post-*practice* ($t(13) = .66, p = .52$).

Table 6.

Mean (SE) for pre- and post testosterone (pg/ml) by athletic setting.

| | PRE | POST |
|-------------|----------------|----------------|
| COMPETITION | 160.44 (22.18) | 244.78 (32.20) |
| PRACTICE | 169.78 (17.28) | 198.97 (42.52) |

Table 7.

Two (Setting: practice vs. game) by 2 (Time: pre vs. post) Repeated Measures ANOVA for Testosterone.

| Source | SS | df | F | p | η_p^2 |
|----------------|--------|----|-------|------|------------|
| Setting | 4656 | 1 | .525 | .482 | .04 |
| Time | 45114 | 1 | 6.261 | .026 | .33 |
| Setting x Time | 10645 | 1 | 1.145 | .304 | .08 |
| Error | 120884 | 13 | | | |

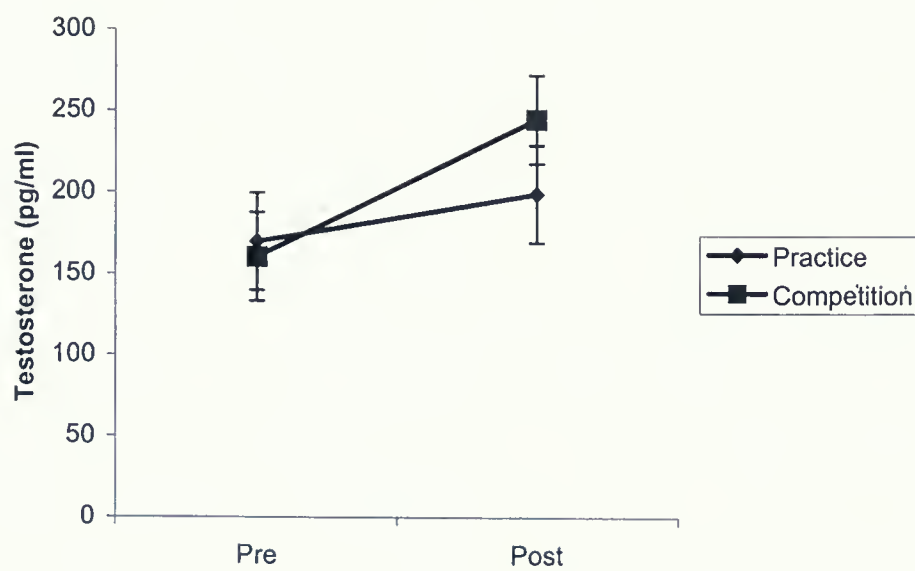


Figure 6. Mean (SE) pre- and post- testosterone (pg/ml) by athletic setting.

To test the hypothesis that athletic setting would moderate the *cortisol* response, we computed a 2 (setting: practice vs. game) by 2 (time: pre vs. post) repeated measures ANOVA. Means (SE) of pre- and post-practice/competition cortisol values are presented in Table 8. Results (presented in Table 9) revealed a main effect of time and a time by setting interaction. The interaction is plotted in Figure 7. Paired t-tests were performed to evaluate any differences in pre- to post-session cortisol depending on athletic setting. Results indicated that there was a significant increase in pre- to post-cortisol for the game sessions ($t(13) = 4.72, p < .001$) and not practice sessions ($t(12) = 1.02, p = .33$).

Table 8.

Mean (SE) for pre- and post cortisol (ng/ml) by athletic setting.

| | PRE | POST |
|-------------|-------------|-------------|
| COMPETITION | 3.41 (0.29) | 6.31 (0.77) |
| PRACTICE | 3.83 (0.40) | 4.64 (1.02) |

Table 9.

Two (Setting: practice vs. game) by 2 (Time: pre vs. post) Repeated Measures ANOVA for Cortisol.

| Source | SS | df | F | p | η_p^2 |
|----------------|--------|----|--------|------|------------|
| Setting | 9.476 | 1 | 1.734 | .212 | .13 |
| Time | 53.571 | 1 | 21.707 | .001 | .64 |
| Setting x Time | 18.924 | 1 | 4.971 | .046 | .29 |
| Error | 45.683 | 12 | | | |

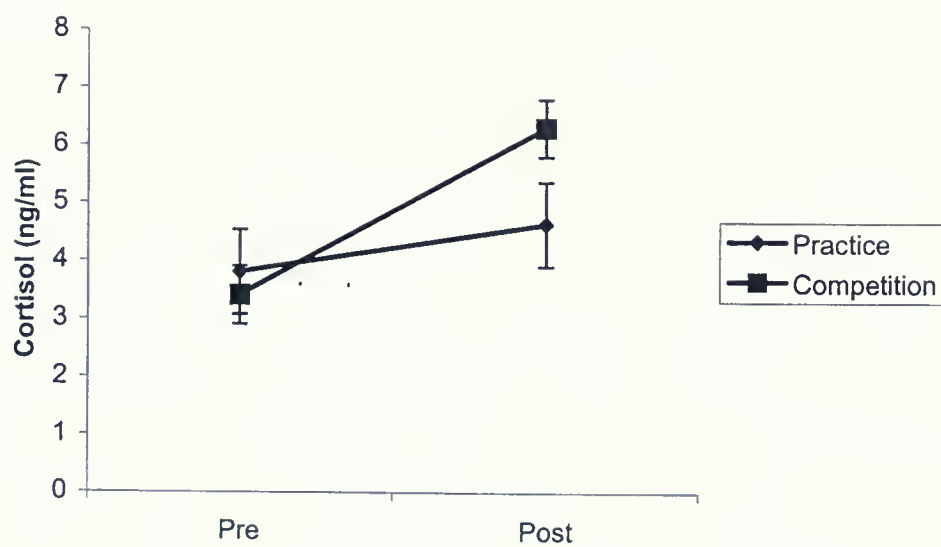


Figure 7. Mean (SE) pre- and post-cortisol (ng/ml) by athletic setting.

Finally, to evaluate whether there were any anticipatory hormonal responses to competition, paired t-tests were computed comparing pre-game hormone levels and pre-practice hormone levels. Pre-game testosterone and cortisol values were averaged across the five games and pre-practice testosterone and cortisol values were averaged across the two practice sessions. There were no significant differences between pre-game testosterone and pre-practice testosterone levels ($t(13) = .47, p = .65$) and no significant differences between pre-game cortisol and pre-practice cortisol levels ($t(13) = 1.29, p = .22$).

3) *Game Location*

To examine the differences in hormone levels with respect to game location, I took the average pre-game testosterone and cortisol values from the three home games and compared these with the average of the two away games using paired t-tests (two-tailed). Results are presented in Figures 8 and 9. As can be seen, pre-game salivary testosterone levels were significantly higher when the team played in their home venue as compared to their opponent's venue ($t(13) = 2.28, p = .04$). Furthermore, despite approaching significance ($t(13) = 1.97, p = .07$), pre-game cortisol levels did not differ depending on game location. There were no differences between testosterone levels obtained from the practice sessions and pre-game testosterone levels at home ($t(13) = .39, p = .70$). Similarly, there were no differences between testosterone levels from the practice sessions and pre-game testosterone levels from the away games ($t(13) = 1.77, p = .10$). Moreover, there were no differences between cortisol levels obtained from the practice sessions and pre-game

cortisol levels at home ($t(13) = .29, p = .78$). However, pre-game cortisol values for away games were lower as compared to pre-game samples obtained from practices sessions ($t(13) = 2.06, p = .06$).

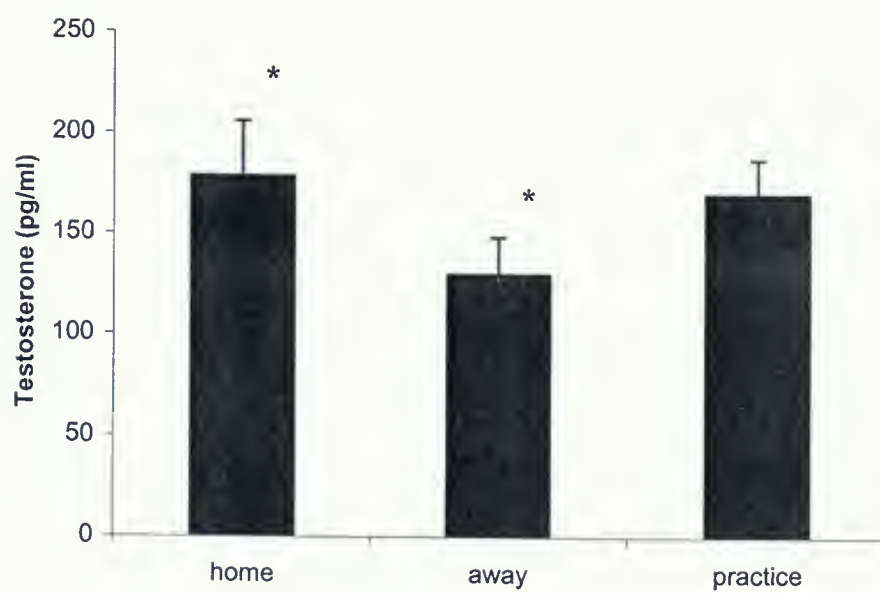


Figure 8. Mean (SE) pre-game and practice salivary testosterone.

* $p = .04$, two-tailed

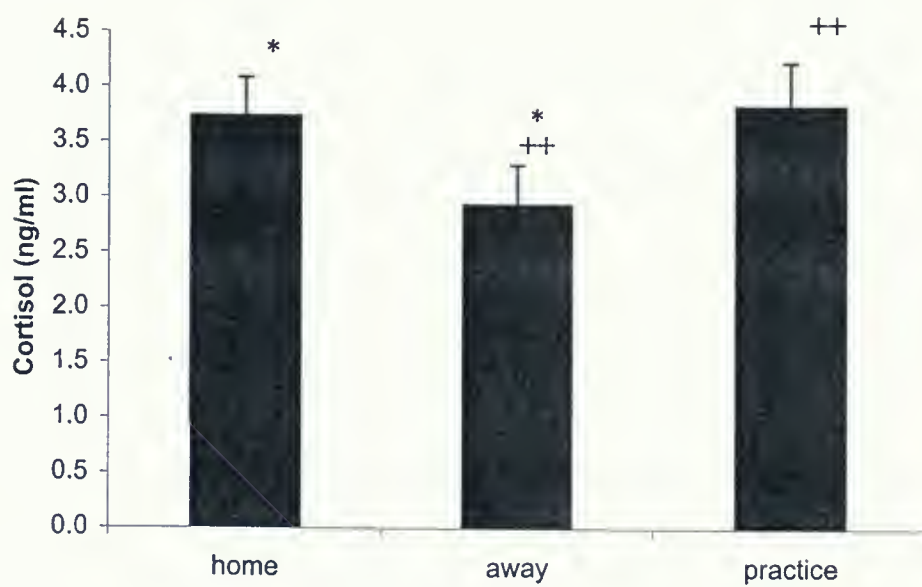


Figure 9. Mean (SE) pre-game and practice salivary cortisol levels.

* $p = .07$, two-tailed

++ $p = .06$, two-tailed

To evaluate differences in psychological states depending on game location, pre-game psychological variables were averaged for the three home games and compared to the average of the two away games using paired t-tests (one-tailed). Analysis of pre-game psychological variables also yielded significant differences between home and away games. Results of these analyses are presented in Table 10. Paired t-tests revealed that the players were more self-confident when playing in their home venue as compared to their opponent's venue. In addition, players had higher somatic and cognitive anxiety prior to games played in their opponents' venue compared to their home venue.

Table 10.

Mean (\pm SE) Pre-game Psychological Variables by Game Location

| Variable | Home M (SE) | Away M (SE) | <i>t</i> | <i>df</i> | <i>p</i> |
|-------------------|----------------|----------------|----------|-----------|----------|
| Self-Confidence | 25.45 (1.22) | 24.25 (1.41) | 2.80 | 13 | .01 |
| Somatic Anxiety | 15.07 (1.08) | 16.61 (1.21) | 2.27 | 13 | .02 |
| Cognitive Anxiety | 18.31 (1.07) | 19.64 (1.33) | 1.87 | 13 | .04 |

Note: Scores ranged from 9-36 on each subscale of the CSAI-2. Higher scores indicate a greater degree of self-confidence, somatic anxiety and cognitive anxiety prior to competition.

4) Individual Performance

To evaluate the relationship between pre-game testosterone and cortisol levels with individual performance, we took the average hormone and performance values from the five games assessed. We computed Pearson correlation coefficients to test the hypothesis that pre-game testosterone would be positively associated with individual performance. Results (presented in Figure 10) revealed a significant *negative* correlation. Regression analyses were computed to test for a curvilinear relationship between pre-game cortisol and individual performance. Performance was regressed on pre-game cortisol on the first step and performance was regressed on (pre-game cortisol)² on the second step. The second step was non-significant ($p = .94$), demonstrating no curvilinear relationship between pre-game cortisol and performance.

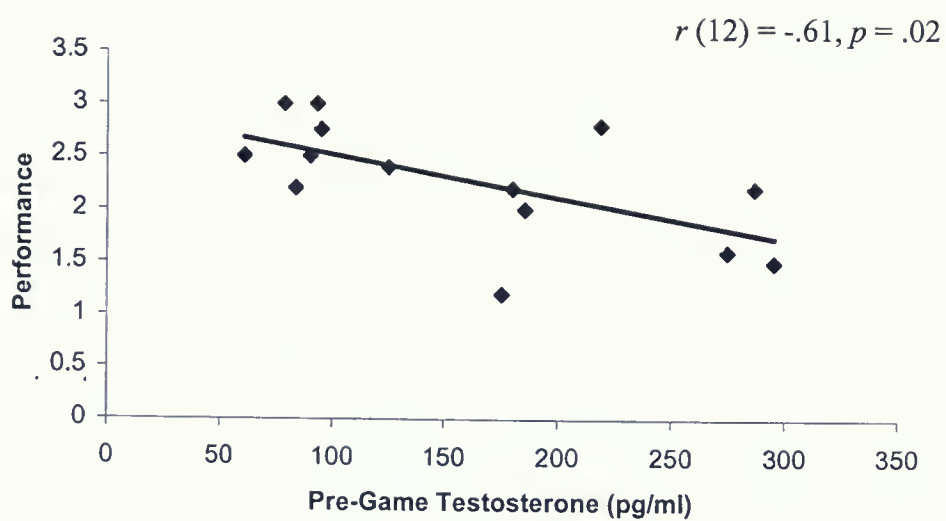


Figure 10. Correlation between pre-game testosterone and individual performance.

In addition to evaluating the relationship between pre-contest testosterone and cortisol and performance, I was interested in examining the relationship between the percent testosterone and cortisol change and individual performance. Again, I took the average percent hormone change and individual performance measures from the five games assessed. Results (presented in Figure 11) revealed a significant positive correlation between percent testosterone change and individual performance and no relation between percent cortisol change and individual performance ($p = .25$).

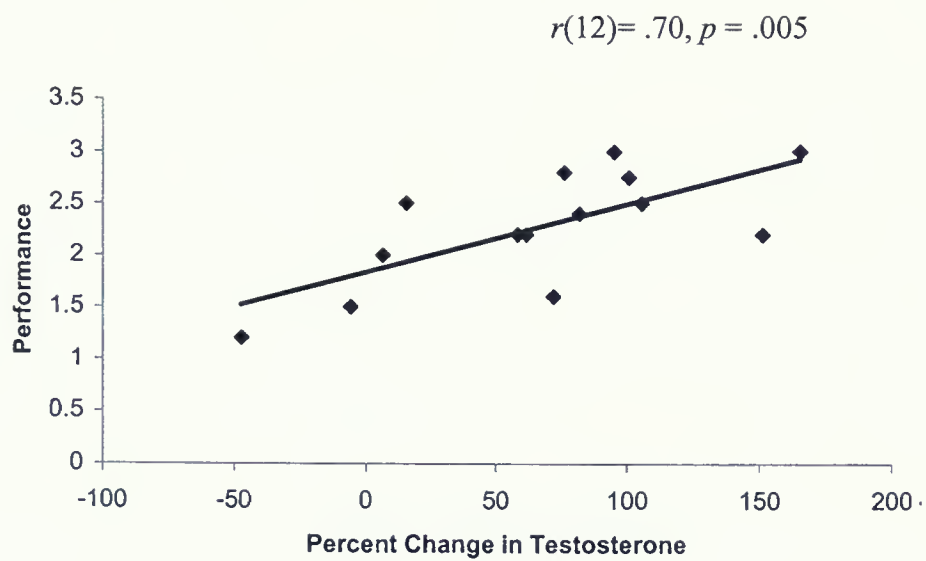


Figure 11. Correlation between percent testosterone change (pre- to post-game) and individual performance.

Finally, to test my hypotheses with regard to the relationship between performance and pre-game psychological variables, we computed Pearson correlation coefficients (two-tailed). As expected, there was a significant positive correlation between pre-game self-confidence and individual performance (presented in Figure 12). There was no correlation between pre-game cognitive anxiety and individual performance ($p = .33$). A regression analysis was computed to test for our hypothesized curvilinear relationship between pre-game somatic anxiety and individual performance. Performance was regressed on pre-game somatic anxiety on the first step and on pre-game somatic anxiety² on the second step. The second step was non-significant ($p = .12$), demonstrating no curvilinear relationship between pre-game somatic anxiety and performance.

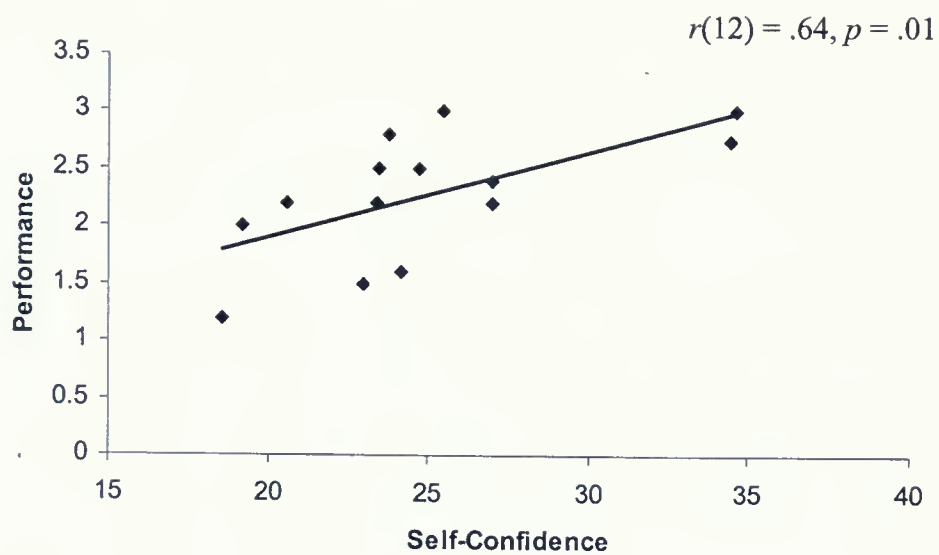


Figure 12. Correlation between pre-game self-confidence and performance.

5) *Exploratory Analysis*

Although not a main focus of this thesis, post-game testosterone and cortisol values were used to compute a testosterone/cortisol ratio for both win and loss sessions and paired t-tests (two-tailed) were computed to evaluate any differences between the ratios as a function of whether the team won or lost the status contest. The average post-game T/C ratio for loss sessions was computed and compared to that of the win session. Results (presented in Figure 13) indicate that the ratio was significantly higher for the win session as compared to the loss sessions ($t(13) = 3.13$, $p = .008$). Furthermore, a plot of the T/C ratio over time is presented in Figure 14.

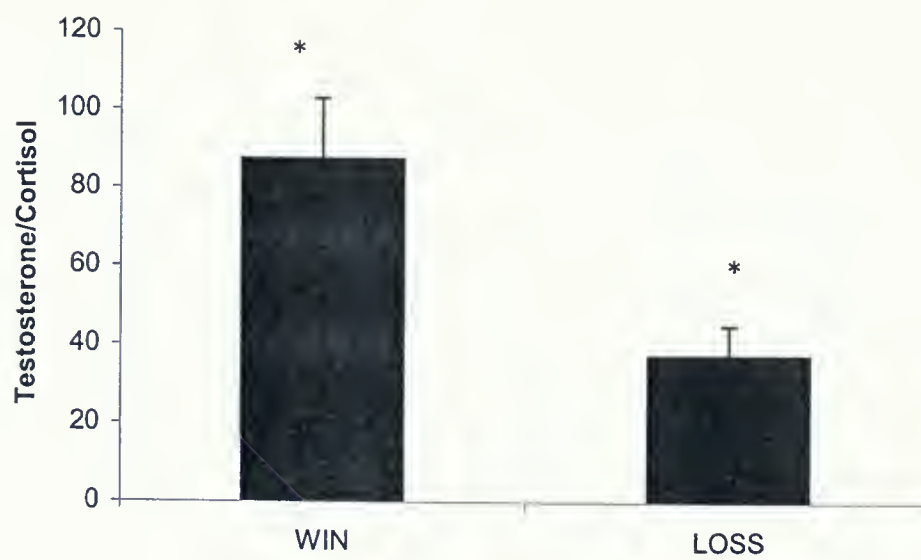


Figure 13. Difference between Testosterone/Cortisol as a function of game outcome.

* $p = .008$, two-tailed



Figure 14. Post-game Testosterone/cortisol ratio throughout athletic season.

SECTION VI – DISCUSSION

The current thesis examined three main questions with regard to: 1) status outcome, 2) athletic setting, and 3) game location. More specifically, Does game outcome moderate the relationship between pre- and post-game testosterone and cortisol?; Does athletic setting (practice vs. competition) moderate the relationship between pre- and post- testosterone and cortisol?; and, Are there any differences in pre-game hormonal and psychological states depending on game location? Several findings from this thesis add to the developing body of research on the relationship between hormones, psychological variables and competition.

First, it was found that status outcome significantly moderated the testosterone response to competition. Previous attempts to support the moderating role of status outcome on the testosterone response in team sports have produced null results (Gonzalez-Bono et al., 1999; Salvador et al., 1987; Edwards, Wetzel, & Wyner, 2006). The current study is the first to demonstrate that the outcome of the status contest is a significant moderator of the pre- to post-game testosterone response in a team sport. Furthermore, although cortisol responses were similar in both win and loss sessions, it was found that cortisol levels were significantly higher after a loss of status. Another interesting finding emerged in that physical activity in this group of elite athletes was not sufficient to produce a testosterone or cortisol surge. Moreover, the current study adds to the sport psychological literature by demonstrating that pre-contest psychological levels were different depending on where the status contest was held. More specifically, pre-game self-confidence levels were significantly higher prior to home games, while somatic and cognitive anxiety levels were significantly

higher prior to away games. Last, our results extend the findings of previous research suggesting that testosterone levels are higher prior to games played in the home venue as compared to the away venue.

Status Outcome

The current study provided general support for the biosocial model of status (Mazur, 1985). That is, status outcome moderated the testosterone response to competition. Mazur (1985) argued for a reciprocal relationship between status and testosterone. His biosocial model of status predicts that testosterone levels will increase in response to a victory, and that this increase in testosterone will make the individual more willing to compete assertively and dominantly in future status contests. On the other hand, a loss of status will be associated with a decrease in testosterone, and this will make the individual less likely to compete assertively and aggressively in future status contests. The individuals in our study demonstrated an increase in testosterone to both victory and defeat; however, the victory was associated with a greater pre- to post-game testosterone increase. Our finding of a moderating role of status outcome on the testosterone response supports past findings conducted on tennis players (Mazur & Lamb, 1980; Booth et al., 1989), wrestlers (Elias, 1981), spectators (Bernhardt et al., 1998), chess players (Mazur et al., 1992) and laboratory reaction time tasks (Gladue et al., 1989). However, our findings disagree with those conducted on judo fighters (Salvador et al., 1987; Suay et al., 1999) and basketball players (Gonzalez-Bono et al., 1999).

The previous studies, mentioned above, that did not find support for a moderating role of status outcome on the testosterone response to competition had several limitations that may have prevented them from detecting an effect of status outcome. For example, these studies were conducted using a between-subjects design with relatively small sample sizes, thus reducing their power to detect a significant interaction. Gonzalez-Bono et al. (1999) reported that winners ($n = 8$) showed an increase while losers ($n = 8$) showed a decrease in testosterone following competition; however, the authors report no significant effect of game outcome. This null effect is certainly not surprising given the small sample size. In addition, these studies have drawn conclusions based on observations made from collecting data from a single status contest. This limitation was addressed in the present thesis by collecting data over the course of a season and taking pre- and post-game averages of win and loss sessions. I suggest that this method of data collection provides a much better picture of an individual's average hormone responses to gaining or losing status following competition.

What, then, is the functional significance of the testosterone surge in response to a rise in status? There may be several reasons for this, which may have a functional relevance to behaviour. First, from an evolutionary perspective, an increase in status may bring about further challenges from others in the hierarchy who are also competing for valued prerogatives such as food and reproductive opportunities. Therefore, in this case, higher levels of testosterone after a victory may serve to facilitate aggressive and/or dominant behaviours, thus increasing their chances of maintaining their high status within the hierarchy. In contrast, decreases

in testosterone may serve to encourage withdrawal from other challenges to avoid a future threat to status and/or injury. This effect of elevated testosterone has been demonstrated in many species of birds (Wingfield et al., 1990) as well as primates (Muller & Wrangham, 2004; Beehner et al., 2006). As demonstrated earlier in the literature review, research with humans has provided ample support for the effect of dominance behaviour (or competition) on testosterone responses, however, much less evidence exists for the reciprocal effect of testosterone on dominance behaviour. (see Archer, 2006; van Anders & Watson, 2006; and Mazur & Booth, 1998 for reviews). That is, gaining status is associated with a surge in testosterone, but does this surge in testosterone make an individual more likely to *behave* more aggressively, dominantly, and/or competitively in future status contests? Mehta and Josephs (in press) attempted to answer this question by designing a rigged experiment in which saliva samples were collected before and after a status contest. At the conclusion of the status contest, winners and losers were asked if they would like to participate again against the same opponent. Interestingly, the authors found support for the effect of testosterone response on status-seeking behaviour. More specifically, losers who showed an increase in testosterone in response to the contest were more willing to compete again against the same opponent compared to those losers who decreased in testosterone. This is the first study to empirically investigate and find support for the hypothesis that a testosterone increase in response to competition is associated with status-seeking behaviours.

Another possible role of the testosterone increase after a rise in status may be to reinforce the behaviour(s) that led to the victory. This hypothesis is based on the

rewarding effects of testosterone reported by several researchers (Packard, Cornell, & Alexander, 1997; Alexander, Packard, & Hines, 1994; Frye, Rhodes, Rosellini, & Svare, 2002). These animal researchers have utilized the conditioned place preference (CPP) paradigm to investigate the relationship between testosterone and reward. The CPP involves pairing an environment with exposure to a certain drug (i.e. testosterone, amphetamine, cocaine) and assessing its rewarding properties by examining whether an increased preference has been established for the environment previously paired with the drug. These studies have demonstrated that systemic and/or direct infusion of testosterone into the nucleus accumbens (NA) and the medial pre-optic area (MPOA) are capable of producing a CPP, demonstrating that testosterone administration has rewarding properties. The research suggests that the rewarding effects of testosterone occur after its conversion to 3α -diol and subsequent actions on gamma-aminobutyric acid (GABA) and dopamine (DA) systems (see Rosellini, Svare, Rhodes, & Frye, 2001 for review). Therefore, based on the rodent studies, it is conceivable that the surge in testosterone after a victory may serve to reinforce the behaviours that were instrumental in gaining status (Schultheiss, Campbell, & McClelland, 1999).

The current study also provides a novel addition to the research on competition and hormones by demonstrating that post-game cortisol values are significantly higher in response to a loss of status. This finding is consistent with those conducted on olive baboons (Sapolsky, 1991) and rats (Blanchard et al., 1993) and suggests that losing status is related to higher glucocorticoid secretion. Studies with humans have been much more variable, with many reporting no difference

between winners and losers, and with others demonstrating higher levels in winners (Suay et al., 1999 and Elias, 1981). Higher post-game cortisol in winners could be related to the excitement of the competition and thus represent a 'positive' stressor. It has also been suggested an individual's implicit power motive, an unconscious desire to have an impact on others through assertive behaviour, is related to his or her response to status contests (Wirth, Welsh, & Schultheiss, 2006). More specifically, Wirth et al. (2006) found that individuals high in this motive showed an increase in cortisol in response to a *loss* of status. Interestingly, the authors demonstrated that those low in this motive showed a rise in cortisol in response to an *increase* in status. Therefore, future research may want to consider personality factors, such as the implicit power motive, that may moderate hormonal responses to both gaining and losing status.

Athletic Setting

The current thesis hypothesized that athletic setting (practice vs. competition) would moderate the testosterone and cortisol responses. This hypothesis was supported, demonstrating that physical activity on its own does not elicit a hormonal response among elite Jr. A hockey players. This finding is consistent with those of Aubets et al., (1995) and Filaire et al., (2001) and suggests that at the elite level of competition, athletes may have habituated to the physical stress of sporting activities. Furthermore, the finding that hormonal responses were specific to athletic competition suggests that it is the addition of psychosocial stress of competition that stimulates testosterone and cortisol responses.

It was also predicted that there would be an anticipatory testosterone and cortisol increase prior to competition. That is, I predicted that pre-game testosterone and cortisol would be significantly higher than pre-practice hormone values obtained from two non-competitive practice sessions. Consistent with a few previous studies (see Archer, 2006 for review), the present study failed to provide support for this hypothesis. However, contrary to these results, most studies have reported anticipatory rises in testosterone and/or cortisol prior to competition (Suay et al., 1999; Mazur et al., 1992; Booth et al., 1989). The current study obtained baseline measures of testosterone and cortisol during two practice sessions (at the same time of day as the competition samples). The failure to detect an anticipatory hormonal response may be related to the baseline sample collected on the practice day. It is possible, that there was some degree of intra-team competition during practice sessions. Although it is unlikely that there was intra-team competition during practice sessions, I cannot rule out this possibility. In addition to collecting baseline samples on practice days, future research may want to collect samples on a rest day to rule out the possible effect of intra-team competition.

Game Location

It was hypothesized that pre-game testosterone values would be significantly higher for games played in the home venue compared to the away venue. The present study lends supports this hypothesis and is consistent with the findings of Neave and Wolfson (2003) demonstrating higher levels of pre-game testosterone when the team played in their home venue. Contrary to the Neave and Wolfson (2003) study, the

athletes in the current study did not demonstrate higher levels of pre-game testosterone at home relative to pre-practice testosterone values. The data appear to indicate lower levels of pre-game testosterone when the team played in their opponent's venue compared to the practice session; however, this difference was not significant. A key methodological difference between the current thesis and the Neave and Wolfson (2003) study is that our practice session took place in the home venue, while that of Neave and Wolfson (2003) was held at a neutral (or away) site. Therefore, future studies investigating possible difference in testosterone depending on game location must consider collecting practice samples from both the home venue and a neutral venue. Although athletes displayed significantly higher pre-game testosterone when playing in their home venue, this may not necessarily lead to a 'home advantage' per se. Despite the higher levels of pre-game testosterone seen for games in the home venue, the team lost all 3 home games. The team did, however, win more games in their home venue than in their opponent's venue during the 2004-2005 season.

No previous study has investigated pre-game cortisol differences depending on game location. Since previous studies have demonstrated that cognitive and somatic anxiety are higher in the away venue, we predicted that pre-game cortisol would be significantly higher for games played in the away venue. Although failing to reach statistical significance ($p = .07$), players tended to have higher pre-game cortisol levels prior to *home* games. This finding suggest that playing in front of friends and family at the home venue may provide for an additional source of stress.

This is highly speculative and future studies must be conducted in order to examine this possibility.

In addition to the hormonal differences observed, pre-game psychological variables also differed depending on location of the game. Consistent with the hypothesis, athletes reported significantly higher self-confidence ratings prior to games played in the home venue, which extends previous studies (Bray et al., 2002; Terry, Walrond, & Carron, 1998). Also consistent with my hypotheses, individuals in the current study had higher pre-game somatic and cognitive anxiety for away games, which was also consistent with previous reports (Bray et al., 2002; Terry et al., 1998). Thus, the present thesis adds to the developing literature on psychological differences with respect to game location and may have important practical relevance to athletic coaches as well as to individuals in the field of sport psychology (see 'Practical Implications' below).

Individual Performance

In addition to evaluating the effects of game outcome, athletic setting, and game location on testosterone and cortisol levels, I was also interested in evaluating the relationship (if any) between individual performance (as assessed by the coach) and hormonal and psychological variables. First, based on the literature associating testosterone with behaviours such as dominance (see Mazur & Booth, 1998 for review), aggression (Scaramella & Brown, 1972), and assertiveness (Booth, Johnson, & Granger, 1999), I predicted that higher pre-game testosterone would be associated with better individual performance. Contrary to this hypothesis, a *negative*

correlation was observed between pre-game testosterone and performance.

Kivlighan et al. (2005) also reported a negative correlation between pre-contest testosterone and performance in elite swimmers. The finding of a negative correlation between testosterone and performance is difficult to interpret. However, Josephs, Guinn-Sellers, Newman, and Mehta (2006) suggest that the status of the individual prior to the contest may moderate the relationship between testosterone and performance. In a controlled laboratory experiment, Josephs et al. (2006) assigned high and low testosterone (top and bottom third of distribution) to high (leaders) and low (followers) status positions. High testosterone individuals assigned to a high status position performed significantly better than high testosterone individuals assigned to a low status position. The authors argue that this may be due to a 'mismatch' between the individual's testosterone levels and his or her current status. The authors further suggest that the high testosterone individuals in a low status position may have been distracted by their lowly status, and as a result, their performance may have suffered. Although our study did not manipulate status directly, the players in the current study were on a team that had a much lower win to loss ratio (an objective sign of status) compared to their opponents. Thus, our results seem to support the concept of the 'mismatch effect' as proposed by Josephs et al. (2006). Furthermore, results from a recent unpublished study from our laboratory are consistent with the mismatch hypothesis (Carré & Muir, manuscript in preparation). Data were collected from two teams with relatively *better* win to loss ratios than their opponents and a significant positive correlation between pre-game testosterone and individual performance ($r(27) = .42, p = .01$) was found. Although further studies

that directly assess an individual's subjective assessment of perceived status prior to the status contest are needed, these findings map nicely onto the hypothesis put forth by Josephs and colleagues (2006), and suggest that perceived status may moderate the relationship between pre-game testosterone and performance.

Along with pre-game testosterone levels, we also hypothesized a positive correlation between the percent testosterone change and individual performance. This hypothesis was based on the suggestion of Salvador (2005) that individual performance should also be considered when looking at the relationship between status contests and testosterone levels. Results from the current thesis support our hypothesis of a positive correlation between individual performance and percent testosterone change. That is, the better a player performed, the greater the percent testosterone increase. It may be argued that asking players to subjectively rate their performance would better assess individual performance. This argument is certainly valid given that an individual's subjective assessment of performance may be more closely related to his or her hormone levels. However, unpublished results from our laboratory (Carré & Muir, manuscript in preparation) suggest that the coach's assessment of individual performance is a reasonable indicator of the player's subjective assessment of their performance ($r(27) = .56, p = .01$).

It has often been suggested that the most important psychological factor associated with successful athletic performance is self-confidence (Woodman & Hardy, 2003; Parfitt & Pates, 1999; Chapman, Lane, Brierley, & Terry, 1997). Therefore, a positive correlation between pre-game self-confidence and individual performance was hypothesized. Our results support this hypothesis, demonstrating

that individuals reporting high levels of self-confidence prior to competition were evaluated as performing the best by their coach. These results are further discussed in the 'Practical Implications' section. The current study did not support our hypothesis of a negative relationship between cognitive anxiety and individual performance. This finding may come as no surprise to those in the field of sport psychology. Some athletes may thrive under pressure, while others may 'choke'. As a result of this variability, another dimension that assesses the athlete's subjective interpretation of the anxiety prior to competition has been added to the CSAI-2 (Swain, Jones, Hardy, & Hagtvet, 1996). This dimension asks athletes to rate whether their anxiety symptoms as facilitating and/or debilitating to their performance. The authors note that those individuals who rated their cognitive anxiety symptoms as facilitating were rated as performing well, while those who rated their symptoms as debilitating performed poorly (Swain et al., 1996). Therefore, it is not surprising that there was no relationship between cognitive anxiety and performance, and future studies must take into account the athletes' subjective interpretation of their anxiety symptoms when examining the relationship between anxiety and performance.

Consistent with the idea that anxiety and performance follow an inverted-u relationship, we predicted a curvilinear association between pre-game cortisol and pre-game somatic anxiety and individual performance. Our findings did not support this hypothesis, demonstrating no curvilinear relationship between performance and either pre-game cortisol and somatic anxiety. Hanin (2000) suggested that the performance-anxiety relationship in competitive sports is complex and that one must consider individual differences in optimal arousal. That is, some individuals will

perform maximally under high levels of pre-contest anxiety, while others may perform poorly. Therefore, future studies must consider identifying individual zones of optimal functioning (IZOF) when assessing performance/anxiety relationships (Hanin, 2000).

Exploratory Analysis

Research suggests that long-term exposure to stress may have a negative effect on the HPG-axis. That is, long-term exposure to cortisol may have a suppressing effect on testosterone levels. Although our research design did not allow us to directly assess this hypothesis, we were interested in looking at the difference in the testosterone/cortisol ratio depending on the outcome of a status contest. That is, does winning a status contest relate to a higher T/C ratio as compared to losing a status contest? Our results demonstrated that winning was indeed associated with a significantly higher T/C ratio than losing. Although this finding is certainly preliminary and exploratory in nature, it is interesting to speculate on its meaning. It would be interesting to see whether multiple losses of status (or a losing streak) would have a suppressing effect on testosterone levels and whether this in turn would affect an individual's status-seeking or dominant behaviour.

Limitations

Although I believe that this study was a methodological improvement over previous studies on competition and hormone responses, there are certainly limitations that must be considered. First, this thesis was conducted with a relatively small sample size. A recent review on the hormonal responses to athletic competition

has revealed that the average sample size in the literature is 14 (Salvador, 2005).

Although our sample size is in line with the average, the results must be interpreted with caution. Further studies should be conducted using larger sample sizes, and perhaps multiple teams.

In addition, the team under investigation lost four of the five games included in this study. Thus, although the current study attempted to evaluate hormonal responses to athletic competition throughout an athletic season we were unable to get hormone levels for multiple win sessions. This limitation is beyond our control, and future studies with a team having a more balanced win/loss ratio must be conducted. Furthermore, although we did find significant effects of game outcome on the testosterone and cortisol responses, the current study did not investigate personality variables, such as the implicit power motive (Wirth et al., 2006), which may have impacted the results.

Last, the current thesis attempted to obtain a baseline value for testosterone and cortisol on a non-competitive practice day. I acknowledge that the values obtained may not represent a true baseline value. That is, there may have been some degree of intra-team competition, which could have impacted the pre-practice testosterone and cortisol levels. Future research may want to collect data on a non-practice rest session and compare these values to practice and competition sessions.

Practical Considerations

The current study has demonstrated that testosterone and cortisol responses are specific to athletic competition and that physical activity in the absence of direct

competition does not result in surges of testosterone or cortisol among elite athletes. This finding is in line with previous reports and may have important significance to coaches and sport psychologists who are always looking for ways to improve athletic performance. 'Practice makes perfect' and 'practice the way you would play' are clichés that are often used by coaches in the world of competitive sports. If practices are not eliciting the same hormonal responses, as do competitions, it may be that practice sessions are not sufficient to prepare athletes for elite competition.

What, then, should athletes do to prepare themselves for competition? Mental imagery may be a prime candidate for consideration. Some have suggested that mental imagery is at the forefront of the anticipatory cortisol and testosterone response reported in the literature (Mazur & Booth, 1998); however, no empirical study has investigated this possibility. A recent, unpublished study from our laboratory suggests that athletes who use mental imagery more frequently, show a blunted or diminished cortisol response to competition as compared to those who do not use mental imagery as frequently (Carré, Gammage, & Muir, in preparation). This finding suggests that athletes using mental imagery may have somehow habituated to the 'stress' of competition and thus demonstrate a much smaller cortisol response. More experimental research on the role of mental imagery in influencing an individual's hormonal responses is certainly needed in order to develop a deeper appreciation for its possible role in altering hormone levels and improving performance.

In addition, it was interesting to see that players reported higher self-confidence prior to games played in their home venue compared to their opponents' venue. Given the strong correlation between individual performance and self-confidence in the current thesis; coaches, trainers, and/or sport psychologists interested in maximizing performance may want to design interventions geared towards enhancing self-confidence levels for games played in the opponents' venue.

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Appendix A

Competitive State Anxiety Inventory-2 - Martens et al. (1990)

| | Not at all | Somewhat | Moderately So | Very Much So |
|--|------------|----------|---------------|--------------|
| 1. I am concerned about this competition | 1 | 2 | 3 | 4 |
| 2. I feel nervous. | 1 | 2 | 3 | 4 |
| 3. I feel at ease. | 1 | 2 | 3 | 4 |
| 4. I have self-doubts. | 1 | 2 | 3 | 4 |
| 5. I feel jittery. | 1 | 2 | 3 | 4 |
| 6. I feel comfortable. | 1 | 2 | 3 | 4 |
| 7. I am concerned that I may not do as well as I could when competing. | 1 | 2 | 3 | 4 |
| 8. My body feels tense. | 1 | 2 | 3 | 4 |
| 9. I feel self-confident. | 1 | 2 | 3 | 4 |
| 10. I am concerned about failing. | 1 | 2 | 3 | 4 |
| 11. I feel tense in my stomach. | 1 | 2 | 3 | 4 |
| 12. I feel secure. | 1 | 2 | 3 | 4 |
| 13. I get concerned about choking under pressure. | 1 | 2 | 3 | 4 |
| 14. My body feels relaxed. | 1 | 2 | 3 | 4 |
| 15. I'm confident I can meet the challenge. | 1 | 2 | 3 | 4 |
| 16. I'm concerned about performing poorly. | 1 | 2 | 3 | 4 |
| 17. My heart is racing. | 1 | 2 | 3 | 4 |
| 18. I'm confident about performing well. | 1 | 2 | 3 | 4 |
| 19. I'm concerned about reaching my goal. | 1 | 2 | 3 | 4 |

| | | | | |
|--|---|---|---|---|
| 20. I feel my stomach sinking. | 1 | 2 | 3 | 4 |
| 21. I feel mentally relaxed. | 1 | 2 | 3 | 4 |
| 22. I am concerned that others will be disappointed with my performance. | 1 | 2 | 3 | 4 |
| 23. My hands feel clammy. | 1 | 2 | 3 | 4 |
| 24. I'm confident because I mentally picture myself reaching my goal. | 1 | 2 | 3 | 4 |
| 25. I'm concerned I won't be able to concentrate. | 1 | 2 | 3 | 4 |
| 26. My body feels tight. | 1 | 2 | 3 | 4 |
| 27. I'm confident of coming through under pressure. | 1 | 2 | 3 | 4 |

Appendix B

Hockey Coaches Performance Assessment:

Name: _____

Date: _____

Before rating each players' performance, please try to recall each players' best performance of this year (2004-2005 season). When rating each player, compare their performance today, to their best performance of the year. How well did they play today relative to their best performance of the year?

| | Poor | Fair | Good | Very Good |
|-------------|----------|----------|----------|-----------|
| <u>1 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>4 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>5 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>7 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>8 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>9 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>11 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>12 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>14 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>15 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>16 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>17 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>19 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>20 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>21 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |
| <u>22 -</u> | <u>1</u> | <u>2</u> | <u>3</u> | <u>4</u> |

Appendix C

Institutional Review Board for the Protection of Human Subjects

October 10, 2005

To: Dr. Susan K. Putnam

Re: Research Project entitled: "Salivary Testosterone and Cortisol Levels in Elite Canadian Junior Hockey Players: Association with Competition-induced Anxiety, Subjective Report of Self-Efficacy, and Performance"

Canisius College's Institutional Review Board has completed its review of the above named project. The proposal was approved as submitted and you are authorized to use human subjects in the manner specified until October 10, 2006. At the end of that time, if your project is not complete, you need to submit a request for an extension and a progress report to continue beyond that date. If it becomes necessary to make changes, please submit them for review and inclusion in your project file. When your project is complete, please notify the IRB in writing.

If untoward incidences or responses should develop in the course of your research, please suspend the project and notify me immediately.

On the behalf of the IRB, I wish you all the luck in your research endeavors. Please do not hesitate to call me at 716-888-6642 if you have any questions.

Sincerely,

A handwritten signature in blue ink, appearing to read "Khalid W. Bibi".

Khalid W. Bibi, Ph.D.
Chair, IRB

