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Pre-competition hormonal and psychological levels of elite hockey players: Relationship to the 'home advantage'

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Abstract

The home advantage is a robust phenomenon that occurs in the world of amateur and professional sport. Athletic teams have been shown to win significantly more games in their home venue as compared to their opponents' venue. Studies have suggested that the home advantage may be related to familiarity with the facility, increased crowd density and even pre-competition hormonal levels. The present study investigated pre-competition physiological and psychological states of elite hockey players in the home and away venues. Physiological measures included salivary cortisol and testosterone, which were assessed using enzyme immunoassays. In addition, pre-competition psychological states were assessed using the Competitive State Anxiety Inventory-2. Physiological measures indicated that the players had significantly higher pre-game testosterone when playing in their home venue as compared to their opponents' venue ($t(13)=2.29$, $p=0.04$); however, this difference was not due to a pre-game rise in testosterone while competing at home. Furthermore, players showed a trend toward higher pre-game cortisol when playing in their home venue ($t(13)=1.96$, $p=0.07$). Psychological measures indicated that players were more self-confident when playing in their home venue ($t(13)=2.8$, $p=0.008$) and also had higher somatic ($t(13)=2.3$, $p=0.02$) and cognitive anxiety ($t(13)=1.87$, $p=0.04$) when playing in their opponents' venue. The present study supports the notion that there are differences in pre-competition hormonal and psychological states that may play a key role in the 'home advantage'.

Keywords: Testosterone; Cortisol; Home advantage; Competition; Self-confidence; Anxiety

1. Introduction

The 'home advantage' is a robust effect in that "home teams in sport competitions win over 50% of the games played under a balanced home and away schedule" [1]. A considerable amount of research has focused on factors assumed to underlie this phenomenon ([1], see [2] for review), and these factors are as follows: familiarity with facility, crowd density, travel and officiating.

It has been proposed that familiarity with one's facility may be advantageous to the home team. A recent study by Pollard [3] 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 [4] found that the only significant predictor of game outcome was crowd density. The authors indicate that, as crowd density increases, so does the home advantage. In contrast, another study found that crowd size rather than crowd density was related to the home advantage [5].

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 [6] and basketball teams traveling in excess of

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200 miles [7] 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 favor 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 the decision maker [8].

Although these areas of research enhance the current understanding of the home advantage, fewer studies have investigated pre-contest physiological and psychological states of athletes in the home and away venues. Recent studies have now begun to focus on the pre-competition psychological and physiological states of athletes playing in their home and away venues. A study by Bray, Jones and Owen [9] 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. Although this study does not explain the advantage of having higher self-confidence and lower anxiety when performing in the home venue, the results do indicate that there are important psychological differences for games played at home and those played at the opponents' venues. In addition, it was found that basketball players had higher pre-game self-confidence when playing in their home venue [10]. Despite these findings, some studies have also failed to find any difference in anxiety depending on game location [10,11]. 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 [12] 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 their home territory. This territoriality phenomenon has been demonstrated in several primate [13] and rodent [14] studies. Wingfield et al. [15] 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 behavior [16], vigor and activation [17,18] and visual-spatial ability [19]. In addition, a biosocial model of social status has been proposed in order to explain the relationship between status and testosterone levels [20]. Mazur [20] states that as one maintains or gains social status during a status contest, one's testosterone levels will presumably rise, making them more likely to engage assertively, competitively and successfully in future status contests. Testosterone levels have been shown to increase in winners of status contests [21–25] and to decrease in losers [24,25]. Furthermore, rodent studies have also demonstrated this phenomenon [26]. These studies suggest that the act of winning leads to a significant increase in testosterone which may enable one to be more assertive, competitive and aggressive in subsequent status contests, thus increasing the likelihood of maintaining and/or gaining status.

Heightened testosterone after a victory has been proposed to increase the organism's chances of winning future status contests [20]. We propose that higher testosterone levels observed prior to competition in one's home venue may be related to the athlete's belief that playing in one's 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 behavioral characteristics.

In addition to research on competition and testosterone, many studies have begun to investigate the stress experienced by athletes before, during and after competition [21,22,37,40,41]. Researchers have been able to objectively assess stress responses by measuring levels of cortisol from saliva. Cortisol has been identified as a reliable marker of hypothalamic pituitary adrenal axis (HPA) activation (see [27] for review) and is a useful means of evaluating physiological arousal prior to games played in the home and away venues.

Research incorporating the psychological and physiological states of athletes prior to competition in both home and away settings may provide additional insight into the concept of the 'home advantage'. The purpose of this study was to investigate the pre-game physiological and psychological states of elite athletes in both home and away competition. It was hypothesized that athletes would have higher pre-game testosterone levels when playing in their home venue. Furthermore, we predicted that cortisol levels would be higher for games played away from the team's home arena. In addition, we predicted that pre-game self-confidence would be higher for home games, while cognitive and somatic anxiety would be higher for away games.

Along with the main hypotheses proposed, we also sought to investigate the relationship between pre-game psychological and physiological measures and post-game ratings of performance. It was predicted that there would be a significant correlation between pre-game testosterone and post-game performance ratings. Moreover, it was hypothesized that self-confidence, somatic anxiety and cognitive anxiety would also be related to post-game performance ratings.

We were also interested in looking at the relationship between salivary cortisol measures (physiological activation) and state somatic anxiety as measured by the Competitive State Anxiety Inventory-2 (CSAI-2). Previous reports have demonstrated mixed results on the relationship between physiological and psychological measures of activation [28,29].

2. Materials and methods

2.1. Sample

The sample was composed of 17 members of an elite Jr. A hockey club located in northern Ontario, Canada. This hockey club participates in the elite Canadian Junior Hockey League and the players ranged in age from 16 to 20 years (M=18.21, S.D.=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 and/or poor performance: therefore, they were eliminated from the main analyses.

2.2. Procedure

This study was approved by the Canisius College Institutional Review Board. 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. Data were collected for five games (three home games and two away games), beginning in October and ending in January. Physiological data were collected 45 min prior to games. Furthermore, psychological data were also collected 45 min prior to games. In addition to the data collected during competition, saliva samples were also collected during two practice sessions that involved individual skills development (shooting, passing, etc.). These samples were obtained 45 min prior to practice session at 6:45 pm and served as non-competition controls. All saliva samples were collected between 6:45 pm and 9:30 pm to control for the diurnal variation of cortisol and testosterone. Players were asked to drool through a straw into a 2 ml microvial. We chose to collect saliva samples due to the non-invasive nature, the independence of flow rate, and because salivary testosterone and cortisol represent the unbound, biologically active portion of the hormone [30,31].

Psychological data were measured using the Competitive State Anxiety Inventory-2 [32]. This assessment tool has been extensively used in the sport psychology literature and assesses each player's pre-game somatic state and cognitive state anxiety levels as well as their pre-game state self-confidence levels. The Competitive State Anxiety Inventory-2 (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 scores ranging from a low of 9 to a high of 36. Higher scores on cognitive and somatic anxiety indicate a higher level of anxiety, while higher scores on the self-confidence subscale indicate a higher level of self-confidence. Martens et al. [32] reported that the CSAI-2 has an internal consistency of 0.79 to 0.90. Furthermore, the authors compared the CSAI-2 to eight scales that measure anxiety and found that "the coefficients are highly congruent with hypothesized relationships among the CSAI-2 subscales and scales of related constructs" [32].

Although the main purpose of the study was to evaluate the pre-game psychological and physiological difference of playing at home as compared to playing at the opponent's venue, post-game performance assessments were also collected. At the conclusion of each game, the team's head coach provided the researcher with a subjective assessment of each individual player's performance. Player performances were rated on a scale ranging from 4 (very good) to 1 (poor).

2.3. Hormonal determination

All saliva samples were stored at −20 °C until assayed for cortisol and testosterone. Samples were centrifuged at 3000×g for 15 min 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 Tween 20/l) 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 min for testosterone, and 2 h 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 h at room temperature, while cortisol plates remained incubated for 1 h. Next, the plates were washed with 50 μl wash solution and 100 μl of a substrate solution of citrate buffer, H_2O_2 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 min. Plates were then read with a single filter at 405 nm 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 picograms or nanograms per well. All samples were assayed in duplicate and ran in the same batch. The testosterone assay has been previously validated [33]. The intra- and inter-assay CVs were 6.5% and 6.8% for salivary testosterone and 7.8% and 6.5% for salivary cortisol.

3. Results

Prior to data analysis, the opponents' winning percentages were computed in order to evaluate any potential 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 percentage of 64%, while games played away (n=2) were played against

teams with an average winning percentage of 63%. Therefore, any difference in pre-game physiological and/or psychological levels would not be attributed to the quality of the opposing team. Furthermore, the team under investigation had an overall winning percentage (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/loss percentage at home was 38%, while their win/loss percentage away was 25%. Furthermore, of the games that the team won during the season ($n=14$), 57% were played in the home venue. Moreover, 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.

In addition, since the present study examined salivary cortisol and testosterone throughout the athletic season (mid October to mid January), paired *t*-tests were computed in order to rule out the 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 between cortisol ($p=0.96$) and testosterone ($p=0.60$) values obtained during practice sessions at the beginning (October) and end (January) of data collection. In order to examine the differences in pre-game physiological levels with respect to game location, paired *t*-tests were performed. Results are presented in Figs. 1 and 2. As indicated, pre-game salivary testosterone levels were significantly higher when the team played in their home venue as compared to their opponent's venue. Furthermore, although failing to reach the conventional level of statistical significance, it was found that pre-game salivary cortisol levels were higher for games played in the team's home venue. There were no differences between testosterone levels obtained from the practice sessions and pre-game testosterone levels at home ($p=0.70$). No differences between testosterone levels from the practice sessions and pre-game testosterone levels from the away games were detected ($p=0.10$). Moreover, there were no differences between cortisol levels obtained from the practice sessions and pre-game cortisol levels at home ($p=0.78$). In addition, although failing to reach

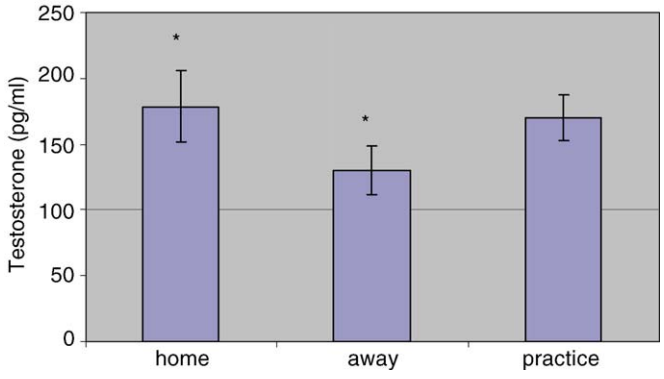

Fig. 1. Mean (±S.E.) pre-game and practice salivary testosterone levels in 14 elite Junior 'A' hockey players. Players showed significantly higher pre-game salivary testosterone levels when playing in their home arena as compared to their opponents' arena (paired *t*-tests, two-tailed). *$p=0.04$.

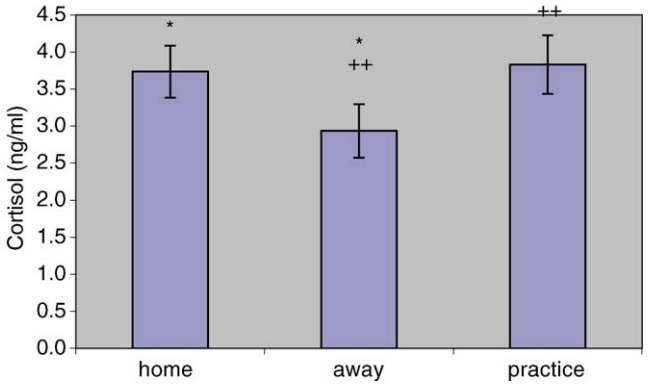

Fig. 2. Mean (±S.E.) pre-game and practice salivary cortisol levels. Players tended to have higher pre-game salivary cortisol levels when playing in their home arena as compared to their opponents' arena (paired *t*-tests, two-tailed). *$p=0.07$, $^{++}p=0.06$.

significance ($p=0.06$), comparisons suggest that cortisol levels actually decreased from baseline values when the team played in their opponents venue.

Analysis of the psychological variables also yielded significant differences between home and away games. Results of these analyses are presented in Table 1. Paired t-tests revealed that the players were more self-confident when playing in their home venue as compared to their opponent's venue. Furthermore, players had higher somatic and cognitive anxiety prior to games played in their opponents' venue compared to their home venue.

Spearman-rank correlations were computed in order to evaluate the association between the head coach's subjective post-game performance ratings and pre-game psychological and physiological measures.

The only significant correlation that was found for home games was between pre-game testosterone and performance. Although the relationship between pre-game self-confidence and performance approached significance ($p=0.09$), all other pre-game measures from home games failed to correlate with the coach's subjective performance ratings (see Table 2). Examination of the relationship between pre-game hormonal and psychological measures and post-game performance for away games revealed a similar pattern in regard to direction of the associations. However, for away games, the association between pre-game testosterone and performance was not significant ($p=0.20$) and the association between pre-game self-confidence was significant ($p=0.007$).

Table 1
Mean (±S.E.) pre-game psychological variables and game location ($n=14$)

Variable	Home	Away	*t*-value	*p*-value
Self-confidence	25.45 (1.22)	24.25 (1.41)	2.80	0.008
Somatic anxiety	15.07 (1.08)	16.61 (1.21)	2.27	0.02
Cognitive anxiety	18.31 (1.07)	19.64 (1.33)	1.87	0.04

Scores ranged from 9 to 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. Statistically significant differences (paired *t*-tests, one-tailed) were observed between home and away self-confidence, somatic anxiety and cognitive anxiety.

Table 2
Relationships between pre-game hormonal levels and psychological measures and performance

	Coach evaluation (HOME)	Coach evaluation (AWAY)
Testosterone	−0.614 (0.02)*	−0.369 (0.20)
Cortisol	−0.073 (0.80)	0.207 (0.48)
Self-confidence	0.379 (0.18)	0.688 (0.007)*
Cognitive anxiety	0.137 (0.64)	0.026 (0.93)
Somatic anxiety	−0.029 (0.92)	−0.522 (0.06)

p-values are noted in parentheses.
All correlations between psychological/hormonal measures and coach evaluations were computed using Pearson product-moment correlations (two-tailed).
* $p<0.05$.

A final correlation analysis was conducted to evaluate whether the psychological measure of somatic anxiety correlated with the pre-game salivary cortisol levels. There was no significant correlation between somatic anxiety and cortisol ($p=0.13$).

4. Discussion

The present study lends support to the findings of Neave and Wolfson [12]. The elite athletes in the present study had significantly higher pre-game testosterone prior to games played in their home venue. Contrary to the Neave and Wolfson [12] study, the athletes in the current study did not demonstrate a pre-game rise in testosterone while playing in their home venue compared to practice. The data appear to indicate a decrease in testosterone when the team played in their opponent's venue compared to the practice session; however, this difference was not significant. Higher levels of testosterone may facilitate acts of aggressiveness, social dominance [16] and assertiveness [34]. 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 three games. However, each of those opponents had a significantly higher win–loss percentage than did the team under investigation. It is difficult to say whether the higher testosterone at home may have led to a 'home advantage' and additional studies must consider assessing games played against teams with equivalent winning percentages.

In addition to the physiological differences observed, pre-game psychological variables also differed depending on location of the game. The athletes reported significantly higher self-confidence ratings prior to games played in the home venue, which was consistent with previous studies [9,35]. Furthermore, the higher pre-game somatic and cognitive anxiety observed for away games in the present study were consistent with previous reports [9,35].

Players had higher pre-game cortisol when competing in their home venue as compared to their opponent's venue. However, higher cortisol observed prior to games played at home was not due to an anticipatory rise in cortisol from baseline practice levels as has been reported in other studies [24,41]. Instead, although failing to reach the conventional level of statistical significance, our results suggest that cortisol values actually decrease from baseline values when the team performs in the away venue. There may be several reasons for this counterintuitive finding. First, although the current study attempted to obtain a non-competitive baseline value, it is quite possible that there was a certain degree of intra-team competition that took place during practices. Thus, it may be that players were vying for status during practice and this may partly explain why practice cortisol values were similar to those observed when the team played in their home venue.

Another explanation for this finding is that away games may have been perceived as less important to the team. Although speculative, it is possible that a greater degree of status is at stake when the team competes in their home venue. During home games, the team competes in front of their friends and family, and thus, it is conceivable that they may have perceived home games as a more important status contest. Although the current study cannot ascertain whether higher levels of HPA activity prior to competition is permissive and/or intrusive, further studies assessing one's individual level of optimal functioning [36] may provide additional insight into the role of the HPA system in facilitating and/or debilitating athletic performance.

Examination of the post-game performance assessment yielded some mixed, yet interesting results. There was a negative correlation between coach evaluation of performance and pre-game testosterone levels for games played in the home venue. Although this relationship was in the opposite direction than expected, other research has reported similar results [37]. One possible explanation for this result may be due to the way that performance was assessed. It may be useful to assess performance by asking the players to subjectively rank their performance based on how they believe they played compared to their 'optimal performance'. Furthermore, despite findings indicating that testosterone is associated with positive qualities such as assertiveness and competitiveness, high levels of testosterone have been shown to be detrimental to performance [38,39]. In addition, a recent study suggests that performance may be impaired among individuals with high testosterone who are in a position of low status [40]. The authors have referred to this as the 'mismatch effect' and suggest that high testosterone individuals in a position of low status may be distracted by their lowly status and are unable to properly focus on the task at hand [40]. The individuals in the current study had a poor win/loss record, and thus may have felt as though they were on the low end of the 'status hierarchy' as compared to their opponents; however, in the current study, individual's perceived status was not measured. Although the 'mismatch effect' was originally applied to a non-physical setting, further studies should examine this effect within the realm of athletic competition.

Gonzalez-Bono et al. [41] reported that increases in testosterone during competition were positively correlated with individual contribution to team outcome. In addition, a recent study suggests that testosterone responsivity or play-related changes in testosterone is related to teammate ratings of playing abilities and self-ratings of connectedness with teammates [42]. Thus, it may be that testosterone responsivity to competitive interactions rather than pre-game testosterone should be the focus of future investigations.

Examination of the relationship between pre-game psychological states and performance revealed a trend towards a positive association between self-confidence and performance for home games and a significant association between self-confidence and performance for away games. Therefore, this study suggests that self-confidence is an important variable in the relationship between pre-game psychological states and athletic performance.

There was no significant association between pre-game cortisol and pre-game somatic anxiety. This finding was consistent with a previous study [29] demonstrating a lack of association between the physiological and psychological markers of anxiety. There are many possible reasons why the two measures do not correlate. First, the lack of association may be due to the timing in which the players provided the saliva sample and completed the questionnaire. All data were collected 45 min prior to all games and this may have led to individual variability in the athlete's stress response. The somatic anxiety items of the CSAI-2 assess many physiological symptoms of sympathetic nervous system arousal. For example, several of these items ask questions such as "my heart is racing", "my hands feel clammy" and "my body feels tense" which could be indicative of the first stage of the stress response, namely the sympathetic nervous system activation. It is possible that individuals reporting high levels of somatic anxiety 45 min prior to the competition may have yet to activate their long-term stress response, and thus may not have experienced any increase in salivary cortisol at this point. Furthermore, those individuals who showed high levels of pre-game salivary cortisol 45 min prior to competition may have subjectively reported lower levels of somatic anxiety because their short-term stress-response occurred prior to the data collection and the long-term stress-response, as evidence by the hypothalamic–pituitary adrenal axis release of cortisol has taken over. In addition, it is also possible that the athletes perceived anxiety as a negative emotion that may be frowned upon, and thus did not answer the questionnaire honestly.

Although the present study provides some strong evidence for differences in pre-game hormonal levels as well as psychological states, there are some limitations that need to be addressed. First, our sample size was small and further studies need to be conducted with larger sample sizes. Many team sports such as ice hockey are composed of 15–20 players, and thus, it may be necessary to investigate several teams in both the home and away venues. Furthermore, another limitation of the present study was the subjective assessment of post-game performance. All home games were lost in the current study, which may have biased the coach's ratings of the individual players. It is recommended that future studies assess individual performance by asking players to self-report on several aspects of their performance. The investigator may ask the individual athlete to compare his or her current performance to that of their past peak performances, which may yield a more reliable and valid assessment of individual performance.

The present study lends support to previous findings that pre-game testosterone levels and self-confidence are higher at home and somatic anxiety is higher when players are in their opponents' venue. Higher pre-game testosterone was not, however, associated with better performance as a significant negative correlation between pre-game testosterone levels and coach assessment of player performance was found. Interestingly, cortisol was higher before games played at home. This may, in part, be the result of cortisol responsiveness to social stress induced by the pressure to perform in front of friends and family who are more likely to be present in the home venue.

Future investigations should focus on competitions between teams with similar rankings and win–loss records in order to better assess the relationship of testosterone and the home advantage. Longitudinal studies that track players over the course of a season may yield data that would elucidate more of the nuances comprising the complex relationship among important psychological variables, hormones and performance in both home and away venues.

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