Testosterone and cortisol: Hormone reactivity as it relates to playing venue in male academy soccer players

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Abstract

(1) Background: The aim of the present study was to assess the psychophysiological changes experienced by male academy soccer players in relation to venue. The team was matched to opponents who were deemed to be of a similar standard to the reference team; this was ascertained by the previous season's league standing and coach ratings of opposition. (2) Methods: The sample comprised 14 male (M_{age} = 17.21, *SD* = .43) academy soccer players who competed for a Premier League Academy team. Salivary cortisol (C) and testosterone (T) levels were monitored at four time points (1 hour before, 30 minutes before, 30 minutes after and 1 hour after) across four competitive fixtures both at home and away, and a baseline training measure. Players also completed psychometric measures of sport emotion and social evaluation. (3) Results Findings showed that T was significantly higher after three defeats compared to training and the home win. Similarly, C was greater 30 minutes post-match compared to other timepoints. (4) Conclusions: In keeping with previous research, there were mixed findings in relation to anxiety and social evaluation. The current study provides further evidence that the relationship between endocrine responses, venue and psychological indicators are highly complex, and results may vary due to team levels, individual differences, opposition characteristics and venue.

Keywords: testosterone; cortisol; soccer; playing venue; competition; social evaluation

Introduction

The home advantage (HA) pertains to the 'consistent finding that home teams in sport competitions win over 50% of the games played under a balanced home and away schedule' (Courneya & Carron, 1992, p13). Explanations for HA include venue familiarity, crowd effects, referee bias and the negative impact of travel for opposing (i.e., away) teams (Carron et al., 2005). The Covid-19 pandemic presented an unprecedented opportunity to assess the HA in light of the absence of crowds, Wunderlich et al. (2021) assessed soccer matches across European football leagues and supported the impact of the crowd on referee bias via reduced fouls and yellow and red cards against the away team, interestingly, they also reported that the HA did not disappear in crowd-less stadiums as the dominance of the home team remained. Moreover, a recent analysis of a five-year data set of European football matches found referees gave more penalties, fewer fouls red and yellow cards to the home team; indeed, in crowd-less venues the HA resulting from referee decisions in favour of the home team was eliminated (Wolaver & Maggee, 2022). The HA is reported to be pervasive across most team sports such as soccer, ice hockey and basketball (Allen & Jones, 2014). Moreover, even with some variation in the level of effect, this advantage has been reported to remain consistent across countries and continents (Pollard & Gomez, 2014).

In the last two decades, research to further explain the home advantage has explored the psychophysiological perspective, with some studies implicating hormones in male ice hockey, soccer, basketball and rugby players (Carré et al., 2006; Gaviglio et al., 2014; Neave & Wolfson, 2003). One of the key hormones studied in relation to HA is testosterone (T). Regulated by the hypothalamic-pituitary-gonadal axis, T is a sex-steroid which contributes to bodily arousal and is also reactive to dominance, challenge and status threats (Archer, 2006; Mazur & Booth, 1998; Mehta & Josephs, 2006). One explanation for the psychophysiological response in T associated with these factors in HA is the territoriality model (Allen & Jones, 2014). This model suggests T increases as an evolutionary response to perceived invasion of home territory. Studies of male soccer players found T levels were significantly higher before home games compared to away games or training (Neave & Wolfson, 2003); and a similar pattern was observed in male ice hockey players (Carré et al., 2006).

Another psychophysiological response hormone of interest is cortisol (C), a glucocorticoid secreted by the adrenal cortex, considered an energising hormone which maintains homeostasis when individuals are faced with a challenge or threat (Wetherell et al., 2006). C is considered a good indicator of both physical and psychological stressors (Arruda et al., 2017). A meta-analysis of laboratory studies found the largest changes in and longest recovery times for C were for uncontrollable and social evaluative events (Dickerson & Kemeny, 2004). A series of competitive dancing studies (Rohleder et al., 2007) found C was substantially higher during competition than a control day, which was attributed to increased social evaluative stress. Higher C levels have also been demonstrated in males pre- and post-game when playing difficult compared to moderate and easy basketball opponents (Arruda et al., 2017). Competition outcome can also increase T levels in males following a

126 victory and decrease levels after a defeat (Carré et al., 2013; Elias, 1981; Zilioli & Watson,
127 2014).
128 Sporting competitions can provide an ideal arena to study T and C reactivity where
129 teams have a clear home venue, inter-individual conflict is apparent, and players experience
130 a range of dominance encounters, alongside psychological and physical stressors (Crewther,
131 2018; Zilioli & Watson, 2014). Mazur's (1985) biosocial model of status has been applied
132 to explain T and C responses in relation to competition outcome with varying success. The
133 model hypothesizes that winning a competitive encounter should result in a rise in T whereas
134 a defeat would lead to a decrease. This model was extended to also account for C, which was
135 proposed to rise following a defeat and decrease after a victory (Salvador, 2005). The model
136 and its considerations provide a good basis from which to study the psychophysiological
137 responses of T and C in relation to playing venue. In men's basketball, playing a home game
138 was associated with elevated pre game T, and despite venue, T and C remained elevated
139 across matches; nonetheless, there were no differences observed for effort or state anxiety
140 (Arruda et al., 2014). Contrasting findings were also reported in men's futsal, with an absence
141 of T and C effects between venues, although there was a significant increase in C from pre-
142 to post-game (Arruda et al., 2016). Similarly, in a male soccer study, there were no venue
143 effects for T; however, C levels were higher at home, and this occurred irrespective of
144 winning or losing (Fothergill et al., 2017).
145 Studies have also sought to examine psychological states of competitors using
146 measures of anxiety to provide further insight into T and C reactivity, with mixed findings.
147 For example, in judo athletes it was found that inter-regional competitions resulted in high
148 anxiety scores, increased C and lower self-confidence (Filaire et al., 2001). Moreover, in elite
149 rugby, no between-venue differences were reported for T and anxiety in starting players
150 (Cunniffe et al., 2015). In a comprehensive study of women soccer players (Casto &
151 Edwards, 2016), T and C were tracked across a series of time points at one home and away
152 venue. Consistent with previous studies, there were elevated levels of C and estradiol in
153 comparison to baseline, but not for T, and C also remained elevated for 30 minutes post-
154 game. Although the authors reported that there were no pre match or competition related
155 changes for venue or match outcome, T and C decreased more during the 30 minutes post-
156 match in the game that was won. The body of evidence highlights the complexity and
157 inconsistency of findings in establishing whether territoriality or competition or contextual
158 factors have more influence, requiring further research to examine hormone reactivity. Thus,
159 the current study builds upon Casto and Edwards (2016) by examining psychophysiological
160 responses in relation to playing venue and competition outcome at four time points. Based
161 on the biosocial model of status, we hypothesised:
162 H_1: Competition outcome would impact T and C; specifically, T would be higher
163 after victories and C higher with losses.
164 H_2: T would be higher at home and C higher at away venues.
165 H_3: Social evaluation, pre-competition anxiety and C would be positively correlated
166 at away venues.

Methods

Participants

After providing written informed consent, players from an under 18 UK Premier League Academy male youth academy soccer team (N =14; M_{age} = 17.21, SD = .43) were briefed regarding saliva sampling procedures (T and C) and psychometrics questionnaires.

Measures

Prior to games, players were asked to complete the Sport Emotion Questionnaire (SEQ) (Jones et al., 2005), which is a 22-item measure with five subscales comprising anxiety, dejection, anger, excitement and happiness. The measure requires athletes to indicate how they feel prior to their upcoming session by selecting 0 (not at all) to 4 (extremely) with initial CFA revealing acceptable model fit and alpha coefficients of 0.81-0.88 (Jones et al., 2005). As this is a competition specific measure which emphasises players emotional states prior to competition it was not deemed feasible to adopt this for the training measure as it has not been previously validated for this purpose.

Players were also asked to complete a measure of perceived social evaluation, similar to psychological measures taken by Rohleder et al. (2007). Players were asked to 'indicate from a list of competition factors they found stressful related to their upcoming game' (opposition, opposition coach, referee, crowd, parents/family, teammates, environment and travel to the game). This was measured on a 7-point Likert scale from 0 not at all to 7 extremely.

Procedure

The study was approved by Northumbria University Faculty of Health and Life Sciences ethics committee. Players were asked to produce saliva samples 60 minutes before, 30 minutes before, 30 minutes after and 60 minutes after two home games, two away games and one training session. Games and training commenced between 11 and 11.30am, and samples were collected from December to April. The testing schedule and game outcome is shown in Table 1. Players were instructed to maintain hydration with water at breaks but not to consume food within 1.5 hours prior to sampling to control for any consequential effects (Walsh et al., 2004). Players were provided with Salivettes ® (Sarstedt, Germany) and asked to place the provided cotton swab in their mouth for one minute before putting it in a Salivette collection tube Samples were stored at -20° within 4 hours post-match. Samples were assayed using the enzyme-linked immunosorbent assay method (Salimetrics-Europe, UK) within the recommended 28-day period (Toone et al., 2013). Samples were assayed in duplicate and inter-assay and intra-assay coefficients of variation for T and C were <10%.

Table 1. Schedule of fixtures and game outcome

	OPPOSITION	FIXTURE	RESULT
GAME 1	Team A	Away	Loss 2-1
GAME 2	Team B	Away	Loss 3-1
GAME 3	Team A	Home	Loss 3-0
GAME 4	Team B	Home	Win 2-1

Results

A within-subjects 5 x 4 design was used to test the effects of competition (HY1) and venue (HY2). Because playing venue and competition outcome were confounded, a 5-level within-subjects independent variable (*fixture*) was created: training, home win, home loss, away loss 1, away loss 2. *Time* of saliva sampling was the second independent variable with four levels: 60/30 mins pre, 30/60 mins post. Dependent variables were testosterone (T) and cortisol (C). *Perceived social evaluation* and *pre-competition anxiety* were used in bi-variate non-parametric correlations to test HY3.

Perceived social evaluation was measured using 7 items from Rohleder et al.'s (2007) questionnaire: opposition players, opposition coach, referee, crowd, friends/family, own coach, and teammates. Wording was modified for the professional football context (e.g., '*Indicate from a list of seven competition factors they found stressful related to their upcoming game*' (0 = *not at all*; 7 = *extremely)*. The total number of social evaluation factors the player found stressful was used to calculate overall perceived social evaluation (*Max* = 49). The 5-item anxiety subscale of the Sport Emotion Questionnaire was used (SEQ) (Jones et al., 2005). Athletes indicated how they felt prior to their upcoming session 0 (*not at all*) to 4 (*extremely*). Anxiety was calculated as the sum of items (*Max* = 20). Both were measured 60 minutes prior to competitive fixtures at the same time as the first saliva sample (60 mins pre).

For analyses of variance, a full player data set would consist of 560 data points (280 T; 280 C); due to injury/illness 115 data points (20.54%) were missing data at random (Little's MCAR x^2 = 130.00, *df* = 292, *p* >. 05). SPSS 28.0 multiple imputation procedure using regression was used to create imputed full data sets and followed guidelines presented by (Jakobsen et al., 2017). The values reported for repeated measures ANOVA are from the

imputed data set closest to the pooled descriptive statistics[1] because F statistics are not provided by SPSS for pooled values. Greenhouse-Geisser-corrected F values are reported due to sphericity violations.

For correlational analyses, two players were eliminated because they did not play in either away fixture. Full data (n = 12) was available for away loss 1; for away loss 2, 3 players did not compete (n = 12). As recommended for small N studies (Field, 2013), one-tailed Kendall's tau (t) was used to test the association between social evaluation, anxiety and C (HY3). T differed by *fixture*, F (2.65, 34.12) = 15.12, $p < .001$. It was significantly higher after the three losses compared to training and the home win (all $p < .01$). The main effect of *time* was also significant, F (2.07, 26.95) = 40.62, $p < .001$. T levels 60 mins pre- and post-match were similar. T at 60 mins pre-match was lower than both 30 mins prior and 30 mins post-match (all $p < .01$); T at 30 mins pre-match was lower than 30 mins post-match ($p < .001$). However, the fixture and time interaction suggested a more complicated pattern, F (4.86, 63.11) = 4.96, $p < .001$ (see Figure 1 for details). Simple effects analyses using Bonferroni correction indicated a competition effect: T was lower at different time points prior to a victory compared to prior to defeats; it was lower 30 mins pre/post-training compared with 30 mins pre/post defeats; and it was higher 60 mins post all competitive fixtures compared with 60 mins post training.

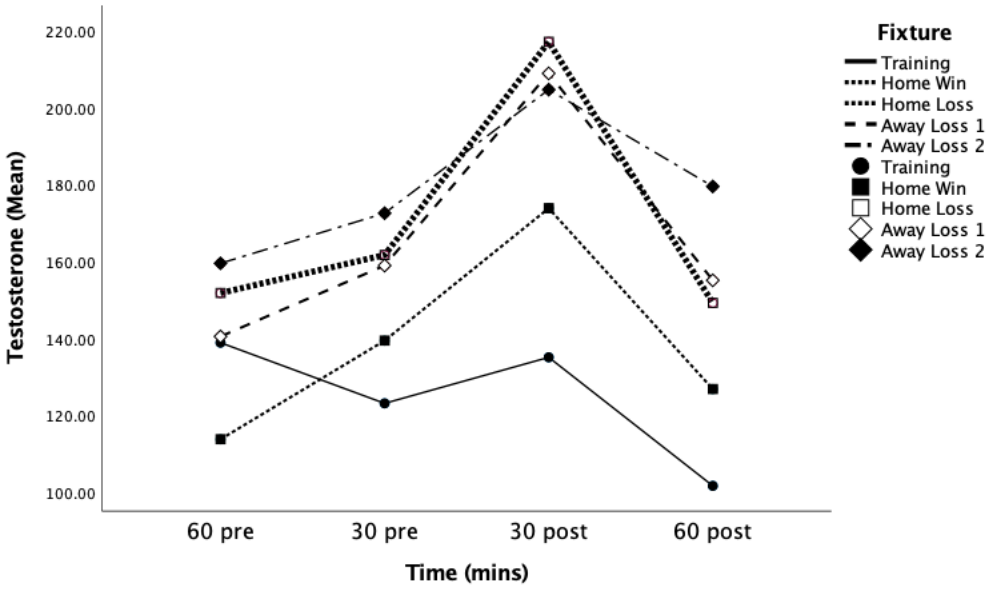

Figure 1: Fixture x Time interaction on testosterone

Note: Only significant post-hoc analyses are reported (simple effects, Bonferroni adjustment, all $p < .01$). 60 pre (home win) < 60 pre (home loss); 60 pre (home win) < 60 pre (away loss 2); Pre 30 (home win) < 30 pre (away loss 2); 60 post (home win) < all losses;

[1] Pooled descriptive statistics are estimated as if the original data had no missing values (IBM, 2021). The most-similar imputed set was chosen by 1) calculating mean differences (imputed vs pooled values) at each level of fixture and time, 2) calculating average mean difference within each imputed data set, to 3) identify the imputed set most like pooled values.

30 pre (training) < all losses; 30 post (training) < all losses; 60 post (training) < 60 post (all competitive fixtures).

Similar patterns were observed for C with a significant *fixture* (F (2.56, 33.35) = 13.55, $p < .001$) and *time* (F (1.65, 21.49) = 28.79, $p < .001$) main effects. C levels associated with training were lower than any competition and greater 30 mins post-match compared to other time points (all $p < .01$). Details of the *fixture* x *time* interaction are represented in Figure 2, F (5.28, 68.68) = 6.44, $p < .001$. Specifically, C was lower at both 30 mins before and 30 mins after training compared to 30 mins pre/post all defeats respectively, as well as 60 mins post training compared with 60 mins after all competitions. One hour before training, C was lower than the same timepoint prior to all competitions. There was a difference between C (30 mins pre) between the home loss and 1st away loss, with stress higher prior to the home fixture. C was lower 30 mins after the home victory compared with the home loss, and 30 mins after the home loss was lower than the 2nd away loss.

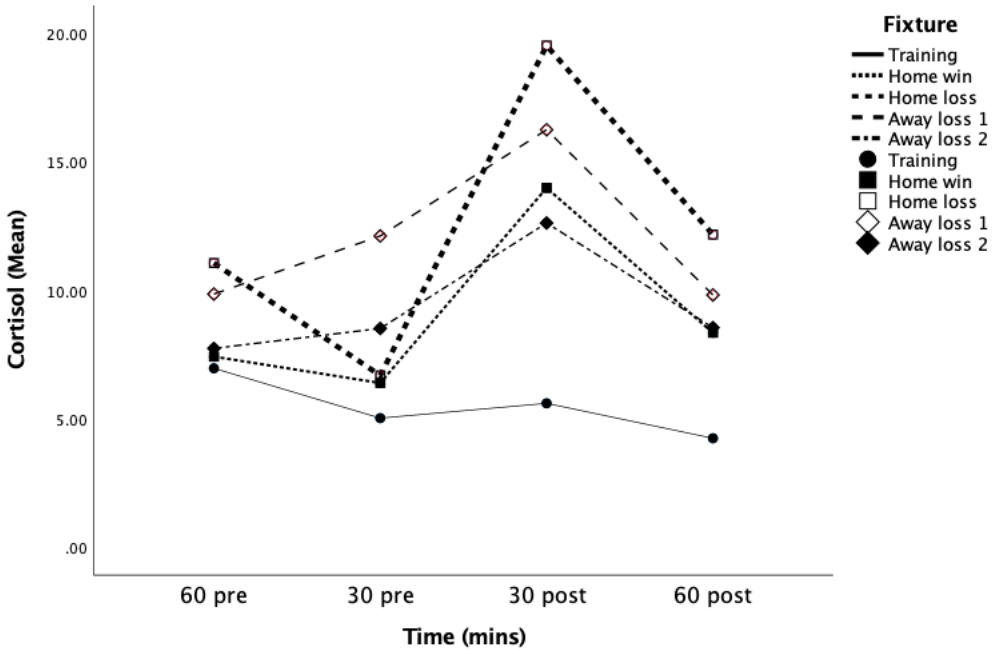

Figure 2: Fixture x Time interaction on cortisol

Note: Only significant post-hoc analyses are reported (simple effects, Bonferroni adjustment, all $p < .01$). 60 pre (training) < 60 pre (home loss); 30 pre (training) < 30 pre (away loss 1; away loss 2); 30 post (training) < all competitions; 60 mins post (training) < 60 mins post (all competitions); 30 pre (home loss) < 30 pre (away loss 1); 30 mins post (home win) < 30 mins post (home loss); 30 mins post (home loss) >30 mins post (away loss 2).

Scatterplots indicated an outlier for C linked to away loss 1 (n = 11). C (60 mins pre) was negatively associated with pre-competition anxiety (t = -.49, p < .02) but not social evaluation (t = -.04, p = .44); anxiety and social evaluation were not significantly correlated, (t = .32, p = .09). For away loss 2 (n = 9), C (60 mins pre) and pre-competition anxiety were negatively correlated (t = -.65, p < .01). Neither C (60 mins pre) and social evaluation (t = .09, p = .38) nor anxiety and social evaluation (t = .17, p = .26) were not significantly correlated.

Discussion

The current study aimed to examine the association between playing venue and endocrine responses of T and C, alongside psychometric measures of emotion and social evaluation in male academy players competing against matched opposition. Surprisingly, the current study did not support hypotheses in relation to replicating endocrine responses associated with the biosocial model of status. Whilst this finding is unusual, Arruda et al.'s (2016) futsal study also did not observe any differences in relation to T or C by playing venue. It can be speculated that at academy level the home advantage is perhaps less pronounced due to smaller venues and crowds. It is conceivable that players at this age do not fully experience the phenomenon, given their career fluidity and uncertainty. This was an explanation also posited by Cunniffe, et al. (2015) who reported that rugby players perhaps did not perceive that, psychologically, playing at home was of greater importance than playing away and may not fully experience the HA phenomenon.

The impact of competition on T and C reactivity was supported, given that baseline measures at training were significantly lower than all competition time points. This concurs with a dance study (Rohleder et al., 2007), where C levels were lower on training days, and also with previous home advantage research where both T and C were lower for training (Fothergill et al., 2017; Neave & Wolfson, 2003). Perhaps the most interesting finding is that, irrespective of venue or result, soccer competition was associated with an increase in T and C; both hormones were significantly elevated 30-mins post-match and decreased a further 30 minutes after competition. Casto and Edwards, (2016) reported female footballers' C remained elevated 30-mins post competition; however, in contrast to the current study, T also declined during this same period and both T and C declined 30 mins post-competition in the game that was lost. In female rugby players, there was an anticipatory rise of T and C, although post-game levels were higher than pre-game and T change was not related to victory or defeat (Bateup et al., 2002). In a football-specific meta-analysis and systematic review (Slimani & Nikolaidis, 2017), T responses varied as a function of game outcome with larger responses in winners; C levels, however, did not vary in relation to outcome. The review proposed that competitive levels could have moderated the C responses, with novice players exhibiting greater C reactivity than their elite counterparts. Moreover, this elevation of T and within 30-mins post-match could also indicate endocrine responses are adaptive, reflecting the competitive nature and stressors of the sport (Arruda et al., 2016; Casto & Edwards, 2016). As an adaptive response to exercise, short-term elevations in C provide energy to the

muscles from an increase in glucose in the blood; this subsequently reduces muscle inflammation (Coutinho & Chapman, 2011).

The findings in relation to psychometrics were mixed, with non-significant findings between pre-game cortisol levels and social evaluation, which contrasts with Rohleder et al.'s (2007) study. Psychometric data pertaining to mood, confidence, somatic and cognitive anxiety have often failed to yield meaningful results, and findings are often equivocal (Jiménez et al., 2012; Neave & Wolfson, 2004). This has been echoed in studies specifically relating to the home advantage with mixed findings reported between mood and psychological responses to playing venue and competition in male soccer players (Fothergill et al., 2017; Neave & Wolfson, 2003). Interestingly, in the current study, pre-match cortisol for both away losses were negatively correlated with pre-competition anxiety. It is typically suggested that glucocorticoid production, i.e. cortisol, and negative affect are elevated as a consequence of stressful situations (Kirschbaum & Hellhammer, 1994). Whilst not in a sporting context, laboratory-based studies have found cortisol can have a mood protective effect with an acute stress laboratory study showing increased cortisol levels and smaller negative affect in male and female participants (Abercrombie et al., 2023). Indeed, the mood buffering effects of cortisol were also reported in another laboratory based acute stress study with findings suggesting cortisol was associated with an attenuated negative affect in relation to the Trier Social Stress Test (Het et al., 2012). Further suggestions for disparate results relating to elicitation of emotional states in relation to sporting competition have included differences in athlete experience, mood measures selected, and the nature of the sport played (Arruda et al., 2014). This also supports the challenge of measuring stressful encounters naturalistically (Abercrombie et al., 2023).

Conclusions

A strength of the present study concerns the naturalistic sampling of two hormones across four competitive matches with four testing timepoints per match. The study also provided a real-world insight into match-specific hormone reactivity in competitive football against opposition who were deemed equivalent in ability. However, as with similar naturalistic studies, a limitation of this study pertains to the small sample size. To limit confounding variables such as diurnal variations and variations in match results, only one team was included in the study; as such, this inevitably led to some incomplete data sets due to sample viability, participant drop out, illness, injury and loan spells which were uncontrollable. Due to the unpredictable nature of competitive sport, it was also unfortunate that game outcomes were not more varied than the three defeats and one home win.

The findings highlight the need to further explore the potential temporal effects of T and C in relation to the home advantage in soccer to gain an insight into why such variability exists in player responses. The current study also provides some informative new information in relation to the 30-min post rise in T and C. Future research may benefit from adopting a longitudinal approach which would include more matches and further timepoints throughout the week leading up to, during and after matches. Whilst not included in the current study,

future research may also wish to examine positional specific profiles of players; to identify whether psychophysiological outcomes including T, C and perceived social evaluation are more pronounced for specific positions e.g., forwards who need to score goals or defensive players who protect home territory. Notwithstanding, the current study provides some new information in relation to the 30-min post-match rise in T and C. Future research may benefit from including GPS data to evaluate physiological effort given the 30-minute post-game rise of C. This could assist researchers in determining the full endocrine profiles and how competitive encounters and effort can impact upon these effects.

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