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1 **Testosterone and cortisol: Hormone reactivity as it relates to playing**
2 **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 H₁: Competition outcome would impact T and C; specifically, T would be higher
163 after victories and C higher with losses.

164 H₂: T would be higher at home and C higher at away venues.

165 H₃: Social evaluation, pre-competition anxiety and C would be positively correlated
166 at away venues.

167 **Methods**

168 **Participants**

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

172 **Measures**

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

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

187 **Procedure**

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

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206 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

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Results

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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.

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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).

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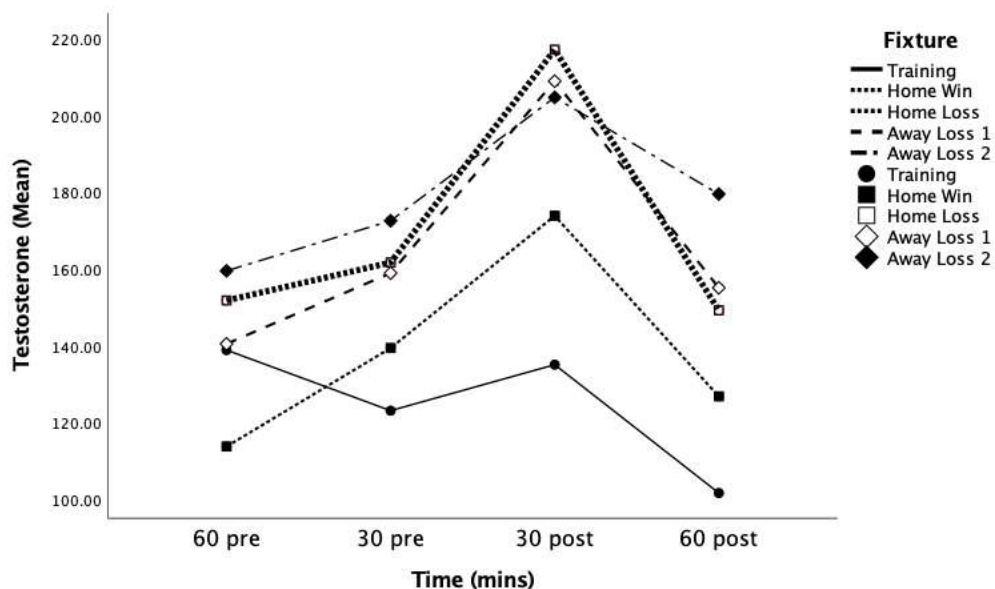
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For analyses of variance, a full player data set would consist of 560 data points (280 T; 280 C); due to injury/illness 115 data points (20.54%) were missing data at random (Little's MCAR $\chi^2 = 130.00$, $df = 292$, $p > .05$). SPSS 28.0 multiple 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

232 imputed data set closest to the pooled descriptive statistics¹ because F statistics are not
 233 provided by SPSS for pooled values. Greenhouse-Geisser-corrected F values are reported
 234 due to sphericity violations.

235 For correlational analyses, two players were eliminated because they did not play in
 236 either away fixture. Full data ($n = 12$) was available for away loss 1; for away loss 2, 3 players
 237 did not compete ($n = 12$). As recommended for small N studies (Field, 2013), one-tailed
 238 Kendall's tau (t) was used to test the association between social evaluation, anxiety and C
 239 (HY3). T differed by *fixture*, $F(2.65, 34.12) = 15.12, p < .001$. It was significantly higher
 240 after the three losses compared to training and the home win (all $p < .01$). The main effect
 241 of *time* was also significant, $F(2.07, 26.95) = 40.62, p < .001$. T levels 60 mins pre- and
 242 post-match were similar. T at 60 mins pre-match was lower than both 30 mins prior and 30
 243 mins post-match (all $p < .01$); T at 30 mins pre-match was lower than 30 mins post-match (p
 244 $< .001$). However, the fixture and time interaction suggested a more complicated pattern, F
 245 $(4.86, 63.11) = 4.96, p < .001$ (see Figure 1 for details). Simple effects analyses using
 246 Bonferroni correction indicated a competition effect: T was lower at different time points
 247 prior to a victory compared to prior to defeats; it was lower 30 mins pre/post-training
 248 compared with 30 mins pre/post defeats; and it was higher 60 mins post all competitive
 249 fixtures compared with 60 mins post training.



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251 **Figure 1: Fixture x Time interaction on testosterone**

252 Note: Only significant post-hoc analyses are reported (simple effects, Bonferroni
 253 adjustment, all $p < .01$). 60 pre (home win) $<$ 60 pre (home loss); 60 pre (home win) $<$ 60
 254 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.

255 30 pre (training) < all losses; 30 post (training) < all losses; 60 post (training) < 60 post (all
 256 competitive fixtures).

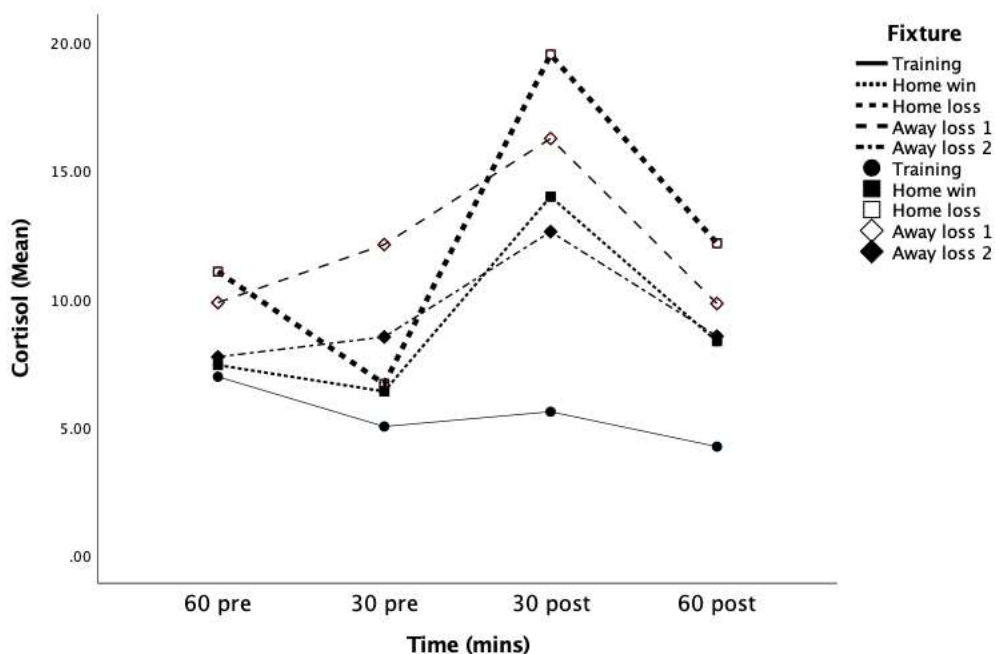
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258 Similar patterns were observed for C with a significant *fixture* ($F(2.56, 33.35) = 13.55$,
 259 $p < .001$) and *time* ($F(1.65, 21.49) = 28.79$, $p < .001$) main effects. C levels associated with
 260 training were lower than any competition and greater 30 mins post-match compared to other
 261 time points (all $p < .01$). Details of the *fixture* x *time* interaction are represented in Figure 2,
 262 $F(5.28, 68.68) = 6.44$, $p < .001$. Specifically, C was lower at both 30 mins before and 30
 263 mins after training compared to 30 mins pre/post all defeats respectively, as well as 60 mins
 264 post training compared with 60 mins after all competitions. One hour before training, C was
 265 lower than the same timepoint prior to all competitions. There was a difference between C
 266 (30 mins pre) between the home loss and 1st away loss, with stress higher prior to the home
 267 fixture. C was lower 30 mins after the home victory compared with the home loss, and 30
 268 mins after the home loss was lower than the 2nd away loss.

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274 **Figure 2: Fixture x Time interaction on cortisol**

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

280

281 Scatterplots indicated an outlier for C linked to away loss 1 ($n = 11$). C (60 mins pre)
282 was negatively associated with pre-competition anxiety ($t = -.49, p < .02$) but not social
283 evaluation ($t = -.04, p = .44$); anxiety and social evaluation were not significantly correlated,
284 ($t = .32, p = .09$). For away loss 2 ($n = 9$), C (60 mins pre) and pre-competition anxiety were
285 negatively correlated ($t = -.65, p < .01$). Neither C (60 mins pre) and social evaluation ($t =$
286 $.09, p = .38$) nor anxiety and social evaluation ($t = .17, p = .26$) were not significantly
287 correlated.

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Discussion

290 The current study aimed to examine the association between playing venue and
291 endocrine responses of T and C, alongside psychometric measures of emotion and social
292 evaluation in male academy players competing against matched opposition. Surprisingly, the
293 current study did not support hypotheses in relation to replicating endocrine responses
294 associated with the biosocial model of status. Whilst this finding is unusual, Arruda et al.'s
295 (2016) futsal study also did not observe any differences in relation to T or C by playing venue.
296 It can be speculated that at academy level the home advantage is perhaps less pronounced
297 due to smaller venues and crowds. It is conceivable that players at this age do not fully
298 experience the phenomenon, given their career fluidity and uncertainty. This was an
299 explanation also posited by Cunniffe, et al. (2015) who reported that rugby players perhaps
300 did not perceive that, psychologically, playing at home was of greater importance than
301 playing away and may not fully experience the HA phenomenon.

302 The impact of competition on T and C reactivity was supported, given that baseline
303 measures at training were significantly lower than all competition time points. This concurs
304 with a dance study (Rohleder et al., 2007), where C levels were lower on training days, and
305 also with previous home advantage research where both T and C were lower for training
306 (Fothergill et al., 2017; Neave & Wolfson, 2003). Perhaps the most interesting finding is that,
307 irrespective of venue or result, soccer competition was associated with an increase in T and
308 C; both hormones were significantly elevated 30-mins post-match and decreased a further 30
309 minutes after competition. Casto and Edwards, (2016) reported female footballers' C
310 remained elevated 30-mins post competition; however, in contrast to the current study, T also
311 declined during this same period and both T and C declined 30 mins post-competition in the
312 game that was lost. In female rugby players, there was an anticipatory rise of T and C,
313 although post-game levels were higher than pre-game and T change was not related to victory
314 or defeat (Bateup et al., 2002). In a football-specific meta-analysis and systematic review
315 (Slimani & Nikolaidis, 2017), T responses varied as a function of game outcome with larger
316 responses in winners; C levels, however, did not vary in relation to outcome. The review
317 proposed that competitive levels could have moderated the C responses, with novice players
318 exhibiting greater C reactivity than their elite counterparts. Moreover, this elevation of T and
319 within 30-mins post-match could also indicate endocrine responses are adaptive, reflecting
320 the competitive nature and stressors of the sport (Arruda et al., 2016; Casto & Edwards,
321 2016). As an adaptive response to exercise, short-term elevations in C provide energy to the

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

324 The findings in relation to psychometrics were mixed, with non-significant findings
325 between pre-game cortisol levels and social evaluation, which contrasts with Rohleder et al.'s
326 (2007) study. Psychometric data pertaining to mood, confidence, somatic and cognitive
327 anxiety have often failed to yield meaningful results, and findings are often equivocal
328 (Jiménez et al., 2012; Neave & Wolfson, 2004). This has been echoed in studies specifically
329 relating to the home advantage with mixed findings reported between mood and
330 psychological responses to playing venue and competition in male soccer players (Fothergill
331 et al., 2017; Neave & Wolfson, 2003). Interestingly, in the current study, pre-match cortisol
332 for both away losses were negatively correlated with pre-competition anxiety. It is typically
333 suggested that glucocorticoid production, i.e. cortisol, and negative affect are elevated as a
334 consequence of stressful situations (Kirschbaum & Hellhammer, 1994). Whilst not in a
335 sporting context, laboratory-based studies have found cortisol can have a mood protective
336 effect with an acute stress laboratory study showing increased cortisol levels and smaller
337 negative affect in male and female participants (Abercrombie et al., 2023). Indeed, the mood
338 buffering effects of cortisol were also reported in another laboratory based acute stress study
339 with findings suggesting cortisol was associated with an attenuated negative affect in relation
340 to the Trier Social Stress Test (Het et al., 2012). Further suggestions for disparate results
341 relating to elicitation of emotional states in relation to sporting competition have included
342 differences in athlete experience, mood measures selected, and the nature of the sport played
343 (Arruda et al., 2014). This also supports the challenge of measuring stressful encounters
344 naturalistically (Abercrombie et al., 2023).

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Conclusions

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

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

363 future research may also wish to examine positional specific profiles of players; to identify
364 whether psychophysiological outcomes including T, C and perceived social evaluation are
365 more pronounced for specific positions e.g., forwards who need to score goals or defensive
366 players who protect home territory. Notwithstanding, the current study provides some new
367 information in relation to the 30-min post-match rise in T and C. Future research may benefit
368 from including GPS data to evaluate physiological effort given the 30-minute post-game rise
369 of C. This could assist researchers in determining the full endocrine profiles and how
370 competitive encounters and effort can impact upon these effects.
371

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