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Testosterone, territoriality, and the 'home advantage'

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Abstract

The consistently better performance seen by teams in various sporting contexts when playing at home is referred to as the 'home advantage'. Various explanations have been put forward to account for this robust phenomenon, though none has yet focussed on possible hormonal factors. In an initial study, we showed that salivary testosterone levels in soccer players were significantly higher before a home game than an away game. In a second study involving a different group of soccer players, this finding was replicated over two home games, two away games, and three training sessions. Perceived rivalry of the opposing team was important as testosterone levels were higher before playing an 'extreme' rival than a 'moderate' rival. Self-reported measures of mood in both studies were not linked to testosterone level. The present results corroborate and extend earlier findings on the relationships between testosterone, territoriality, and dominance in human competitive encounters and further suggest an important role for testosterone in the home advantage seen in various team sports.

Keywords: Testosterone; Home advantage; Competition; Territoriality

1. Introduction

The home advantage in sport is well documented in virtually every team game such as baseball, American football, ice hockey, rugby, and basketball [1,2]. The phenomenon is particularly pervasive in association football (soccer), where teams consistently win more games and score more goals when playing at home as opposed to away, regardless of their level of expertise. Table 1 depicts the remarkably similar home advantage patterns across the various divisions of the English Football League in the 2000–2001 season. Furthermore, an analysis of 30 countries' international games reveals that 60% of home games and only 43% of away games are won, with overall goals at home averaging 19.17, at the opponents' venue 13.27, and at neutral venues 10.70.

Several factors have been proposed to account for this effect. One view is that the home crowd encourages and inspires the home team to play well. Proponents of this theory note that the home advantage increases with noise and crowd density [3]. American football and baseball teams whose stadia are domed, and therefore noisier, appear to have an increased home advantage [4].

Referee bias is also likely to contribute to the home advantage. According to the Opta Football Yearbook [5], referee statistics for the 2000–2001 English Premiership football season reveal significant differences in yellow cards (698 against the away team, 512 against the home team) and penalties (42 against the away team, 26 against the home team). Nevill, Balmer, and Williams [6] found that when football referees were shown incidents without any crowd noise, the home advantage was virtually eliminated.

A third explanation relates to familiarity with the home venue. Familiar visual cues may increase spatial awareness, allowing a footballer who falls or turns quickly to reorient more efficiently at a home venue than when playing away. Knowledge and experience of a football pitch's size and surface can contribute to this effect. In a study of results over eight seasons, Barnett and Hilditch [7] found that teams playing on artificial surfaces had a moderately inflated home advantage.

Travel fatigue and routine disruption may also contribute to the home advantage. Snyder and Purdy [8] reported a greater disadvantage for basketball teams who travelled more than 200 miles, though most other studies (e.g., Ref. [9]) show minimal or no effects for travel or time zone changes.

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Table 1
Home advantage statistics, English Football Leagues, 2000–2001

Division (*N* teams)	Average home wins	Average away wins	Proportion of wins at home	Average home goals	Average away goals
Premiership (20)	9.20	4.75	0.66	29.35	20.25
Division 1 (24)	10.29	6.54	0.64	32.54	24.67
Division 2 (24)	10.08	6.62	0.61	35.08	26.00
Division 3 (24)	11.38	5.08	0.70	35.13	23.08

One explanation that has received little attention is that of territoriality, the protective response to an invasion of one's perceived territory. Territoriality is prevalent amongst many animal species, which typically display agonistic behaviours and attack more readily and with greater vigour when defending a home territory [10]. Several studies have shown a 'home advantage' for an animal when its territory is threatened or attacked, even when the defender is smaller than the rival, suggesting an important motivational incentive in territorial defense [11].

Several lines of animal research suggest that agonistic behaviours in male animals are related to levels of the steroid hormone testosterone. Firstly, seasonal variations in testosterone coincide with seasonal variations in aggression [12]. Second, testosterone levels show a marked increase at puberty and recorded levels of aggression rise accordingly [13]. Third, artificially raising testosterone levels increases aggressiveness [14]. Finally, territorial aggression in animals has been related to circulating levels of testosterone, with an 'invasion' triggering a subsequent rise in this hormone [15]. Similar changes in testosterone level are seen when dominance hierarchies are being formed, and when sexually receptive mates are being guarded [16]. However, it must be noted that not all studies find such links between testosterone, seasonality, and aggression in animals (e.g., Refs. [17,18]).

While the relationship between testosterone levels and human aggression remains equivocal [19], one review concluded that testosterone does appear to be linked with dominance and competitiveness in humans [20]. The authors argued that testosterone rises in the face of a challenge and activates behaviours intended to dominate and enhance status, though not all researchers agreed with these views (see peer discussion following Ref. [20]). In human societies, aggression has been ritualised in the form of competition and sport, and higher testosterone levels have been associated with threats, fights, and attacks in male judo competitors [21] and with professional basketballers' contributions to the game outcome, measured by the score/time playing ratio [22]. Increases in testosterone have also been reported in winning tennis players [23,24], although the direction of causality remains unclear.

In terms of territoriality, evidence exists from nonsporting contexts that humans are more dominant and activated within a territory defined as their own. Male students involved in decision-making tasks exert more control and behave more assertively when the session takes place in their own room, even when they have not been assigned a position of control [25] or when they are low in the personality trait of dominance [26].

Although some studies have shown increased aggression and arousal at home venues in the context of ice hockey [27] and rugby [28], very few studies have assessed links between perceived territoriality and the home advantage in sport. If testosterone levels are indeed linked with assertiveness and dominance, and if humans also fight harder to defend their perceived home territory, there may be alterations in testosterone levels in sports competitors when playing at home and away. The aim of the present study was to investigate possible changes in testosterone levels of football players dependent upon match venue. As testosterone changes have also been linked with the mood of a competitor [23], this study also examined relationships between testosterone level and self-reported mood and dominance. In order to address these aims, two studies were conducted.

2. Study 1: Materials and methods

2.1. Sample

The sample was composed of 17 male soccer players from a team playing in the Unibond Football League (UK). All players completed an informed consent form and a personal data sheet indicating that they were healthy and free of steroid medication. Ten of the sample played in both the home and away matches of interest and were included in the final analyses, the average age of this sample being 26.57 (S.D. = 4.39), with a range of 21–35 years.

2.2. Procedure

After gaining approval from the Division of Psychology Ethics Committee and permission from the club manager to approach the squad, the experimenters met with the players in their changing room 1 h before a home game (end of February) and 1 week later at an away game (beginning of March) against the same opposing team, whose position in the league standings was close to that of the experimental team. The away venue was approximately 65 miles away from the home venue. The players were given labelled, lidded cups and sugarless chewing gum, and were asked to chew the gum and deposit enough saliva to fill the bottom of the cup (5 ml). Sample collection took 1–3 min. All samples were collected 1 h before the games began (16:45 h), and the samples were then frozen to −20 °C. The players completed short mood questionnaires before and after the matches consisting of 16 independent mood items such as *enthusiastic*, *confident*, *anxious*, *dominant*, and *aggressive*, answered on a *Not at all–Extremely* five-point Likert scale. Conventional mood measures were deemed too

long, due to time constraints, and difficult; indeed, an original item, 'subdued,' was omitted when it transpired that many of the players did not know its meaning.

2.3. Hormone measures

Salivary testosterone was used as it is less stressful and invasive than serum sampling and causes minimal disruption to normal routines [29]. A strong correlation has been reported between salivary and serum testosterone levels [30]. As circadian and circannual changes in testosterone have been reported [31–33], samples were collected at the same time of day.

Testosterone levels in saliva samples were measured using a modified serum radioimmunoassay. Before assaying, the previously frozen samples were thawed and centrifuged. The assay utilised the Coat-A-Count total testosterone kit (Euro/DPC, Wales, UK), which is a solid phase radioimmunoassay, based on testosterone-specific antibodies immobilised to the wall of a polypropylene tube. ^{125}I-labelled testosterone competes for a fixed time with testosterone in the saliva sample for antibody sites. The tube is then decanted, to separate antibody-bound testosterone (on walls of the tube) from free testosterone (in the decanted solution). The tubes are counted using a gamma counter and the amount of testosterone present in the saliva sample is determined from a calibration graph of known standards, where higher gamma counts equate to lower testosterone levels. This procedure has to be modified to allow for measurement of the lower hormone concentrations in saliva by diluting the supplied Coat-A-Count testosterone standards 20-fold and extending the incubation time from 3 h at 37 °C to 24 h at room temperature. Each sample was assayed in duplicate and the mean value for the two duplicates taken as the value for each sample. The tubes were each counted for 1 min using a Packard Cobra II gamma counter.

Table 2
Changes in mean mood ratings in Study 1

	Home	Away
Enthusiastic	3.6 (0.70)	3.6 (0.97)
Energetic	3.6 (0.70)	3.5 (0.71)
In control	3.8 (0.63)	4.0 (0.67)
Unsure	1.9 (1.10)	1.7 (0.95)
Good-natured	3.5 (0.85)	3.9 (57)
Confused	1.9 (1.20)	1.8 (1.14)
Cheerful	3.7 (0.48)	3.9 (0.57)
Anxious	1.9 (0.99)	2.0 (1.05)
Tired	3.1 (1.10)	2.6 (0.70)
Confident	3.7 (0.48)	4.0 (0.71)
Angry	2.3 (1.00)	2.1 (0.99)
Mentally alert	3.4 (0.70)	3.4 (0.52)
Downhearted	1.5 (0.85)	1.8 (1.03)
Calm	3.8 (0.92)	3.6 (1.17)
Dominant	3.3 (0.82)	3.4 (0.70)
Aggressive	2.8 (1.40)	3.0 (1.15)

Standard deviations are in parentheses.

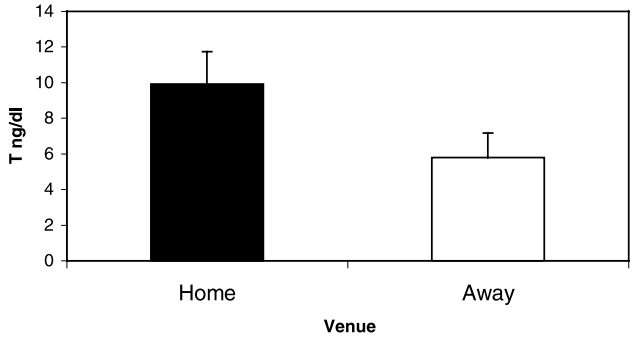

Fig. 1. Mean testosterone level in 10 soccer players before a home and away game.

3. Results

Matched pairs t tests showed no significant differences between any of the individual mood measures before the home and away matches (see Table 2) However, a matched pairs t test ($t = 2.75$, $df = 9$, $P < .02$) revealed that testosterone was significantly higher before the home game (mean = 9.93 ng/dl, S.E. = 1.80) than the away game (mean = 5.79 ng/dl, S.E. = 1.39) (see Fig. 1). No significant correlations between testosterone and the various mood measures were found in either home or away conditions.

4. Study 2: Materials and methods

4.1. Sample

The sample consisted of 25 players from an under-19 squad of a Premiership football team (UK). Players again completed an informed consent form and a personal data sheet which indicated that they were healthy and free of steroid medication. Nineteen of the players (average age 18.37, S.D. = 1.01, range from 16.75 to 19.33 years) were present in all conditions and included in the analyses.

4.2. Procedure

Following ethical approval, the same procedure as that used in the first study was followed. Samples were taken 1 h before home and away matches against the same two teams, as well as an hour before three different training sessions. All sampling was conducted in the morning between 10:00 and 11:00 and took 1–3 min. The competition samples were collected between October and March of the same season, with the training samples collected at the beginning, middle, and end of this period. Mood questionnaires were also completed, and three coaches rated the players on a number of dimensions. The items for both the self-reports and coach

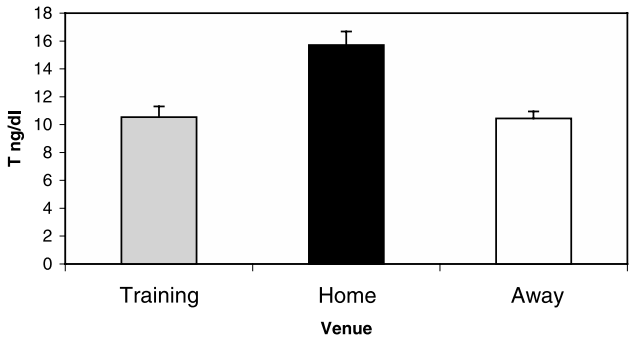

Fig. 2. Mean testosterone level in 19 soccer players before home and away games and neutral training sessions.

ratings were similar to those used in the first study, again using a *Not at all–Extremely* five-point Likert scale. The two away games were held relatively near to the experimental team's home grounds (15 and 29 miles away, respectively). The players were also asked to rate the extent to which they felt a sense of rivalry toward different teams in their league; however, a ceiling effect indicating extreme rivalry toward every team necessitated a re-wording of the item, requiring players to identify the one team in the league towards whom they felt the greatest degree of rivalry.

4.3. Hormone measures

The same method of collecting, storing, and measuring testosterone was used as in the first study, and the time of saliva collection remained constant. However, due to the fixtures being out of experimental control, the home and away games were separated by several months (both home games took place in October, while the away games took place in December and March). This possible confound is addressed in the discussion.

5. Results

Mean testosterone levels for the training, home, and away venues were analysed. A repeated measures ANOVA [$F(2,18) = 23.66$, $P < .001$] followed by Tukey post hoc comparisons revealed that testosterone levels were significantly higher in the home condition (mean = 15.71 ng/dl, S.E. = 0.97) than the away (mean = 10.45 ng/dl, S.E. = 0.50) and training (mean = 10.5 ng/dl, S.E. = 0.77) conditions (see Fig. 2). There was no difference between the away and training conditions.

High ratings of rivalry were indicated toward both teams, but one team was endorsed by 89% of the players as the team to whom they felt the most extreme rivalry, while only one player felt the highest degree of rivalry toward the other team. A further mixed two-way ANOVA, varying venue and level of rivalry, revealed the expected main effect for venue [$F(1,18) = 34.47$, $P < .001$] as well as a main effect for rivalry, with testosterone levels against the extreme rival team averaging 14.52 ng/dl and moderate rival team averaging 11.65 ng/dl [$F(1,18) = 27.55$, $P < .001$] (see Fig. 3). No interaction was found.

As in the first study, the self-report ratings of such states as dominance and aggression did not relate to testosterone, venue or rivalry, nor were any differences found when a composite measure of positively worded items was analysed (see Table 3).

Some effects for player position were indicated (see Fig. 4). Overall, the strikers (offensive players) tended to have higher levels of testosterone across the different venues, while the goalkeepers were lowest in training and highest

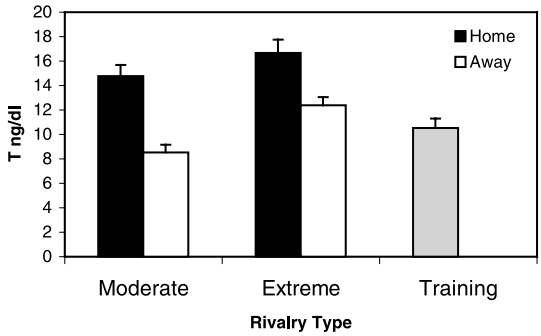

Fig. 3. Mean testosterone level in 19 soccer players playing against moderate and extreme rivals before home and away games, with mean level before neutral training sessions included for comparison.

Table 3
Changes in mean mood ratings in Study 2

	Home		Away		Training
	Extreme rival	Moderate rival	Extreme rival	Moderate rival	
Positive mood	35.83 (3.79)	34.50 (6.38)	35.76 (3.46)	35.06 (2.98)	33.56 (3.76)
Aggression	4.17 (1.04)	3.89 (1.18)	4.47 (0.80)	4.22 (0.73)	4.06 (0.68)
Dominance	4.65 (4.65)	4.00 (0.73)	4.52 (0.62)	4.39 (0.50)	4.00 (0.87)

Standard deviations are in parentheses.

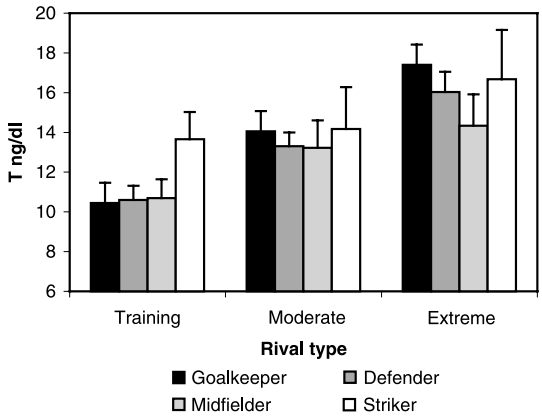

Fig. 4. Mean testosterone levels in 19 soccer players before playing against moderate and extreme rivals according to player position.

against the extreme rival. However, due to the low numbers of players in the analysis, particularly goalkeepers ($N = 2$), these interesting patterns remain speculative.

6. Discussion

Both studies indicated that salivary testosterone levels in male soccer players vary as a function of the venue before a competitive match, levels being significantly higher before a home than an away game or a training session.

Previous studies have shown a pre-competition anticipatory rise in testosterone [23,34,35]. The present results found only an increase before home games but no difference between levels before training and away games. Mazur, Susman, and Edelbrock [35] have shown that a pre-game rise in testosterone is less likely to occur if the event is regarded as unimportant, which could explain the lower levels found before training. However, the similarly low levels before the away games are more difficult to interpret, as the games are highly unlikely to have been perceived as unimportant. The fact that increases in testosterone were higher when the teams played an extreme rival (in Study 2) provides further support to previous reports attesting to the perceived importance of the rival to be played [24,36,37]. It could be that our results reflect a surge in testosterone before home games rather than a deflated level at the away games. While the players in the first study were older than those in the second study (around 8 years on average) and their testosterone levels were lower than in the younger sample, the same pattern of higher pre-competitive levels at home and lower levels away was seen.

Self-report mood ratings taken in both studies did not relate to physiological changes before home games, away games, and training sessions. The extent to which a surge in testosterone should be discernable by an individual, and if so, whether this finding represents an unawareness of an underlying physiological state, is difficult to ascertain. An alternative interpretation is that although the players were assured of confidentiality throughout the study, they might have harbored concerns that their coach would indeed have access to their questionnaires and thus consciously disguised their true feelings. Another possibility is that the players might have modified their responses in order to feel personally impervious to the changes in playing conditions, thus increasing confidence in their mental stability.

The difficulty of relating mental states to playing conditions and physiological changes is highlighted by the fact that the coaches' ratings of players did not relate to any testosterone or mood measures. Although this present study did not find any relationship between players' self-reported mood and testosterone, subsequent studies may consider alternative mood questionnaires and/or physiological measures (e.g., cortisol). However, the failure to find links between testosterone with self-report measures and coaches' ratings is not wholly unexpected. Certainly, studies relying on paper-and-pencil measures have yielded few relationships with testosterone [19], though most of these have attempted to relate testosterone to behaviours more distant in time.

In our second study, players also indicated the extent of their rivalrous feelings towards the opposing teams and a noteworthy effect was found when responses to the extreme versus the moderate rival opponents were compared. While testosterone levels were still consistently higher before the home than the away games, levels were even higher when the opponents were perceived as being extreme rivals. This occurred for both home and away conditions.

Interesting effects for player position were revealed, though due to the small numbers involved, such findings remain speculative. Overall, strikers tended to have higher testosterone levels across the different venues, while the goalkeepers had the lowest levels in training, but the highest when facing the extreme rival team. It might be that the goalkeeper represents the last line of defense and thus will be particularly susceptible to hormonal changes when confronting an important opponent. This intriguing possibility requires further experimental confirmation.

A possible confound concerns the fact that both home games in the second study occurred in the same month (October), while the away games took place later on in December and March. The specific games were chosen because their location allowed for the control of proximity to the home venue while level of rivalry varied, but fixture dates were out of experimental control. As there are known seasonal fluctuations in testosterone [32,33], it could be that the observed differences between home and away levels represent circannual changes rather than changes in perceived territoriality, as testosterone levels are reportedly higher in winter than in spring [32]. However, the fact that levels before a training session taken a week before the final away game were higher than those before the subsequent competitive fixture, and no different from the training session in the winter, somewhat refutes this. Furthermore, the fixtures in Study 1 were both in the winter and only a week apart, and the same significant effect was found. Still, future studies should address this potential problem. On a positive note, potential carry-over effects of outcome [23] in Study 1 due to the close proximity of testing dates were also reduced by the longer testing intervals in Study 2.

Although the sample sizes in both studies are small, these results provide evidence that differential performance in competitive encounters when playing at home or away may be partly mediated by testosterone, a hormone implicated in animal studies of territoriality and aggression (see Ref. [38]) and human studies of competitiveness (for review, see Ref. [20]). It is interesting to speculate how testosterone may improve sporting performance. While links between testosterone and aggression remain unclear [19], some authors have proposed that rising testosterone levels are related to expressions of dominance [20], especially in face-to-face social encounters [39,40]. Furthermore, the pre-competition rise before the home game may make the

competitor more willing to take risks [41], improve reaction time [42], enhance certain aspects of spatial ability [43], and increase the metabolic rate of muscles [44]. While it may be hypothesised that these represent adaptive responses to facilitate the defense of one's territory, the precise mechanisms remain unclear.

In this current study, some of the popular explanations for the home advantage can be at least partly eliminated [1,6]. The games did not attract large, noisy crowds, so crowd support and referee bias—if it is accepted that this is mediated by crowd noise—were less likely to be important factors. The distances travelled to the away venue were relatively small, so overnight stays were unnecessary and disruptions to routines were minimal.

In summary, the results from this current study indicate possible links between testosterone, perceived territoriality, and changes in competitive performance in humans. While testosterone level may indeed be linked to overall better team performance when playing at home than away, further research is needed to explain how testosterone may be acting at an individual level to influence performance during competition and whether an individual's testosterone level pre-match can predict actual performance variables within the match. In addition, the intriguing finding that those team members who subjectively feel that the burden of 'defending the territory' lay with them (goalkeepers) had higher levels when playing 'extreme rivals' needs further investigation. We are currently attempting to address these issues.

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