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Blunted anticipatory stress responses on competition day in team sports athletes compared to individual sports athletes

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ABSTRACT

Knowledge of anticipatory stress responses before sports competitions is limited, thus this study examined the relationship between anticipatory stress in terms of salivary cortisol secretion in athletes on the morning of a competition and a comparison baseline day. Thirty-seven athletes collected three saliva samples over a 45-min period post-awakening (0, 30 and 45 min). Anticipatory stress was expressed as Area Under the Curve compared to ground (AUCg; total cortisol secretion). There was no significant difference in AUCg between baseline and competition days. However, a mixed two-factor ANOVA with day and sport type (individual vs. team) revealed a significant main effect of sport type ($p < 0.01$) and a significant interaction ($p = 0.001$). Individual athletes demonstrated increased AUCg on competition day compared to baseline, while team athletes demonstrated decreased AUCg on competition day compared to baseline. This blunting response was also observed when analysing the raw cortisol secretion levels upon awakening. These findings suggest there may be substantive differences in anticipatory stress between individual and team sport athletes.

1. Introduction

1.1. Stress and athletes

Anticipatory stress is the perceived stress in response to a future event which, in the case of athletes, could be an upcoming competition [1]. Short-term stress exposure can induce heightened biological responses characterised by elevated neuroendocrine levels driven by the hypothalamic-pituitary-adrenal (HPA) axis that are supposed to prepare the body mentally and physically for performance [2,3]. On the other hand, chronic psychological stress, and thus sustained HPA axis activity, may induce negative health effects in athletes such as injury, illness due to immunosuppression [4] or may lead to psychological disorders such as depression and burnout [5].

Athletes are subject to highly stressful environments with various physiological and psychological demands [6]. From a physiological perspective, athletes must manage high volumes of training both in terms of duration and intensity [7]. Athletes further face a collection of psychological stressors unique to sport including aspects of competition (e.g., perceived levels of physical and psychological preparedness, ruminative thoughts about goals), financial matters (e.g., sponsors, funding), and interpersonal relationships (e.g., expectations from coaches, teammates, relatives; [7]). The combined effects of physiological and psychological stressors can affect motivation, as well as the mental and physical health of athletes [8]. Stress is also thought to be a key factor in determining the success or failure of athletic performance and a large body of research has examined stress processes and management in this setting [9–11].

1.2. Stress theory

Exposure to sporting environments alone, however, does not mean an athlete will experience stress. Whether stress is perceived depends on the athlete's appraisal of the situation [12]. According to the transactional model of stress [13] such appraisal happens in two stages. At first, the individual evaluates whether the situation creates pressure for them in the primary appraisal stage. If they believe the situation creates pressure, they will determine whether they have enough coping resources to manage this pressure during secondary appraisal. Only if the athlete perceives pressure and does not believe they have enough coping

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resources available to manage this, will they experience stress. While chronic stress (frequent, multiple events) has been associated with detrimental outcomes like burnout [7], short-term stress (single event) exposure may improve athlete performance [14].

Physiologically, stress can be measured by analysing cortisol levels. This is because cortisol is considered the main stress hormone of the body [3]. Cortisol release stimulates increased availability of metabolic substrates (e.g., gluconeogenesis) which mobilises energy reserves. Elevated levels of cortisol, thus, are considered beneficial for athletic performance as higher availability of metabolic substrates can heighten physical and mental performance on a short-term basis [15]. Cortisol further plays a key role in the circadian rhythm where levels are at their lowest during sleep but rise sharply within the first hours of awakening [16]. This anticipatory cortisol response can be expressed in terms of the Area Under the Curve relative to the ground (AUCg [17]), for a particular sampling period (e.g., upon awakening) which represents total cortisol secretion (or output) [1,16]. This rise in cortisol secretion serves to prepare the individual for the day ahead and this proxy of HPA reactivity has been used as a salivary biomarker of stress in psychosocial [18] and exercise science [15].

1.3. The present study

The purpose of the present study is to analyse anticipatory stress by measuring cortisol total secretion upon awakening (AUCg), in a group of team and individual athletes using the naturalistic setting of a competition. The study was designed to induce the largest changes in anticipatory stress by subjecting participants to an environment they would perceive as stressful (i.e., competition). It was hypothesised that the competition day awakening AUCg would be significantly higher than the baseline day in both groups. While research is beginning to explore anticipatory stress in athletes [1], this is the first study with a sample of both individual and team sports athletes.

2. Materials and methods

2.1. Design

The present study took a within-subjects observational design by comparing the anticipatory stress response expressed as (awakening) total cortisol secretion (AUC_g) of athletes on a normal day (baseline) to a competition day.

2.2. Participants

The sample consisted of 38 amateur athletes (mean age = 26.8 years, SD = 9.0). An adult sample was chosen to minimise any age-related confounds on the total cortisol secretion. Convenience sampling was used to recruit participants from a range of sports across the UK at varying levels of competition.

Only participants who completed both the baseline and competition day collection were included in the sample. Participants were further screened for health conditions and medication use (e.g., glucocorticoid steroids) and were excluded in the analyses on a case-by-case basis for factors known to influence cortisol (e.g., Cushing's disease). One participant (football player, regional level) was removed due to this criterium. The remaining 37 athletes reported to spend an average of 12.7 (SD = 5.9) hours per week training/competing and had been participating in their respective sports for an average of 11.6 (SD = 7.4) years. The cyclists (N = 22) were downhill and enduro mountain bikers competing at national level (mean age: 32 years, SD 8.2), The judo players (N = 2) competed at an international competition and were both 19 years old whilst the footballers (N = 13). Were academy players competing at regional level (18.8 years, SD 0.8). All athletes were male except for three female cyclists.

All competitions were deemed of a suitable competitive level to be perceived as stressful by the athlete to ensure comparative importance. For example, for the cyclists, the competition day was set as the final round of a national series, they were deemed to be important events for the athletes. With the help of their coach, the footballers chose the date of a competition they perceived as important, and this was set as the competition date. Ethical clearance for this study was gained from the Institutional Research Ethics Committee.

2.3. Sample collection

Cortisol was measured from saliva samples as this represents a stress-free and non-invasive way of measuring cortisol levels [19]. Saliva samples were obtained using the passive drool method into polypropylene 2 mL cryovials (Eppendorf, UK). Participants were trained in the collection method during induction and were asked to refrain from eating, drinking, smoking, or exercising until collection of all three samples on each day was complete. Samples were stored at −20 °C until transferred to the laboratory where they were thawed and centrifuged at (3000×g; 15 min) to separate the mucins prior to analysis on the same day.

2.4. Procedure

The cortisol anticipatory response was determined using the total cortisol secretion over the first 45 min post awakening) expressed as the area under the curve with respect to ground (AUCg) [17]. The total cortisol secretion (AUCg) was assessed on two occasions: on the day of an important competition (competition day), and one week prior (baseline day) to minimise weekday-weekend variations in cortisol secretion levels. To assess the AUCg, participants were instructed to collect saliva samples immediately upon awakening (t = 0, and at 30- and 45-min post awakening on baseline & competition day) [3].

2.5. Saliva cortisol assay

All samples were analysed in duplicate using commercial enzyme-linked immunosorbent assay (ELISA) kits (Salimetrics, State College, PA, USA) validated for the determination of salivary cortisol. All standards, controls and samples were pipetted by hand and a manual washing process was implemented throughout. The assay sensitivity is reported to be < 0.007 μg/dL and the inter- and intra-assay coefficients of variation were 7.93 % and 2.98 % respectively.

2.6. Data analysis

The anticipatory stress response was determined using the standardised mean difference (Cohen's *d*) based on the baseline and competition cortisol concentrations [1]. The total cortisol secretion is expressed in terms of area under the curve (AUC) that is created by the three measurements (awakening, 30 min post awakening, 45 min post awakening), as a function of absolute (with respect to the ground: AUC_g), using the trapezoid formulas [17].

For all analyses, R and R Studio (R Core Team, 2021) were used. As the data were found to violate parametric assumptions of normality, we used appropriate robust descriptive statistics like trimmed means and Median Absolute Deviations (MAD) as well as robust techniques like bootstrapping and an M-estimator [20] to account for this. Differences between competition and baseline day samples were assessed with a paired *t*-test based on the percentile bootstrap (N = 10000) and on 20%-trimmed means. We further calculated a two-factor mixed ANOVA with day (baseline vs. competition) and sport type (individual vs. team) as the two factors and AUC_g as the dependent variable. Huber's M-estimator that is robust to deviations from normality was used for this analysis [21]. The assumption of homogeneity of variance between groups (individual vs. team athletes) was met in a Levene's test on both the baseline day (F (1,36) = 0.08, p = 0.78) and competition day (F (1,

36) = 2.09, $p = 0.16$).

3. Results

3.1. Anticipatory stress (AUC_g) on baseline compared to competition day

Anticipatory stress in athletes was assessed by comparing the total cortisol secretion upon awakening (in terms of AUCg) in saliva samples collected on the morning of a competition to a time-matched baseline day. No significant differences between baseline and competition day AUCg were found (t (1,36) = −0.77, $p = 0.43$, CI [-4.72,2.04], $d = 0.15$) where the 20%-trimmed mean on competition day AUCg was 19.4 (±7.96 MAD) compared to baseline day levels of 18.10 (±5.93 MAD).

3.2. Anticipatory stress (AUC_g) on baseline compared to competition day by sport type

We then assessed whether there were differences in anticipatory stress (AUCg) between the different sport types (Individual vs. Team). A two-factor mixed ANOVA was conducted to examine the effect of sport type and day on anticipatory stress (AUCg). There was a statistically significant simple main effect of sport type (F (1,36) = 10.43, $p < 0.01$, CI [1.81,7.58], $\eta^2 = 0.11$, 1- β = 0.50). Individual athletes showed higher AUCg (trimmed mean = 20.66) than team athletes (trimmed mean = 15.51). There was no difference between competition and baseline days (F (1,36) = 0.01, $p = 0.93$, CI [-2.75,3.02], $\eta^2 = 0.03$). However, there was a statistically significant interaction between the effects of sport type and day on AUCg (F (1,36) = 12.16, $p < 0.001$, CI [4.38,15.91], $\eta^2 = 0.16$, 1- β = 0.67) with individual athletes showing higher AUCg on competition day (trimmed mean = 23.0), while team athletes showed a lower AUCg on competition day (trimmed mean = 13.6) compared to baseline day (individual, trimmed mean = 18.0; team, trimmed mean = 18.2).

3.3. Cortisol secretion profiles of individual and team athletes

The pattern of cortisol secretion upon awakening was visualised by observing the raw salivary cortisol levels over 45 min post-awakening (see Fig. 1). Raw cortisol secretion profiles on competition day in both cohorts were similar in profiles as they both exhibited a gradual rise in concentration over the 45 min post-awakening. Competition day mean cortisol awakening profiles in individual athletes were consistently greater in terms of magnitude than in team athletes (see Table 1).

In individual athletes, salivary cortisol levels on competition day were significantly greater than baseline values at awakening (t (23) = 2.36, $p < 0.05$, CI [0.02,0.18]) and 45 min later (t (23) = 2.58, $p < 0.05$, CI [0.04,0.37]). The opposite trend was observed in team athletes where competition day cortisol levels were statistically lower than baseline upon awakening (t (12) = 2.29, $p < 0.05$, CI [0.02,0.22]) and 30 min later (t (12) = 1.97; $p < 0.05$, CI [0.01, 0.24]).

4. Discussion

The present study aimed to examine whether competition-induced anticipatory stress responses expressed in terms of total cortisol secretion (AUCg) upon awakening were significantly higher than baseline. No effect was observed for the complete cohort; however, differences were revealed when exploring the subgroups of team ($n = 13$) and individual athletes ($n = 24$). While competition day AUCg was elevated for individual athletes, the opposite trend was observed in team athletes. In the latter group, lower cortisol secretion levels were observed as indicated by (i) blunted raw cortisol secretion profiles and (ii) a significantly lower AUCg on competition day compared to baseline samples.

The elevated anticipatory cortisol secretion levels (AUCg) seen with the individual athletes compares favourably with data from studies measuring HPA axis reactivity on the day of the stressor (test day) and a

Table 1
Descriptive statistics of raw cortisol scores over the first 45 min post awakening in individual and team athletes.

	Individual athletes			Team athletes		
Time point	20%-TM	MADs	Range	20%-TM	MADs	Range
t = 0	0.38	0.17	0.04; 1.07	0.27	0.09	0.13; 0.51
t = 30	0.49	0.17	0.11; 1.14	0.38	0.17	0.06; 0.89
t = 45	0.45	0.27	0.10; 1.53	0.38	0.12	0.06; 0.80

Note. 20%-TM = 20 % trimmed means; MADs = Mean Absolute Deviations.

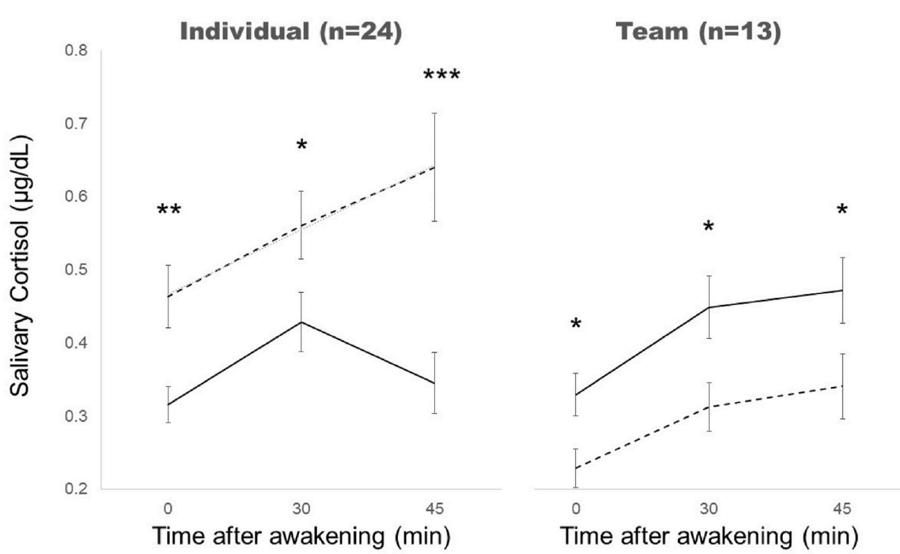

Fig. 1. Cortisol Secretion Profiles of Individual and Team Athletes
Note. Solid line = baseline day. Dashed line = competition day. Mean salivary cortisol values (µg/dL) were determined over 45 min (t = 0, 30 & 45 min) post-awakening in athletes on the morning of a competition and compared to a time-matched baseline day. Athlete cortisol secretion profiles were categorized as belonging to either Individual (cyclists and judo, left-hand panel) or Team sports (footballers, right-hand panel). Error bars represent standard errors of the mean. All statistical analyses were carried out using bootstrapped t-tests (two tailed; $N = 1000$) to compare differences between Competition and Baseline days (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$).

baseline day immediately prior (2-day model). For example, heightened awakening salivary cortisol AUCg profiles were measured on the test day in healthy young adults immediately prior to an acute laboratory stressor [16] and elite junior shooting players anticipating a competition [22]. Van Paridon et al. [1] performed a meta-analysis incorporating 25 studies (348 participants) which also showed an increased anticipatory cortisol response on competition days compared to a time-matched control day, suggesting that competition-induced anticipatory stress affects the cortisol secretion profile in these athletes. Taken together, these observations suggest the enhanced cortisol secretion observed is in response to the anticipated stressor (whether experimental or naturalistic) reflecting a heightened biological and psychological response to prepare for the event. Such a response has been suggested to be ideal on the morning of a competition day as it contributes to an optimisation of psychological and physical ability in the event [23].

The finding that anticipatory cortisol responses were blunted in team athletes has not been reported in the literature. One possible explanation could be the level of competition (regional vs. national). Individual athletes in this study were performing on a national and international level, while the team athletes were performing on a regional level. A difference in the level of competition could create differences in the perceived importance of the events and thus the degree of anticipatory stress. This is evidenced in a study of elite youth volleyball players ($n = 12$) where significantly heightened salivary cortisol levels were observed in a competitive match perceived as more important (final championship match) compared to a regular season game and a baseline rest day [24]. This suggestion is, however, not supported by Van Paridon et al.'s [1] meta-analysis that found no significant differences in cortisol responses between athletes competing at different competition levels. In a similar study in individual athletes (12 male martial artists), no increases in anticipatory salivary cortisol output were observed in the week prior to and including a national-level competition day despite self-reported anticipatory responses being recorded. This blunting of the HPA axis reactivity was attributed to these trained athletes' habituation to competition anxiety [25].

Alternatively, the social interaction, feeling of belonging and support structure provided in teams, particularly cohesive groups, may alleviate these stressors as team athletes have been shown to be less prone to competition anxiety [26]. Differences in training regimes of athletes may play a role as HPA reactivity can become blunted in response to exhaustive exercise regimes [2,27] and may also level off after athletes become habituated to the exercise regime [15]. As such, the exercise regime of the athletes could have played a key role in determining the cortisol secretion profile on baseline and competition days. Since the team athletes in this study were all footballers playing for the same academy, they were subject to the same exercise regime that could have created the blunted response. Finally, future research should investigate this by controlling for the training load of the athletes [24].

The perception of the forthcoming competition possibly determines the nature of the anticipatory cortisol response as well. For instance, Jones et al. [28] suggested that if the competition is not perceived as challenging then one should expect no or a blunted anticipatory response. This importance of the perceived challenge is also highlighted byLazarus & Folkman's [13] transactional stress theory. According to this theory, whether stress is experienced depends on (1) how the situation is perceived and (2) whether the athlete perceives enough coping resources to be available. As such, if the athlete does not perceive the situation as important and thus, potentially threatening, they will not experience stress. The lack of an anticipatory stress response then likely translates to blunted cortisol secretion levels. However, based on this theory, the cognitive appraisal of the situation is highly subjective and other contextual factors like perceived coping resources and that team athletes may view competition more positively due to the social peer support may also play a role in the stress response through secondary appraisal. As such, further research is needed to determine which factors play into anticipatory stress responses as well as how these may relate to performance.

The present study has several limitations. The participants in this study performed the saliva collection without direct researcher oversight thus compliancy to study protocols which critically relies on participants closely following a timed sampling schedule, beginning with the moment of awakening [29], is unclear. Indeed, where both sample collection and awakening time are known, post-awakening cortisol secretion levels have been shown to become unreliable within as little as 4 min post-awakening. Furthermore, cortisol secretion levels can be affected by the athletes' sleeping patterns (amount of sleep, when they went to sleep & woke up) which were not recorded in this study. Future studies should attempt to control for this by implementing apps such as OnTimePoint Saliva Collection Management System or use of wearable activity trackers. Only three female participants were included in this study, but it is noted by Benz [30] that menstruation phase can influence cortisol secretion patterns significantly, so to account for gender differences, they suggest extending the sampling period to 120 min post awakening.

The HPA-axis proxy cortisol was used as a stress-associated biomarker. Testosterone negatively influences cortisol secretion [31] and, as they both exhibit similar circadian patterns [32], testosterone/cortisol ratios maybe a more accurate measurement of physiological stress. HPA axis activity is associated with harmful stimuli [1], whereas perceptions of challenge lead to activation of the sympathetic nervous system (SNS) with a healthier impact on mobilising resources [2]. Future research should examine SNS activity biomarkers alongside HPA activity using surrogate indicators like salivary α-amylase [33]. To consider the subjective context of each individual and ensure the two sport groups (e.g., team vs. individual) are comparable in this aspect, it may further be useful to measure perceived challenge of the competition and match participants in each group based on this variable to control for such differences. Finally, this study was underpowered for the size of effect that was found, as such, the true effect size may be lower, and this should be further investigated in future studies to confirm the observed effect.

5. Conclusion

The present study aimed to examine differences in anticipatory cortisol-mediated stress in athletes on competition compared to baseline days. While no such differences were found in the full sample, subsample analyses showed individual athletes to have an elevated anticipatory stress in terms of AUCg and conversely team athletes to have a blunted cortisol secretion on the morning of the competition day. This difference could be due to a habituation to the exercise regime or a lack of perceived challenge in team athletes.

Data statement

The data is stored on our institutional open data repository service Research at York St John Data Repository (RaYDaR).

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CRediT authorship contribution statement

Michael Page: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hanna L. Glandorf:** Writing – review & editing, Validation, Formal analysis. **Sarah H. Mallinson-Howard:** Writing – review & editing, Methodology, Formal analysis. **Danial J. Madigan:** Writing – review & editing, Validation, Methodology, Investigation. **Scott A.**

Dawson: Writing – review & editing, Validation, Software, Methodology, Investigation. **Susan Jones:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Owen Kavanagh:** Writing – review & editing, Supervision, Methodology, Data curation, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

Generative AI and AI-assisted technologies were not used in the writing process.

Declaration of competing interest

No conflict of interest.

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